INSTITUTO
UNIVERSITÁRIO
DE LISBOA

Quality Management Maturity: Its Application and Evaluation in Chinese Private Equipment Manufacturing Enterprises

ZHU Guojie

Doctor of Management

Supervisors:
PhD Álvaro Augusto da Rosa, Associate Professor,
ISCTE University Institute of Lisbon
PhD CHEN Guangyu, Professor,
University of Electronic Science and Technology of China

January, 2022

BUSINESS
SCHOOL

Marketing, Operations and General Management Department

Quality Management Maturity: Its Application and Evaluation in Chinese Private Equipment Manufacturing Enterprises

ZHU Guojie

Doctor of Management

Supervisors:
PhD Álvaro Augusto da Rosa, Associate Professor,
ISCTE University Institute of Lisbon
PhD CHEN Guangyu, Professor,
University of Electronic Science and Technology of China

January, 2022

BUSINESS
SCHOOL

Marketing, Operations and General Management Department

Quality Management Maturity: Its Application and Evaluation in Chinese Private Equipment Manufacturing Enterprises

ZHU Guojie

Doctor of Management

Jury:
PhD José Manuel Gonçalves Dias, Associate Professor with Habilitation,
ISCTE - University Institute of Lisbon
PhD Margarida Saraiva, Assistant Professor with Habilitation,
Universidade de Évora
PhD Ma Yongkai, Full Professor,
University of Electronic Science and Technology of China
PhD Virgínia Maria Trigo, Emeritus Professor,
ISCTE - University Institute of Lisbon
PhD Álvaro Augusto de Rosa, Associate Professor with Habilitation,
ISCTE - University Institute of Lisbon

January, 2022

iscte INSTITUTO UNIVERSITÁRIO DE LISBOA	**Quality Management Maturity: Its Application and Evaluation in Chinese Private Equipment Manufacturing Enterprises**	ZHU Guojie

Declaration

I declare that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university and that to the best of my knowledge it does not contain any material previously published or written by another person except where due reference is made in the text.

Signed: ZHU Guojie Date: 2022.01.01

Name: ZHU Guojie

作者申明

本人郑重申明：除了论文致谢中明确说明并致以谢意的部分外，所呈交的论文不包含任何他人或作者本人已用于获得任何教育机构的学位和证书而使用过的材料。同时尽我所知，除了文中特别加以标注引用的内容外，本论文不包含任何其他个人或集体已经发表或撰写的成果作品。

作者签名：ZHU Guojie 日期：2022.01.01

姓名(拼音)：ZHU Guojie

[This page is deliberately left blank.]

Abstract

Although China's private equipment manufacturing enterprises have made significant progress, quality problems still occur because of the weak quality foundation. Therefore, it is necessary to scientifically evaluate the quality management of equipment manufacturing enterprises, identify the deficiencies and defects of quality management, and provide systematic and targeted countermeasures and suggestions.

The thesis conducted text analysis on the quality award self-assessment materials of three companies and constructed an evaluation model for private equipment manufacturing enterprises including four sub-systems (management process, support process, customer-oriented process and result) through three-level coding. Meanwhile, in order to empirically test the quality management maturity evaluation model of private equipment enterprises and explore the relationships between the sub-systems, the thesis selected 6 private equipment enterprises located in Guizhou province as the pre-survey objects and selected 80 private manufacturing enterprises located in Beijing, Zhejiang province, Guizhou province, Hunan province, and Sichuan province as the formal survey objects to carry out hypothesis test. Moreover, the thesis developed a maturity evaluation scale. Applying the scale to the case GXTF company, the thesis proposed improvement strategies for GXTF company.

In theory, the thesis enriched the research on the quality management of private equipment manufacturing enterprises. In practice, the thesis provided reference for maturity evaluation, and provided an updated version for GJB9001C quality management accreditation institutions.

Keywords: private enterprise; quality management; maturity; evaluation system
JEL: L64, M19

[This page is deliberately left blank.]

Resumo

Embora as empresas de manufaturação privadas da China têm feito progressos significativos, existem ainda problemas de qualidade uma vez que as fundações para a qualidade são débeis. Por isso mesmo, é relevante avaliar de forma científica a gestão da qualidade das empresas de manufaturação, bem como, identificar os defeitos e as deficiências da gestão da qualidade nessas mesmas e, por fim, apresentar sugestões e medidas de melhoria.

Esta tese conduziu um estudo com base em procedimentos de auto-avaliação para concurso de prémios de qualidade fornecidos por três empresas e construiu um modelo de avaliação da maturidade da gestão da qualidade com quatro subsistemas (processo de gestão, processo de suporte, processo de foco no cliente e resultados) e três níveis de desempenho. Com o intuito de o testar empiricamente, foram selecionadas 6 empresas particulares de manufaturação da província de Guizhou para o pré-teste. E ainda, foram selecionadas 80 empresas sediadas em Beijing, nas províncias de Zhejiang, de Guizhou, de Hunan e de Sichuan para formalmente testar as hipóteses do modelo. Por outro lado, concebeu-se um guião para análise de processos de maturidade da gestão de qualidade e foi selecionada a empresa GXTF para este estudo.

Contribuímos para a teoria com o enriquecimento da investigação da gestão da qualidade em empresas de manufaturação. E, contribuímos para a prática da gestão, com um novo modelo de avaliação da maturidade da gestão da qualidade e ainda de elementos para a atualização da norma GJB9001Cl da gestão da qualidade.

Palavras-chave: empresas privadas; gestão da qualidade; maturidade; sistema de avaliação
JEL: L64, M19

[This page is deliberately left blank.]

摘要

近年来，我国民营装备制造企业发展迅速，但是由于质量基础薄弱，各种质量问题时有发生。因此，科学评价装备制造企业的质量管理水平，识别质量管理的不足和缺陷，对质量管理给出系统的、有针对性的对策建议十分必要。

本文首先对三家企业的质量奖自评材料进行了文本分析，通过三级编码的方法构建了以管理过程、支持过程、以顾客为导向过程和结果为子系统的民营装备制造企业质量管理成熟度评价模型，然后分别选取了贵州省的 6 家民营装备企业和位于北京市、浙江省、贵州省、湖南省、四川省的 80 家民营制造企业作为预调查和正式调查的对象，对民营装备企业质量管理成熟度评价模型进行实证检验，验证了四个子系统间的关系，最后开发了成熟度评价量表，利用量表对 GXTF 公司进行了案例研究，并针对 GXTF 公司提出了质量管理成熟度改进策略。

本文在理论上丰富了民营装备制造企业质量管理的研究，在实践上为民营装备制造企业开展成熟度评价提供了参考，同时也为 GJB9001C 质量管理体系认证机构提供了认证升级版。

关键词：民营企业；质量管理；成熟度；评价体系

JEL: L64, M19

[This page is deliberately left blank.]

Acknowledgements

First of all, I would like to thank my supervisors Professor Álvaro Rosa, Professor Chen Guangyu and Associate Professor Liu Wenbin. The lion's share of the credit goes to Professor Álvaro Rosa and Professor Guangyu Chen, who contributed much efforts to this thesis. I also would like to thank Professor Virginia Trigo and Professor Xiao Wen for their hard work on the ISCTE-UESTC project and thank Professor Sun Ping and the teachers of the project team for their thoughtful arrangements!

IDMgt2016 is like a wonderful big family, where I was enlightened by the teachers and established friendship with the classmates. Many thanks to our monitor Luo Shi, the class committee and classmates in Chengdu for their care.

I would like to thank many people who have supported me during the thesis writing. Thank my Junior schoolmate Zhang Hongyue for her support in data analysis and thesis translation; thank friends and colleagues from companies such as Gaoxin Taifeng, Guizhou Kaihong Huida, Dadongfeng, and Baiyun Zhonghang for their help during the questionnaire survey; thank experts from Beijing Tianyizheng Certification Center Co., Ltd and Guizhou Provincial Quality Association for their assistance in the case study; thank Chu Shanzhong, Zhong Kaochi and other friends for their encouragement.

Last but not the least, I would like to thank my parents, who are the role models for my life. My father joined in the Third-Front Movement in the 1960s and was awarded the honor of "Dedicated to National Defense Science and Technology" by the Commission of Science, Technology and Industry for National Defense. My mother is 83 years old and is still concerned about my studies and work. I am always on business trips and spend little time with my family. Thank my family for their understanding and support.

Graduation is around the corner. Gratefulness and thanks to all the teachers, classmates, friends and relatives who have taken care of me, help me and supported me!

[This page is deliberately left blank.]

致谢

首先要感谢的我的导师刘文彬副教授、陈光宇教授和 Álvaro Rosa 教授。尤其是陈光宇教授和 Álvaro Rosa 教授对我的论文给予了非常大的帮助。感谢肖文教授和 Virginia Trigo 教授，为这个项目付出的努力；感谢孙平教授和中葡双方项目组老师们周到安排！

IDMgt2016 级是一个美妙的大家庭，聆听了老师的教诲，感受了同学的情谊。感谢罗实班长、班委和成都同学的周到照顾。

在论文写作过程中，要感谢的人很多。张红月师妹提供了数据分析和论文翻译支持；问卷调查得到了高新泰丰、贵州凯宏汇达、大东风、白云中航等企业很多朋友和同行的帮助；案例研究得到了北京天一正认证有限公司、贵州省质量协会有关专家的支持；还要感谢储善忠、钟考持等好朋友的鼓励。

最后要感谢的是我的父母，他们是我一生的榜样。父亲 60 年代支援三线建设，被国防科学技术工业委员会颁发“献身国防科技事业”荣誉勋章；母亲 83 高龄，依然牵挂我的学业、工作，而我常常出差，陪伴家人时间比较少，感谢家人的理解和支持。

毕业在即，感恩所有关心、帮助我的老师、同学、朋友、亲人们！

[This page is deliberately left blank.]

Contents

[This page is deliberately left blank.]

List of Tables

[This page is deliberately left blank.]

List of Figures

[This page is deliberately left blank.]

Chapter 1: Introduction

1.1 Research background

The well-known quality management master Joseph Juran predicted in his book *Juran's Quality Handbook* that "The 20th century was the century of productivity, the 21st century is the century of quality. Quality is the peaceful occupation of the market and the most effective weapons" (Godfrey & Juran, 1999). Nowadays, people's safety, health and happiness are protected by the "quality dam", and the quality of products and services directly relates to people's daily life (Gryna, 2007; Juran, 1995; Y. T. Zhu, 2015). Only by building a solid "quality dam" can a happy life be guaranteed (Joseph & Frank, 2017). Otherwise, people's interests and the country's economy will be harmed. The infamous "Sanlu Milk Powder Incident" and "Changchun Changsheng Vaccine Incident" are both bad examples. Quality is not only important to people's lives, but also to the industries, especially to the equipment manufacturing industry, which is the industry that manufactures various technical equipment to satisfy the development of economy and security (Shida & Anada, 2011; J. H. Wu, 2017; Zhong, 2011). Quality is an important force for the development of the national economy. Moreover, it is the key to the construction and development of modern national defense (Z. C. He et al., 2013). The equipment manufacturing industry is of strategic significance to the country, which transcends economic value (Y. Wang, 2019). In 2020, the EVA of the equipment manufacturing industry in China has increased 3.6% in comparison with 2019, and the growth rate was 3.8% faster than that of the average industries. China has taken a leading position in fields such as power generation equipment, rail transit, and communication equipment. For decades, China's equipment manufacturing companies, especially private equipment manufacturing companies, have made significant progress and development (Y. Zhang, 2020). However, the weak quality foundation of private enterprises still causes quality problems from time to time. In 2016, *Equipment Manufacturing Standardization and Quality Improvement Plan* was jointly issued by several national departments. The *Plan* pointed out the necessity to highlight the supporting effect of quality in the equipment manufacturing industry, implement the industrial quality improvement actions, and improve the equipment quality (J. J. He, 2020). Faced with the changeable international environment, it is important for private equipment manufacturing

industry to find out quality problems and improve quality.

Modern management theory suggests that quality comes from management, and the level of quality management determines the level of quality (Hutchins & Anderson, 2020; S. X. Zhu, 2016). Traditionally, most private equipment manufacturing enterprises are managed by family or based on experiences, which has three problems. Firstly, the management thinking, quality concept, and quality awareness of the managers are still unsatisfactory. Meanwhile, the managers' understanding of quality still remains at whether the product quality can meet the requirements, instead of whether QMS including six product characteristics (reliability, maintainability, security, safety, environmental adaptability, testability), technology management, and risk management has been established (Weng, 2019). Secondly, the consciousness of quality accreditation is poor, and many private equipment manufacturing companies are accredited for the needs of their business or due to the market pressure. Thirdly, quality management remains a formality, leaving the quality function and quality responsibility unclear. For these enterprises, quality management is just a slogan, and the gap between the reality and the standards still exists. With the development of private equipment manufacturing enterprises, traditional quality management modes can no longer satisfy the enterprises, which leads many private equipment manufacturing companies to reform and innovate their quality management modes. In such a competitive environment, quality management has experienced the four stages from purely quality inspection to quality management, and the modern quality management in China has undergone the process of "quality inspection, total quality management, QMS accreditation, and excellent quality management" (Díaz et al., 2018; W. C. Wang, 2017; Werner, 1992).

For private equipment manufacturing companies, scientific and effective quality management can help improve their market competitiveness by identifying and controlling the potential risks. However, only high-level quality management can guarantee process monitoring and quality improvement. Under this circumstance, finding a method to evaluate the quality management level of equipment manufacturing enterprises, identifying the deficiencies and limitations in the quality management, and giving systematic and targeted countermeasures and suggestions are necessary to private equipment manufacturing enterprises (Y. Li, 2014). At present, the research on the evaluation of enterprise quality management performance can be categorized into three. Firstly, Crosby QMM grid, which divides the business operation into five periods: uncertainty period, awakening period, enlightenment period, wisdom period, and definite period (Crosby, 1980; Engle, 2012). The second is *ISO9004.2018 Quality Management-Organizational Quality-Guidelines for Achieving*

Sustained Success standard. The statistical data shows that more than 150 countries (regions) worldwide have implemented the *IS09000 accreditation system* (ISO, 2018). By the end of 2018, there were a total of 481 accreditation agencies in China, with 92,452 accreditation practitioners. A total of 1.954 million accreditation certificates had been issued, and 630,500 organizations had been accredited. However, many enterprises did not pay much attention to the quality management evaluation after obtaining being accredited, so IS09004 standard is still not used or even ignored in the company, leading to weak links in the quality management evaluation (L. Li, 2009). The third are the world's three major quality awards and excellent performance management model. J. J. He and Zhang (2020) hold that Japanese Deming Award, Malcom Baldrige National Quality Award, and European Quality Award, the world's three most famous quality awards are all management rewarding system centered around the excellent performance management (Chikati & Mpofu, 2014; J. J. He & Zhang, 2020). It is worth mentioning that the American Quality Institute has formulated an international standard for quality system maturity: ANSI/ISO/ASQ Q9004.2000, which divides the quality maturity from the perspective of performance (C. F. Zhang, 2014). This standard describes the basic elements required for the establishment and implementation of enterprise QMS. Meanwhile, this standard guides companies to implement the ISO system (Q. Su et al., 2010). J. Li et al. (2002) find that the effects achieved by different companies are obviously different even if they implement the same quality management practice (J. Li et al., 2002). J. Li et al. (2002) attribute this phenomenon to the different quality management levels of each enterprise and defined it as Quality Management Maturity. As an important method for evaluating the quality management, QMM conforms to the trend from "small quality" to "large quality", and describes the process of quality from less complete to more complete. H. P. Liu and Liu (2021) hold that the quality management of Chinese enterprises still regards inspection and control as the basic requirements for management, leading to a low management level (H. P. Liu & Liu, 2021). It is of necessity to establish a complete and systematic QMM system, upgrade the level of enterprise quality management, and enhance the competitiveness of the enterprise. Jing (2021) hold the view that a mature QMS can promote the proceduralization, standardization, institutionalization, and systemization of quality management, enhance the implementation of quality management, benefit the achievement of quality goals, and improve the competitiveness of the products and services (Jing, 2021).

Therefore, it is of great significance to start from QMM and establish a QMM model for private equipment manufacturing enterprises to carry out self-diagnosis and self-improvement.

As for QMM research, the development of various national and regional quality award

standards and the international standard ISO9004 have made quality evaluation rather than the QMS, but also the organizational performance brought about by the system operation. Many foreign studies use the model of the quality award as the structural elements of total quality management to carry out quality performance evaluation research (Chikati & Mpofu, 2014; Y. Wu, 2010; C. X. Zhao, 2021). In 2003, Dr. Iizuka Yutaka made an innovative research based on ISO9004. In the research, he constructed a new quality management model which added learning, innovation, and the needs of customers and potential customers. The new model can help the enterprise maintain competitive advantages in the changing market and achieve sustainable development (Dror, 2008; Yoshinori, 2005, 2016).

The domestic research on quality management evaluation mainly focuses on the promotion and application of China's national quality awards or excellent performance standards, which emphasize on the comparison of the excellent performance models and standards as well as the problems in the application of excellent performance models (J. L. Wu, 2018). For example, Shanghai Juran Quality Research Institute started research on excellent performance in 1998 (S. W. Han, 2018; Y. Wu, 2010). In 2002, Zhang and Sun made a comparative analysis of Malcom Baldrige Quality Award, Japanese Deming Award, and European Quality Award, and pointed out the weak links and specific measures for improving the quality management of Chinese enterprises (W. J. Su, 2006; G. X. Zhang & Sun, 2002). At present, most domestic research concentrates on the measurement of quality management, and there lacks comprehensive researches on the effectiveness and efficiency of quality management. Meanwhile, there is no effective evaluation system for QMM measurement, diagnosis, and decision analysis.

There are still some limitations in the existing research on the QMM of private manufacturing enterprises.

For the first limitation, the evaluation system is immature. For private manufacturing enterprises, ISO9001-2015 and GJB9001C-2017 quality system standards are adopted. However, there is no QMM evaluation standards that not only base on the GJB9001C-2017 standard, but also consider the characteristics of the private manufacturing industry.

For the second limitation, evaluation indicators are not quantified. The evaluation and improvement of enterprises' QMM cannot be achieved overnight. Instead, it is a staged process in a certain period which requires consideration of "diagnosis, evaluation, improvement, and re-diagnosis" (Y. Wu, 2010). The judgment of the QMM requires comparisons with the industry benchmarks to achieve the strategic goals and promote the quality management. When evaluating the quality management of private manufacturing enterprises, although qualitative

methods such as external audit and internal audit are adopted (C. Chen, 2020), quantitative methods and steps are still barely used.

For the third limitation, the application of the evaluation results is poor. Low correlation between the evaluation results and the enterprise business indicators can neither provide a basis for the enterprise's decision nor improve the QMS (C. Chen, 2020). It is of necessity to analyze and verify the key influencing factors of the comprehensive evaluation. Only by finding the shortcomings that affect enterprise's quality management result can we make targeted improvement to the QMS.

Therefore, the thesis focuses on QMM and studies the characteristics, changes and development trends of quality management in China's private equipment manufacturing enterprises. The thesis aims to construct a QMM model for private equipment manufacturing enterprises to find the problems and shortcomings in quality management, and provide strategies and paths for private equipment manufacturing enterprises to improve quality management.

1.2 Research questions

In GJB9001C-2017 quality management system, the "process" consists of customer-oriented process, support process and management process. The customer-oriented process connects with external customers through input and output, which directly affects customers and benefits the company. The support process provides main resources or capabilities to achieve the company's business goals and support the customer-oriented process, which is a necessary process to achieve the function of the customer-oriented process. Management process measures and evaluates the effectiveness and efficiency of customer-oriented process and support process, and it converts customer requirements into goals and indicators, determines the company's organizational structure, and generates decisions and goals. GB/T19580-2012 *Performance Excellence Evaluation Criteria* divides quality management maturity evaluation into process and result. The former evaluates from approach, deployment, learning and integration, and the latter evaluates from level, trend, compare and integration.

Combining the above two quality management evaluation methods, this thesis studies the quality management maturity of Chinese private equipment manufacturing enterprises from management process, support process, customer-oriented process, and results, and puts forward four research questions.

(1) Is the management process in Chinese equipment manufacturing enterprises mature in

quality management perspective?

(2) Is the support process in Chinese equipment manufacturing enterprises mature in quality management perspective?

(3) Is the customer-oriented process in Chinese equipment manufacturing enterprises mature in quality management perspective?

(4) Is the result in Chinese equipment manufacturing enterprises mature in quality management perspective?

To solve the above four research questions, this thesis attempts to conduct text analysis on the materials of three foreign and domestic enterprises and extract key indicators for assessing the QMM. In that way, the thesis could construct an evaluation model for the QMM of private equipment manufacturing enterprises and conduct effective assessment on the quality management of enterprises, laying a foundation for the quality management in the future. The QMM model of private equipment manufacturing enterprises proposed in this thesis is obtained from qualitative research, and lacks test through quantitative analysis. Therefore, this thesis proposes research hypotheses on the relationship between the indicators in the QMM model and then tests the hypotheses. Moreover, this thesis takes GXTF company, one of the 6 research objects in the pre-survey, as the research case. The thesis applies the QMM model of private equipment manufacturing enterprises to GXTF company and analyzes the existing problems and causes based on the results. The thesis also provides strategies and measures for enterprises to improve quality management, which has verified the feasibility and applicability of the QMM model from a practical view, further verifying the evaluation standard of the QMM standard.

1.3 Research significance

1.3.1 Theoretical significance

1. The thesis constructs a QMM (quality management maturity) model for private equipment manufacturing enterprises.

The thesis constructs a QMM model of private equipment manufacturing enterprises with management process (MP), support process (SP), customer-oriented process (COP), and results (RE) as the sub-system. The first-level indicators of the model include leadership, strategic management, risk management, measurement, analysis and improvement, resource management, documented information control process, design and development of product and service, product production and service provision, and quality management results. The

secondary indicators include 41 indicators such as leadership and commitment, strategy formulation, risk planning, measurement analysis and evaluation, and human resource management process.

2. The thesis verifies the relationship between the indicators in the QMM model of private equipment manufacturing enterprises.

The thesis explores and discusses the inner relationships between management process (MP), support process (SP), customer-oriented process (COP), and results (RE), the four quality management processes. In total, the thesis proposes 8 hypotheses including direct and indirect effects, and then testify the hypotheses using the structural equation model.

3. The thesis develops the scale for evaluating the QMM of private equipment manufacturing enterprises.

Based on the model and the questionnaire on QMM of private manufacturing enterprises, the thesis develops the scale for evaluating the QMM of private equipment manufacturing enterprises through the Delphi method, AHP and fuzzy comprehensive method. Moreover, the thesis applies this scale to a specific enterprise through case study.

1.3.2 Practical significance

For the first significance, the thesis helps to understand the current status of the private equipment manufacturing enterprises in China.

The QMM of private equipment manufacturing enterprises directly determines the private equipment manufacturing quality. The maturity evaluation assesses private equipment manufacturing enterprises' level of quality management and the extent to which quality management are conducive to quality improvement. On the one hand, the investigation of more than 100 private equipment manufacturing enterprises can help us know the status of China's private equipment manufacturing enterprises. On the other hand, the QMM model can help the private equipment manufacturing enterprises recognize their quality management status, understand their strengths and weaknesses, and decide how to formulate and implement improvement plans.

For the second significance, the thesis provides a method for private equipment manufacturing enterprises to carry out self-diagnosis and self-improvement.

Maturity evaluation is enterprises' cognition of their quality management problems. The purpose of maturity evaluation is understanding the problems and weaknesses in the quality management, and then exploring the possible path of improving quality management. The

QMM model and QMM scale proposed in this thesis enable the accreditation institution to provide private equipment manufacturing enterprises with specific criteria, rather than only non-conformity. On the one hand, the thesis can provide a basis for auditing the QMS, and promote private equipment manufacturing enterprises in term of self-diagnosis, self-improvement. On the other hand, the thesis can help promote the transformation and upgrading of accreditation.

For the third significance, the thesis is helpful in improving the overall level of China's private equipment manufacturing enterprises.

Maturity evaluation aims to help private equipment manufacturing enterprises implement higher quality management, better quality improvement, and stronger quality management awareness. Improving the QMM of private equipment manufacturing enterprises will bring value to the enterprises and create good social and economic benefits. Through the in-depth analysis of the maturity evaluation results, the thesis can help enterprises find solutions to quality problems, improve the quality of management and product, and enhance the competitiveness of China's private equipment manufacturing enterprises' quality.

1.4 Research method and research path

1.4.1 Research method

Text analysis, questionnaires, Delphi method and case study are adopted in the thesis.

Text analysis is an important qualitative research method, which goes from the surface of the text to the deep of the text and is effective in finding the deep meanings that cannot be grasped by simple reading (J. Guo, 2017). Quantitative research emphasizes on verifying the existing theories or modifying others' hypotheses, but it cannot tell how these theories or hypotheses came into being and how to build our own theories (Roberts, 2015; S. X. Zhu, 2016). As an important qualitative research method, text analysis adopts inductive research strategies, constructs concepts, categories, and structures from the textual material, and reveals the coordination of different parts. The thesis conducts text analysis on the materials of three foreign and domestic private manufacturing enterprises. Through the three-level coding method of the text, the key activities and structural associations of the quality management of private equipment are extracted, and the QMM model of private equipment enterprises is constructed on this basis.

Questionnaire survey is a survey method which hopes to know the situation or seek

observations from the selected respondents using a designed questionnaire (Hu, 2020). At the pre-survey stage and the formal survey stage, the thesis conducts a questionnaire survey on the quality management of 6 private equipment manufacturing companies in Guizhou province and 80 private equipment manufacturing companies in Beijing, Zhejiang province, Guizhou province, Hunan province, and Sichuan province. Statistical software such as SPSS22.0 and Mplus8.0 are used to test the structural dimensions of the maturity evaluation model, analyze the QMM, and explore the path effect of the key indicators.

Delphi method, an assistant technique for structured decision, aims to acquire objective information and opinions with the help of experts through their independent and subjective judgment (Helmer, 1963). Considering maturity is a subjective evaluation, this research consults the experts in terms of maturity evaluation indicators selection, indicator weights determination, design and test of the maturity evaluation scale. Firstly, Delphi method is adopted at the stage of determining maturity evaluation indicators. Expert's opinions are collected to add maturity evaluation indicators related to the characteristics of Chinese private equipment manufacturing enterprises (S. X. Zhu, 2016). Secondly, Delphi method is adopted at the stage of scale design. Experts' suggestions are collected to ensure the conformity between the scale and the principles of quality management and the characteristics of quality management activities in private equipment manufacturing enterprises. Lastly, at the case study stage, the weights of maturity evaluation indicators are determined by expert scores, on the basis of which fuzzy comprehensive evaluation is carried out.

Case study is a method where one or several objects are selected, data and information are collected, and detailed research is conducted to explain a situation or a phenomenon of the real life (R. K. Yin, 2010). In order to better demonstrate the maturity model, this study selects GXTF company as the case. Through the AHP method and Delphi method, the case study shows how private equipment manufacturing enterprises could evaluate, improve, and make the best of the QMM.

1.4.2 Research path

The research path of the thesis is presented in Figure 1.1.

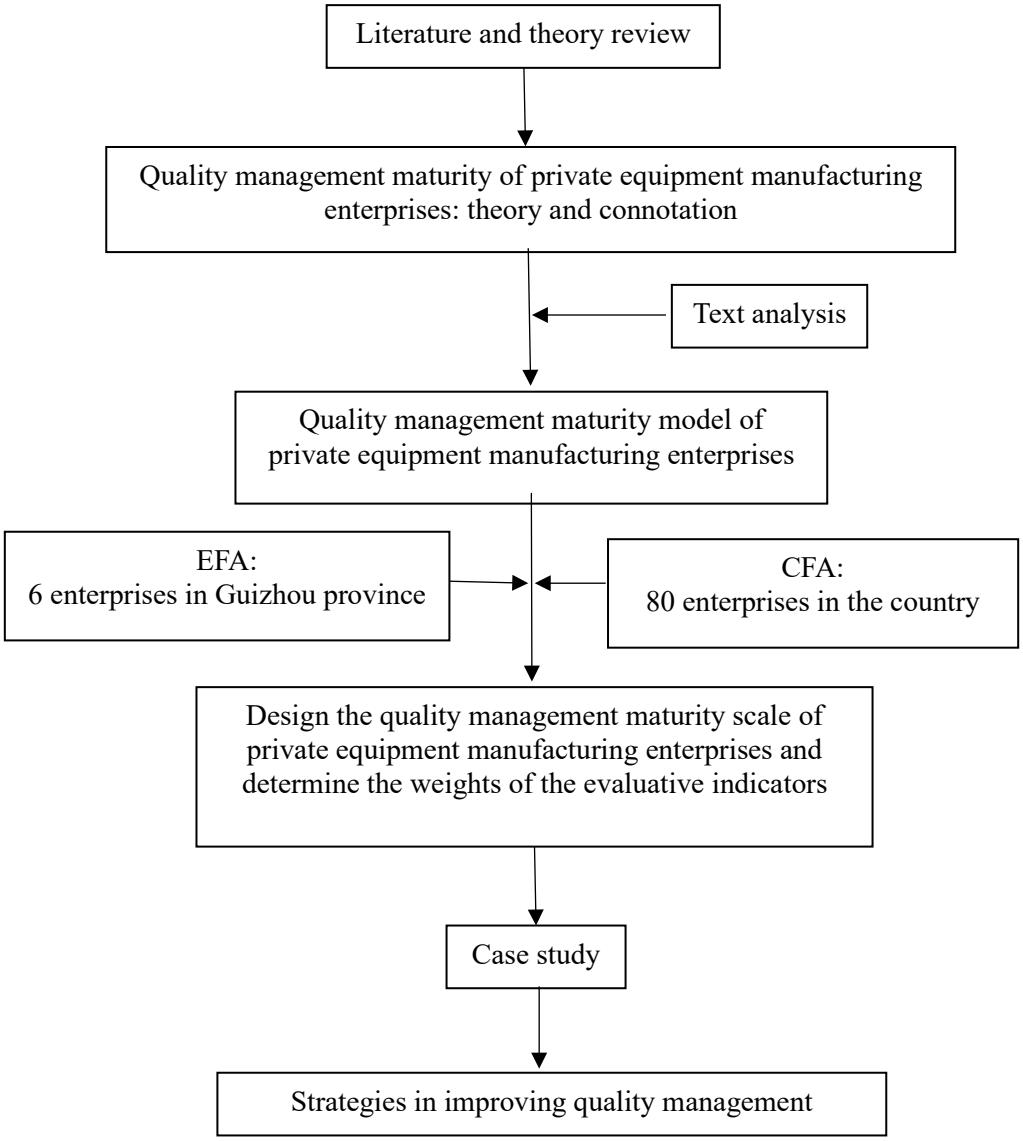


Figure 1.1 Research path

1.5 Thesis structure

In this thesis, there are 6 chapters, and the content of each chapter is illustrated as follows.

Chapter One: Introduction. This chapter is the guiding principle of the thesis. In this chapter, research background, research questions, research methods and research path, and thesis structure are expounded.

Chapter Two: Literature Review. This chapter is theoretical basis of the thesis. In this chapter, we reviewed the related literature such as the definition and development of quality as well as quality management, the development of QMS worldwide, and the connotation, model and evaluation model of the QMM.

Chapter Three: QMM Model of Private Equipment Manufacturing Enterprises. Based on

the literature review, this chapter carries out the text analysis on the materials of three foreign and domestic private manufacturing enterprise that have done well in quality management. Through the three-level coding of the qualitative analysis, the key activities and structure of the QMM of private equipment manufacturing enterprises are extracted. On this basis, the QMM model of private equipment enterprises is constructed.

Chapter Four: Empirical Study of the QMM Model. Based on the questionnaire survey, this chapter tests the maturity model through EFA and CFA. Structural equation model (SEM) is adopted in analyzing the path effect of the maturity model using the data of 100 private equipment manufacturing enterprises in Guizhou province. Moreover, the structural relationships and influence paths between the indicators of the maturity model are discussed.

Chapter Five: Application of the QMM Model. After the investigation and Delphi method, this chapter develops the QMM scale of private equipment manufacturing enterprises based on the maturity model. Taking GXTF as the case, this chapter shows in detail how to use the AHP and fuzzy evaluation method to conduct maturity evaluation, and how to use the evaluation results to enhance and improve the quality management of private equipment enterprises.

Chapter Six: Conclusions. This chapter summarizes the research content, clarifies the academic contributions and innovations, and points out the limitations and research prospects.

1.6 Chapter summary

This chapter is the introduction. The chapter discusses the research background, proposes the research questions, highlights the research significance, explains the research methods and research path, expound the structure and content of the thesis.

[This page is deliberately left blank.]

Chapter 2: Literature Review

2.1 Quality

In physics, quality is defined as “the amount of matter”. The quality of an object will not change regardless of the position, state, or shape, because quality is a physical property (P. L. Wang, 2014). In modern Chinese dictionary, quality is defined as “whether the product or work is good or not” (GJB, 2009).

In *IS09000: 2005*, quality is defined as “the degree to which the inherent characteristics meets the requirements” (GB, 2008; P. L. Wang, 2014). Characteristics are divided into key characteristics and important characteristics. Key characteristics (GJB1405A 4.5) refer to the characteristics of the product that will endanger personal safety and cause the failure of the main tasks if the requirements are not met. Important characteristics (GJB1405A 4.6) refer to the characteristics of the product that will cause the failure of the main tasks if the requirements are not met (GJB, 2006; J. Han et al., 2020).

According to China’s national standard *GB/T6583.94*, quality is defined as “the characteristics reflecting an entity’s ability in meeting explicit or implicit needs” (GB, 1995). Quality is essentially an object’s attribute of having certain abilities (James, 2011). With these abilities, objects can meet people’s needs. As for these needs, there are two situations. The first situation is when the needs are clear under the regulation of contracts, laws, standards, and technical specifications. These needs, which is demander’s clear need of the product or service, are usually stipulated through the contract. The second situation is when the needs are implicit, which requires the supplier to identify. With the development of productivity, the needs of people are becoming higher and higher (W. S. Yang, 1996).

Quality is also defined as the sum of the characteristics of products or services that could satisfy a need, which can be understood as the degree to which quality meets or exceeds customer requirements (X. S. Guo, 2016). Crosby, the American master of quality management and zero defects, believes that quality means meeting standard requirements. Juran believes “quality for use”, and the task of an organization is to provide customers with products that meet their needs.

Juran holds the view that quality is customer satisfaction and customer loyalty. It has two components: product characteristics and flawlessness, which are the main determinants of satisfaction (Joseph & Frank, 2017). In the manufacturing industry, product characteristics are

manifested as performance, reliability, durability, ease of use, serviceability, aesthetic, choice, scalability, and credibility. Meanwhile, flawlessness is manifested as having no defects and flaws in the process of delivery, use, and overhaul, and having no rework cycle, redundancy, and waste in all processes. Product characteristics in quality have an impact on sales through price and market share, with the focus being increasing revenue. Flawlessness is achieved through production schedule, quality assurance, and waste reduction, with the focus being reducing costs under the premise of the above control. Juran believes that both the internal and external views of quality are necessary (Joseph & Frank, 2017). As the science, technology, and economy rapidly develop, people's demands for quality continue to increase, bringing changes to the concept of quality. When supply exceeds demand, quality is manifested as meeting the requirements of product standards. Customers have low quality requirements, and customers are satisfied as long as there is stock and quality meets the product standards. When supply exceeds demand, quality is manifested as adaptive quality. Customers have higher quality requirements. To satisfy the customers, products should meet not only the product standards, but also the customer expectations or implicit requirements. In 21st century, quality is manifested as management quality (the relevant parties are satisfied with the quality), which should not only meet the product standards, but also meet the expectations or implicit requirements of the relevant parties. Table 2.1 summarizes some definitions of quality.

Table 2.1 Definitions of quality

Researcher	View
Shewhart	There are two levels of quality, which are subjective level and objective level (1931).
Crosby	Quality is meeting the requirements (1979).
Genichi	Quality is the feature that can avoid losses to the society after the product goes on the market (1979).
Feigenbaum	Quality can meet the expectations of customers (1983).
Deming	Quality can be defined from multiple aspects (1988).
Juran	Adaptive quality (1988).
Strelec	Quality can be defined from maintaining operations and optimizing value (2001).
Smith	Quality can be defined from sustainability (2004).
ISO	Quality refers to the degree to which inherent characteristics meets the requirements (2008).

Source: Shen (2005)

In *IS09000: 2015*, quality is defined as a kind of culture that an organization wants to achieve through satisfying the needs and expectations of customers and relevant parties (J. S. Su, 2018). This culture will be reflected in the behaviors, attitudes, activities, and processes. The product and service of the organization depend on the ability to satisfy the customer's performance as well as the influence on relevant parties. The product and service not only include the expected functions and performance, but also involves customers' perception of the

value and benefits. Figure 2.1 presents the evolution of quality.

Figure 2.1 The evolution of quality

It can be seen from the above viewpoints that although the definition of quality is different, the essence of quality is the same: (1) From the perspective of market, quality should meet customer needs; (2) Quality is measurable and can be expressed by data; (3) Quality is controllable through management; (4) Quality is valuable; (5) Quality is a comprehensive process involving all aspects of business management (J. P. Zhu, 2011).

2.2 QM (Quality Management)

2.2.1 Definition

Quality management refers to the one-person or one-group activities that direct and control the organization in terms of quality (Y. G. Sun & Pang, 2014). Generally, quality management includes things centered around quality such as its policy, objective, planning, monitoring and improvement (GB, 2008).

Deming holds that the quality management process should be observed from a statistical perspective and controlled with statistical tools (Derming, 2003). Deming considers that customers are the criteria for evaluating quality. In order to give feedback to customer needs and dissatisfaction, and to meet customer needs, PDCA theory was proposed.

P-PLAN: Everything needs meticulous planning. It is essential to specify the plan, formulate countermeasures, and answer the “5W1H”, that is: Why the measure was formulated; What goals should be achieved; Where to carry out; Who is responsible; When to complete; How to complete (X. D. Sun et al., 2018).

D-DO: implement the plan according to the requirements.

C-CHECK: check during or after the execution of the plan to see if the expected results and effects of the plan are met, that is, effect check. Effect check is required to verify and evaluate whether the plan is effective and whether the goals are accomplished. After confirming the countermeasures, evidence is summarized and analyzed to compared with the goals to see if the goals are reached.

A-ACTION: take corresponding measures based on the inspection results. The task of this stage is consolidating the achievements, incorporating successful experience into the standards, and leaving the remaining problems to the next PDCA cycle (Z. Y. Wang & Sun, 2005), which is called Deming cycle. Deming also proposed fourteen laws to point out the principles and methods of business management. There are four aspects of content: emphasize the system, understand the variation, knowledge theory, and psychology (Derming, 2003).

Crosby expounded his understanding of quality in his first book *Quality Free*. In his point of view, the essence of the quality is "the law of quality management" and "the basic elements of improvement" (Crosby, 2006). By conducting research on quality management in the U.S. and Japan, Crosby put forward the following questions: Why are their products good, but ours problematic? Why do they spend their time on sales instead of maintenance? Why is their execution strong, but ours weak? These questions are put forward because the management level does not take product or service requirements seriously, and American workers cannot work like Japanese workers (J. P. Zhu, 2011). The traditional view holds that mistakes are inevitable. In fact, as long as mistakes are allowed in the work standards, there will be mistakes. If we have 100 steps, and the correct rate of each step is 99%, then the correct rate of the connected 100 steps can be calculated by self-multiplying 100 times, with the overall correct rate being 36.4%, which is clearly unacceptable. Therefore, Crosby proposed the concept "DO IT RIGHT THE FIRST TIME".

Faced with the market competition in the early 1960s, relying on quality inspection and statistical methods is not enough to guarantee and improve product quality (C. X. Zhao, 2021). It is also inappropriate to delegate the quality function to professional quality management engineers and technicians. In Feigenbaum's *Total Quality Control* published in 1961, it is emphasized that all the staff have the responsibility of quality, and solving quality problems cannot be limited to the product manufacturing process. Besides inspection and mathematical statistics, there are many ways to solve quality problems. The purpose of total quality control is to carry out market research, design, production, and service in the most economical way and with user requirements taken into account (J. Shi, 2019). The development, maintenance and

improvement of quality activities are incorporated into an effective system (H. P. Liu & Liu, 2021; W. S. Yang, 1996).

Genichi Taguchi elaborated on the economic value of variation reduction and believed that the definition of quality has inherent flaws in manufacturing industry. There are not many differences between products that exceed and approach the required value and products within the required value range. Although the difference will not influence the performance of the product, adjustments must be made to meet the requirements, which will increase the process cost and caused the loss (C. D. Su, 2004).

According to *JSZ8101-1981 Japanese Industrial Standard Quality Management Term*, quality management is defined as "a system that economically produces goods or service that meet the quality requirements of buyers" (Zhou, 2021). Quality control is abbreviated as QC. As modern quality management adopts statistical methods, quality management sometimes specifically refers to statistical quality management. In order to effectively implement quality management, enterprises need to conduct overall-phase activities (A. L. Wu, 2018). The entire enterprise must work together and gather all the power of the entire company to truly implement quality control, so this kind of quality control is also called company-wide quality control. To implement the company-wide quality control, all departments need to participate and the person in charge of each department should take the lead. Meanwhile, everyone should be involved in the implementation of QC. In order to produce products that are popular among consumers and the society, while taking quality as the first, it is also necessary to comprehensively manage costs (C: selling price, profit), quantity, delivery time, and safety (C. X. Shi, 2019).

The Juran trilogy proposed by Juran divided quality management into: quality planning, quality control, and quality improvement. The idea of "living under the protection of quality" derives from the coastal levee in Netherlands. About one-third of the land in the Netherlands is below sea level. To take advantage of the land, consolidated coastal levees need to be built and maintained. Thanks to the speedy science and technology, people have enjoyed a more colorful material and civilized life. At the meantime, people also need to put their safety, health, and daily life under the "protection of the quality levee which is built by quality management" (Godfrey & Juran, 1999). Juran holds that behind the levee of quality management, there are not only individuals, but also the country and the national economy (W. S. Yang, 1996).

The method of quality management proposed by Yoshinori (2016) is based on management principles, such as process management, work standardization. The elements of process management are described in Table 2.2.

Table 2.2 Elements of process management

Process	Elements
Input	Objects, information, and status that can be converted in the output process. Examples: objects (raw materials, parts, auxiliary materials, processing objects.), information (instructions, input information, reference information), status (initial state of the object before the activity)
Output	Object, information, and status that have been converted. Examples: objects (finished products, semi-finished products, parts), information (output information, knowledge, analysis results, judgment), status (final state)
Activity	Activities needed from input to output. Examples: implementation items, steps, methods, conditions
Resources	Activities or business resources to support the process. Examples: talents, suppliers/partners, knowledge/technology, equipment/machines, facilities, work/business environment, utilities (water, electricity, gas), support process, support system, public facilities.
Measurement/Management	Things required to master and manage the goals and activities of the process, such as the measurement/management items/management indicators and control/intervention, management, responsibility/authority, role sharing. Example: output characteristics, process activity status, process condition characteristics.

Source: Yoshinori (2016)

After the 1980s, science and technology development has brought changes to the quality management (Y. H. Yang & Song, 2019). Total quality management (abbreviated as TQM) was proposed in the U.S., total quality assurance (abbreviated as TQA) was proposed in some European countries, and ISO issued IS09000 standards for guiding companies establish and operate a quality system effectively, which not only requires companies to ensure product quality, but also meet the customer needs and form a process-oriented model centered with customers (W. J. Su, 2006).

In 2003, Spanish scholar Merino used 965 valid questionnaires from various industries in Spain as the sample and divided quality management activities into five dimensions: new product development, production process management, supplier quality management, relationship with customers, human resources management (Q. H. Chen, 2006). Through multiple regression method, the research focuses on the impact of quality management on corporate performance, and comes to the following two conclusions: new product development can significantly affect corporate performance; the correlation between human resource management and corporate performance is significantly higher than other dimensions of quality management activities (De Cerio, 2003).

In Chinese standard *GB/T6583.94*, quality management is defined as “the activities that

centered around quality such as determining the policy, objectives, and responsibilities as well as implementing management functions in the quality system".

Chinese scholar Peng believes that companies that value quality management should have the following characteristics: top managers value quality and regard quality management as a technical task; quality management personnel have strong execution and innovation awareness, and quality improvement is a PDCA cycle which requires persistence; quality management personnel have a strong initiative (Peng, 2009).

Long and Li (2002) sorted out the elements of quality management activities. They argued that the focus of quality management lies in six aspects: senior support, employee management, relationship with suppliers, relationship with customers, process management, and statistical control. Based on this, they proposed countermeasures and methods such as improving the relationship with customers, strengthening the relationship with suppliers, dealing with employee management, increasing senior support, focusing on process management, and intensifying the statistical control (Long & Li, 2002).

2.2.2 Development of QM

2.2.2.1 The development of QM abroad

QM (quality management) has gone through quality inspection, quality control, total quality management, and excellent quality management (C. Chen, 2020; X. S. Guo, 2016; J. Shi, 2019; W. S. Wang, 2020; Xiao, 2019).

(1) Quality inspection stage (from the early 20th century to the late 1930s)

The main feature of this stage is post-inspection. In the early 1900s, Taylor put forward a theory which separated quality inspection from the production process as a management function. A full-time inspection system was established. In the system, the professionals made qualified and unqualified judgments after inspecting parts and components, which has guaranteed the quality of products to a certain degree.

(2) Statistical process control stage (1940s to late 1950s)

From post-inspection to process control, the management method that combines post-inspection and preventive control is preferred. During the World War II, the U.S. national defense industry had an urgent need to ensure the quality of military products. At that time, the U.S. Bell Telephone Laboratory established two research groups: one is the process control group lead by Shewhart, who put forward the SPC theory of statistical process control and pioneered control charts in the 1920s, and the other is the product control group lead by Dodge

and Romig, who proposed sampling inspection theory. Shewhart and Dodge introduced mathematical statistics to quality management and were the founders of statistical quality control theory (James, 2011).

(3) Total quality management stage (1960s-1990s)

The representatives of total quality management are Feigenbaum and Juran (Q. H. Chen, 2006; C. X. Zhao, 2021). The three "totals" include total quality, total process, and total staff (H. H. Zhao, 2012). The theory originated in the U.S., but took effect in Japan. In the 1980s, the U.S., who was at a disadvantage in the fierce international business competition, re-recognized the importance of quality management. Under the advocacy of quality management expert Dr. Deming, the SPC theory and method of statistical process control was promoted and achieved remarkable results (Z. He & Zhao, 2008).

(4) Excellent quality management stage (1990s-present)

The representatives of excellent quality management are Baldrige and Jack Welch (X. S. Guo, 2016).

In the early 1980s, the U.S. was faced with challenges in both product quality and process quality. For 20 years, the productivity growth of the U.S. lagged behind competitors, with poor-quality cost accounting for 20% of the sales revenue (Duan, 2018; L. F. Lu, 2020). At that time, the U.S. economic circle began to notice the problem, and started a "quality revolution" all over the country by learning from Japan and re-importing TQM. Baldrige became the Secretary of U.S. Commerce Bureau in 1981 and died in an accident in July 1987. During his tenure, Baldrige advocated quality management and spared no effort to promote the legislation of quality improvement (L. F. Li, 2013). In 1987, the U.S. Congress passed the *Quality Improvement Act* (J. T. Liu et al., 2019; W. R. Wang, 2020).

Under the leadership of Jack Welch, General Electric (GE) has adopted 6Sigma as a management strategy since 1996. 6Sigma management has achieved significant results in the company by only taking 5 years to complete the original 10-year plan. Because of this, GE's CEO Jack Welch became famous all over the world and was hailed as the world's first CEO (Y. Chen, 2019; H. B. Yang, 2019). When 6Sigma was introduced in 1995, the average quality level was 3σ. After 22 months of hard work, the average quality level reached 3.5σ, with the revenue increasing significantly. In 1996, the revenue increased by 13%, in 1997 by 14%, and in 1998 by 16.7%. In 1996, the revenue brought by 6Sigma was $300 million and in 1997 the revenue brought by 6Sigma exceeded $600 million (A. H. Wang, 2011).

Each quality management stage is the product of the era, so problems surely exist. Problems in the quality inspection stage include: there lacks a systematic concept, and responsibilities are

unclear when quality problems occur; there lacks prevention thinking in the production process, and the problems are found rather than prevented; 100% inspection for finished products does not equal to 100% correction, which is uneconomical and meaningless for mass production. Problems in the statistical quality management stage include: statistical methods of quality management are overemphasized and the quality management itself is paid insufficient attention to, which led companies to think that quality management is just a statistical method. This kind of thinking has not only undermined quality management, but also restricted the promotion of quality management statistical methods. Problems in the total quality management stage include: the process identification is insufficient, the awareness of participation is low, the correction measures are merely formals, there lacks effective countermeasures, there is a gap between the actual implement as well as quality management and the system.

2.2.2.2 The development of QM in China

The quality management in modern China has experienced three major development stages (Y. J. Liu et al., 2018).

(1) The first stage: quality inspection

The first modern quality system was introduced in 1978. At that time, the quality system mainly embodies the post-control based on inspection.

(2) The second stage: total quality management

From 1985 to 1991, total quality management (TQM) was implemented in state-owned enterprises as required by the Chinese government. However, due to the absence of the statistical process control stage, there was a lack of statistical technology in the enterprises, which cause the implement of the prevention measures inefficient.

(3) The third stage: QMS accreditation and excellent quality management

In May 1991, *Regulations on Product Quality Accreditation in China* was formally promulgated, marking China's quality accreditation has entered a stage of comprehensive and standardized implementation. In addition to comprehensively establishing and implementing product accreditation, important progress has also been made in the management system. Accreditation systems have been successively established. The former State Burau of Quality and Technical Supervision successively established the China National Accreditation Commission of Registrars (CNACR), China Registrar Board of Accreditation (CRBA), China National Accreditation of Conformity Laboratories (CNACL) and China National Accreditation of Conformity Product (CNACP) to carry out accreditation work in the domestic

market (L. J. Zhi, 2019). Meanwhile, the former Entry-Exit Inspection and Quarantine Bureau successively established the CNAB and CCIBLAC to carry out accreditation work in the import and export field. China began to implement QMS accreditation to improve product quality. In August 2001, the CNCA was established for unified management, supervision and comprehensive coordination of national certification and accreditation, which marks the establishment of a unified certification and accreditation management system in China. Many enterprises started to implement management system accreditation such as ISO9000 and ISO14000. Some enterprises also began to implement advanced theories and methods such as 6Sigma and excellent performance evaluation as well as hold quality month and QC group activities, which have achieved outstanding results (J. J. He & Zhang, 2020). The results of a random inspection of product qualification rate showed that the average qualification rate of Chinese enterprises' products had increased by 8.9% in 2011 compared with 1999 (Shen, 2005). In 2013, the national QC team activities achieved an economic benefit of ¥46.5 billion and a cumulative benefit of ¥746.5 billion (GB, 2008). China promulgated the *Quality Promotion Program (1996-2010)* in 1996 and the *Quality Development Program (2011-2020)* in 2012. In 2013, China Quality Award was launched in the name of the country, which reflects a great emphasis on quality work from the national strategic level.

In January 2018, the State Council issued the document which clearly regarded quality accreditation as an important starting point of advancing supply-side structural reform and a meaningful measure for decentralization and service reforms (Joseph & Frank, 2017). In February 2018, when president Xi Jinping delivered a work report where he specifically emphasized promoting the construction of quality accreditation systems. In April 2018, the General Administration for Market Regulation was newly established. The responsibilities of the State Certification and Accreditation Administration were transferred to the General Administration for Market Regulation to do unified management of certification, accreditation, inspection, and testing. All of these have shown that certification, accreditation, inspection, and testing work has been highly valued and arisen from a quality management method to an important tool for national governance.

CNCA implements the *Opinions of the State Council on Strengthening the Construction of Quality Accreditation System and Promoting Total Quality Management* on March 21st, 2018 (CNCA). In the *Opinions*, the following aspects are required. Firstly, actively adopt the international advanced quality management standards, comprehensively transform advanced quality management methods such as 6sigma in accordance with China's actual conditions, and initiatively develop quality management tools such as traceability management, supply chain

management, and business continuity management to adapt to the needs of new business formats and create a toolbox for quality management in China. Secondly, fully exert the effectiveness of industry authorities, encourage all industries to sort out the industry characteristics and promote the combination of general quality management requirements with industry special requirements, develop new quality management tools, and spread the results and experiences of advanced quality management industries and enterprises. Thirdly, carry out activities for enterprises to learn and apply the QMS standards, encourage enterprises to use quality accreditation to strengthen quality management, and extend advanced quality management standards and methods to the primary, secondary and tertiary industries and social governance. Fourthly, establish and implement a QMS, use advanced quality management methods such as excellent performance, introduce third-party quality governance mechanisms (S. W. Han, 2018). Fifthly, use the new version of ISO9001 QMS and other international advanced standards to improve accreditation requirements, transform traditional accreditation models with new techniques such as the Internet, and upgrade QMS accreditation to drive the overall upgrade of enterprise quality management (Huo, 2020).

2.3 QMS (Quality Management System)

2.3.1 The development of QMS abroad

The world's first QMS standard was issued by the U.S. military. In 1959, the U.S. Department of Defense issued MIL-Q-9858 Quality Standards. The Standards requires manufacturers of military products to "fully guarantee the quality in all processes including designing, developing, processing, assembling, inspecting and testing, maintaining, packing, storing and installing". Meanwhile, the U.S. Department of Defense issued MIL-Q-45208A Inspection System Requirements to meet the quality needs of simple weapons and equipment. Moreover, in order to interpret and evaluate the above standards, the U.S. Department of Defense has also formulated documents such as MIL-HDBK-50 Contractor Quality Standard Evaluation and MIL-HDBK-51 Contractor Inspection System Evaluation, thus forming a relatively complete set of QMS standard documents. The U.S. military product manufacturer has achieved good results by implementing U.S. military standards as well as establishing and improving a quality management (guarantee) system, which has also obtained the attention of other developed countries.

In the 1970s, the British Standards Institute (BSI) started on quality management

certification activities to promote quality development. In 1987, ISO established TC176, and the standards developed by TC176 are named ISO9000 series standards, which has promoted the development of QMS certification worldwide.

Later, countries such as Italy, Germany, France, Spain successively implemented the ISO9000 series standard quality system certification system. CEN and CENELEC have jointly formed the European Standards Institute CEN/CENELEC to formulate and publish the *European Community EN standards*, requiring the countries in the European Community to comply with. In 1987, European Community adopted the ISO9000 series standards as the EN29000 series standards, requiring all member states to implement them as quality assurance system standards. The EN45000 series of standards on test, certification, and accreditation issued in 1988 were also recognized by ISO and used worldwide.

In 1989, European Community put forward a global standard certification proposal to ensure the product circulation, and the uniform use of "CE" mark is required. The European Community implement the "CE" mark regulation for children's toys, mechanical products, pressure vessels, construction products and materials, electromagnetic compatibility products, personal protective equipment, medical appliances, non-automatic scales, gas appliances, food utensils and appliances. The above-mentioned products without the "CE" mark cannot be sold on the European Community market. Products with the "CE" marks are required to gradually use the ISO9000 quality system, while the sales of the above-mentioned products without the "CE" marks in the European Community market will be restricted. Therefore, it is necessary to set up and improve a quality system that meets the requirements of ISO9000 as soon as possible for the product departments and enterprises related to the above mandatory directives. Due to the important position of the European Community in global trade, international standardization and quality system certification of products in these countries are promoted and accelerated.

In May 1980, the Quality Assurance Technical Committee (TC176) was established in Ottawa, Canada, to study the standardization of quality management and quality assurance and to formulate relevant international standards. The secretary country of ISO/TC176 is Canada, with the secretary being QMI, an organization under the Canadian CSA. Canada adopts the CSA2999 national standard formulated based on ISO9000.

On the basis of the American standard *ANSI/ASQCZ1.-15* and with reference to standards in other countries, ISO9004 standard is compiled. The U.S. Department of Defense has announced the cancellation of two MIL quality specification standards and fully adopts the ISO9000 series standards. That is to say, if a company wants to sell products to the Department of Defense, the products must pass the system review and registration of the ISO9000 series

standards. The U.S. has begun to show greater concern about ISO9000. The unified market of Europe has not only increased the involvement of government departments, but also strengthened the coordination with technical regulations, standards, and quality system certification with the European Community. The U.S. UL company has also moved closer to the ISO9000 system certification and formulated the ULISO9000 registration plan.

At the beginning, Japan took a cautious attitude towards the ISO9000 standard. When TC176 sent a survey letter to countries to inquire about ISO9000 in 1991, Japan did not respond. Affected by the international promotion of ISO9000 standards, Japanese companies become increasingly interested about the ISO9000 series standards. According to the list of countries adopting ISO9000 standards published by the ISO/TC176 secretariat, Japan has put ISO9000 standards in a position equivalent to the Japanese *JISZ9000-1991* series standards.

Up to now, more than 150 countries and regions have equally converted the ISO9000 standards standard into a national standard.

2.3.2 The development of QMS in China

(1) The first stage

To adjust to international economic cooperation and trade exchanges, China adopted the *ISO9001-1987* standards. However, there are some problems in the ISO9001-1987 standards: (1) it mainly applies for manufacturing; (2) it is suitable for large and medium-sized enterprises; (3) it gives limited emphasis on the successful experience of total quality control (TQC); (4) the coordination between standards is poor. In 1988, GB/T 10300.2.1988 quality management model including development, design, production, installation and service is issued to improve the corporate QMS, consolidate and deepen TQM, standardize quality management and assurance activities, eliminate technical barriers to international trade, and develop international economic and technological exchanges. *GB/T 19001-92* was officially approved as the national standards China on October 12th 1992 and implemented on January 1st, 1993.

GB/T 19001-1994 was officially approved on December 24th, 1994 and implemented on June 30th, 1995. The 94 edition ISO9000 series standards have undergone transitional revisions. Compared with the 87 edition standards, the 94 edition ISO9000 series standards maintained 20 elements, made some changes, and added some guidelines and technical standards. GB/T 19001-1994 standard provides the requirements of the quality system, which is used for situations that demand the supplier's ability to design and provide qualified products. The main purpose of the standard is to satisfy customers by preventing nonconformity from design to

service.

At this stage, QMSs are rarely implemented in private enterprises, and quality management is mainly carried out through inspection.

(2) The second stage

With the wide application of ISO9000 series standards in the international arena, deficiencies and problems began to appear. 94 edition ISO9000 standard has flaws in the following aspects: 1) it did not fundamentally solve the problems in 87 edition ISO9000 standard; 2) the increasing number of standards has made it inconvenient to use; 3) The huge family standards have led to a poor coordination. ISO/TC176 revised the 1994 edition 1S0000k standard after summarizing the application of the ISO9000 series standards in various countries, and issued the 2000 edition ISO9000 standard at the end of 2000. The 2000 edition ISO9000 standard includes four core standards, one supporting standard, three brochures, and seven technical reports, as illustrated in Table 2.3.

Table 2.3 Core standards and supporting standards

Core standards and supporting standards
Core standards
QMS basics and predicates
QMS requirements
QMS performance improvement guide
Quality and/or environmental management system audit guidelines
Supporting standards and documents
Measurement control system
Quality management -project management quality guide
Quality management -guidelines for technical state control
Guide to QMS
Quality and economic management guidelines
Quality management-training guide
Statistical technical guide
Brochures
Quality management principles
Selection and use guide
Application in small business

Source: ISO (2000)

Compared with the 1994 edition standard, 2000 edition ISO9000 standard has changed greatly in terms of the overall structure and content. 2000 edition ISO9000 standard firstly integrates the quality assurance system with the QMS, thereby improving the enterprise quality from quality assurance to quality management; secondly highlights the concept of process and shifts the focus of attention from broad quality to process quality; thirdly emphasizes the role of statistical technology in supporting quality management; fourthly underlines the continuous improvement of the quality management and product quality, so that companies can get more benefits.

Figure 2.2 presents a process-based QMS model.

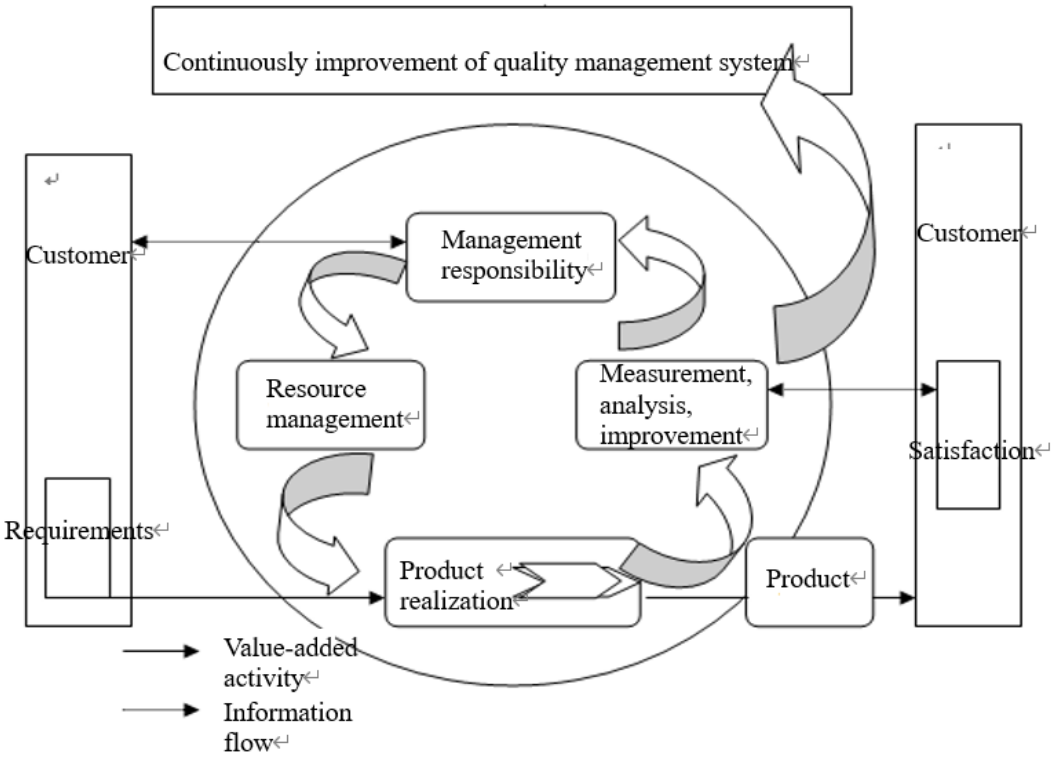


Figure 2.2 Process-based QMS model

Source: ISO (2000)

After the implementation of 2000 edition ISO9000 standard, new requirements were put forward for military quality management. In order to be in line with international standards and meet the requirements of weapon quality, national military standard GJB9001A-2001 standard is issued on May 31st and formally implemented the standard on October 1st, 2001. The standard adopts the A+B model, in which A is equivalent to GB/T19001-2000 standard, and B adds special requirements for military products. While taking into account design and development, production, installation and service, the standard highlights key processes, underlines customers, and put forward content such as risk management, quality information, technical status management, operational reliability, maintainability, and security (Jia, 2006).

(3) The third stage

ISO9001-2008 QMS Requirements is issued in 2008. China issued *GB/T19001-2008 Quality Management System Requirements*, which revised GB/T19001-2000 and enhanced its compatibility with GB/T24001-2004 standard. On December 22nd, 2009, national military standard *GJB9001B-2009 Quality Management System Requirements* is issued. The standard not only emphasizes the customer-oriented process, but also clarifies that the revision of standard should be under customer supervision, the planning and adjustment of QMS should be communicated with and approved by the customer, and the customer should be invited to

participate in the trial production preparation status inspection. Being a promoter of engineering technology and management activities with six characteristics such as reliability, maintainability, and supportability, the standard firstly advocates the six characteristics to the management level, then uses the six characteristics to give design report and review. Moreover, the standard further emphasizes the effectiveness and continuous improvement.

(4) The fourth stage

ISO9001-2015 Quality Management System Requirements is issued in 2015. China issued *GB/T19001-2016 Quality Management System Requirements* on December 30th, 2016, which revised GB/T19001-2008 and strengthened the consistency of ISO90001 standard with other standards. The new version of the standard has significantly changed in terms of the structure and the clause order, which embodies the process method + PDCA + risk-based management idea and changes the principles of quality management from eight principles to seven principles. The systematic approach of management is incorporated into the process approach instead of being a separate principle. Meanwhile, the mutually beneficial supplier relationship is changed to relationship management, and full participation is changed to active full participation (GB, 2016). The elements of single process are shown in Figure 2.3.

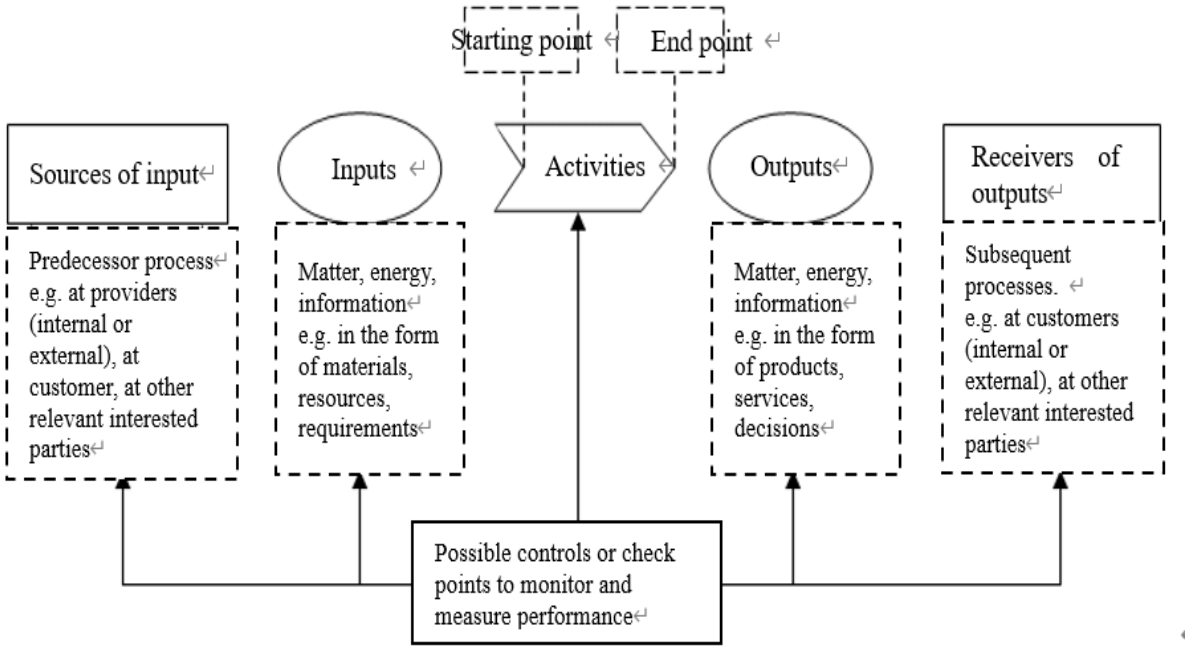


Figure 2.3 The elements of single process

Source: GB (2016)

GJB9001C-2017 was released on May 18th, 2017, and summarized three major processes for the QMS. The first process is customer-oriented process (COP), which includes product design and development, general quality characteristics work process, external provision

process, production process, marketing services. The second process is management process (MP), which includes leadership, strategic management, target management, risk management, technical status management, information management, and improvement process. The third process is support process (SP), which includes human resources, infrastructure, process operating environment, monitoring and measurement, statistical technology, document and record control (W. S. Wang, 2020).

2.4 QMM (Quality Management Maturity)

2.4.1 Definition of QMM

In Cambridge International English Dictionary, maturity is defined from the perspective of physical growth (Bao, 2016). In the paper Quantity Project Management Ability, John Schlichte defined maturity as a developing process stage as well as the understanding of being successful and avoiding conventional problems (Q. Y. Yang & Fu, 2011). Maturity is the development process of immature to relatively mature to fully mature, which reflects the improvement of organizational capability with time going by (H. Q. Wang & Wang, 2009).

Patti et al. defined QMM as how the company implement quality management. The better is the quality management, the higher the QMM is (Patti et al., 2001). Crosby holds that one of the senior management level's jobs is to ensure that all quality management functions can be operated normally, and the degree of function operation is actually management maturity (Crosby, 2006).

Li et al. hold the view that different quality management effects are due to the nature of companies. Therefore, even if the quality management measures are the same, the effects are still very different. Moreover, Li et al. defined the degree and level of quality management practices as QMM (J. Li et al., 2002).

2.4.2 QMM model

2.4.2.1 QMM grid

In the book Quality Free published in 1980, Crosby, the master of quality management, proposed the QMM grid, as in Table 2.4.

Table 2.4 QMM grid

Evaluation items	Stage 1: uncertainty	Stage 2: awakening	Stage 3: enlightenment	Stage 4: wisdom period	Stage 5: definite
The	Have no	Recognize	Participate in the	Participate in	Think that

awareness and attitude of management level	awareness that quality is a management tool, and blame quality problems on the quality department	that quality management may be valuable, but not willing to invest time or money to improve	quality improvement plan, have a better understanding of quality management, give more support and assistance	activities, be aware of basic principles of quality management, understand the role of individuals in continuous improvement	quality management is a basic part of the company's management
The position of quality management in organization management	Quality is a matter for the manufacturing department or engineering department; there may not be an inspection department in the organization, and more attention is paid to product evaluation and classification	Appoint a capable quality leader whose basic task is to make production smooth. Quality leader is only part of production or other departments	The quality department is responsible for the management. All evaluation results are included in the formal report, and the quality manager has a certain position in the company.	The quality manager is an important member of the company who reports effective work conditions, takes preventive measures, and participates in customer-related and assigned events	The quality manager sits on the board of directors as non-voting delegates. Prevention is the basic focus, and quality is considered as the guide of the company.
Problem solving	Just solve the current problem which cannot solve the problem. There is no clear quality standard, and departments in the organization attack each other	Form a working group to solve major problems, but there is no long-term overall problem-solving strategy and method	Establish an effective communication channel for error correction activities, openly face problems, and solve them in a planned way	Problems can be found in the early stages of development, and all departments accept public improvement suggestions and implement improvement activities	Most problems have been prevented in advance.
Quality improvement activities	Have no quality activities and not understand such activities	Try some short-term improvement activities when interested	Completely understand and implement each step of the 14 improvement steps	Continue to perform the 14-step activity and begin to move towards determination	Quality improvement is a daily and continuous activity
Company's mentality about quality	We don't know why there are quality problems	There are always quality problems	Through the commitment and quality improvement activities of the management level, we have been able to find and solve our problems	Defect prevention is part of our daily work	We know why we have no quality problems

Source: Crosby (1980)

QMM grid is the earliest model that summarizes and evaluates the production process quality of an enterprise. It divides the business operation into five periods: uncertainty period, awakening period, enlightenment period, wisdom period, and definite period (Crosby, 2006; Keith et al., 2016; Y. Wu, 2010).

Based on the maturity grid, an enterprise can roughly find out its own characteristics, judge the current stage and the next step, and make correct business decisions (Gochermann & Nee, 2019; Shewfelt, 2014). However, the quality management process maturity grid created by Crosby only summarizes the characteristics of the five main aspects of quality management, without performing meticulous evaluation on the process and results (Q. Y. Yang & Fu, 2011; Y. Zhang & Liao, 2015).

2.4.2.2 CMM

Humphrey (1990) introduced the maturity framework. After adding the maturity levels, the maturity framework is then developed into CMM (capability maturity model) by the Software Engineering Institute of Carnegie Mellon University, which aims to provide customers with methods to evaluate the capabilities of software developers and to help software developers improve their software processes (Song, 2012; T. Zhang, 2020).

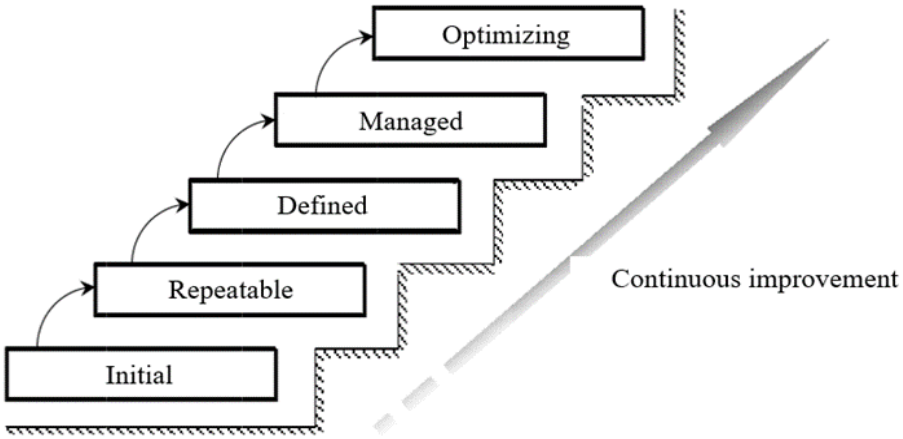


Figure 2.4 CMM

Source: Wang and Zhang (2020)

CMM provides a stepped structure for software companies to improve the capability. CMM divides maturity into initial, repeatable, defined, managed and optimizing level (Paulk, 1994; Suhardi et al., 2015), as shown in Figure 2.4. From initial level to optimizing level, the maturity level represents the upgrading of management level from chaos to maturity (Qin & Zhao, 2017).

The characteristics of the five maturity levels are as follows.

Initial level: There lacks software engineering management system, which is chaotic. Lacking management and planning, the time and expense often overruns. Being reactive, the management method at this level is mainly used to cope with crises, with the process being unpredictable and unrepeatable. When there are software engineering specifications but still fail to cover the basic key process requirements and there is no support from related resources during execution, the maturity level is still the initial level (Tiku et al., 2013).

Repeatable level: A basic project management system is established and certain resource control methods have been adopted based on the experience of similar projects. Managers can discover problems in time and take countermeasures. The primary problem of software development is not a technical problem but a management process, which is repeatable (Raber et al., 2012).

Defined level: The software process is documented and standardized. The development process can be improved according to requirements, the review method is used to ensure software quality, and the case management tool is introduced to improve quality and efficiency. The implementation standards are integrated into the enterprise software development standard process. The enterprises can either choose to implement the standard process or adjust according to the specific situation. However, the adjustment needs to be confirmed and approved by relevant personnel (Geoffrey et al., 2012).

Managed Level: Clear measurement methods and measurement indicators are established in all the processes. The measurement is detailed and can be used to understand and control the software process (Yu et al., 2016). Enterprises at this level will formulate quality and efficiency goals, collect and measure the corresponding indicators, and use statistical tools to analyze and take improvement measures.

Optimization level: The enterprises could improve the next execution process according to the feedback, optimize the execution steps, and steadily improved the quality and efficiency.

CMM is efficient in ensuring software quality and has been widely used since its appearance (Y. N. Su, 2008). Since then, many scholars and organizations have put forward various maturity models based on CMM.

2.4.2.3 International quality maturity model (IQMM)

In April 2002, India's Qimpro Standards Organization (QSO) released the version 1.1 of its International Quality Maturity Model (IQMM) (Ji et al., 2018). As shown in Figure 2.5.

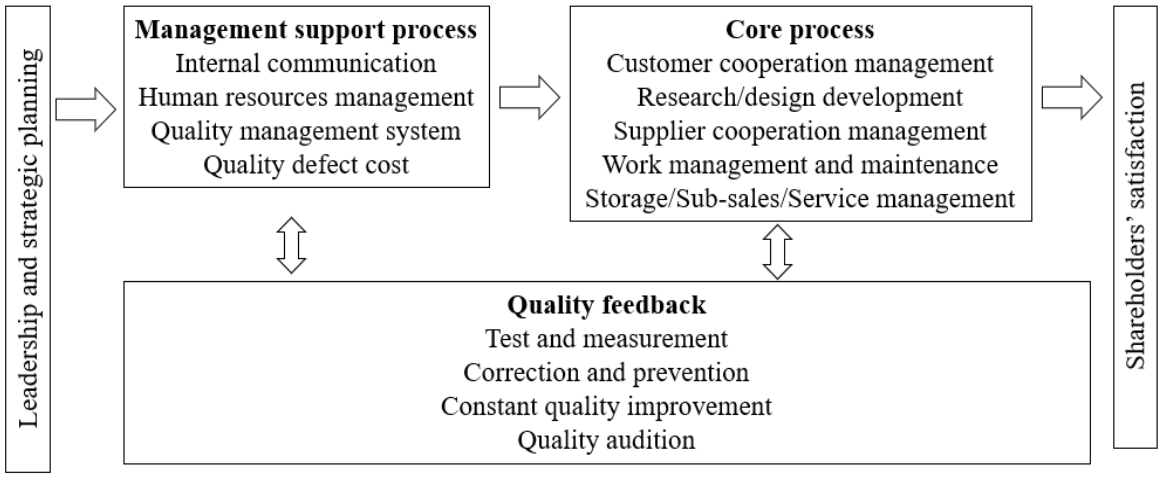


Figure 2.5 IQMM

Source: Yang (2012)

IQMM, a new tool used to measure and evaluate the QMS, consists of 15 business (functional) elements based on world-class quality management. The 15 business elements can be further decomposed into 10 lower-level sub-elements, which have referred to the quality management model elements of ISO9001 standard, QS9000 standard, Deming quality model, Baldrige Quality Award, European Quality Award, and National Quality Award established by Indian Ministry of Commerce (Y. B. Li, 2007; C. X. Shi, 2019).

Starting from leadership and strategic planning, quality support process, core process, quality feedback, and customer satisfaction, IQMM used the 15 sub-goals under the indicators to evaluate the enterprise quality. Due to the atypical characteristics of the business and the sub-goals, the model evaluation system is not highly targeted and has poor operability (L. F. Li, 2013). However, the model is of guidance meaning to establishing the QMM model evaluation.

2.4.2.4 ISO 9004 maturity model

The International Standard Organization issued ISO 9004:2018 in April 2018. The standard provides a systematic framework and guidelines for organizations to surpass accreditation requirements, maintain and improve the comprehensive ability to satisfy the needs and expectations of customers and other related parties, and achieve long-term sustainable success (Z. L. Zhang, 2013). In other words, ISO 9001:2015 focuses on providing trust for the organization's product and service quality, while ISO 9004:2018 focuses on providing trust for the organization's ability to continue to succeed.

According to the maturity evaluation model and evaluation criteria in *ISO 9004:2018 Quality Management-Organizational Quality-Guidelines for Achieving Sustained Success*, organizations can conduct the maturity of management system through self-assessment in the

following ways: 1) Understand the needs and expectations of related parties; 2) Monitor the organization's background changes; 3) Identify possible areas to be improved, learnt and innovated; 4) Formulate and implement policies, strategies and goals; 5) Manage the process and resources; 6) Demonstrate confidence in employees, thereby increasing participation; 7) Establish interest relationships with related parties. This self-assessment tool uses five maturity levels, which can be added with other levels or be customized as needed.

Table 2.5 provides a general framework for clarifying how performance standards relate to the maturity level. Organizations should evaluate the performance according to the standards, determine the current maturity level, and identify the strengths, weaknesses, as well as related risks and opportunities for improvement. Aiming for higher standards can assist the organization understand the issues and determine the improvements needed to reach higher maturity levels (W. S. Yang, 1996).

Table 2.5 ISO 9004:2018 maturity model

Key element	The maturity of sustainable success				
Level	1	2	3	4	5
Factor 1	Principle 1				Principle 1
	Baseline				Best practice
Factor 2	Principle 2				Principle 2
	Baseline				Best practice
Factor 3	Principle 3				Principle 3
	Baseline				Best practice

Source: ISO (2018)

ISO 9004:2018 maturity model presented in Table 2.5 can be used to clarify the performance standards and the maturity level. The organization should evaluate the performance according to the standards, then determine the current maturity level as well as the strengths, weaknesses, and related risks and improvement.

According to the statistics, over 150 countries and regions worldwide have implemented the IS09000 accreditation system. By the end of 2018, there were a total of 481 accreditation agencies in China, with 92,452 accreditation practitioners. A total of 1.954 million accreditation certificates had been issued, and 630,500 organizations had been certified. However, many enterprises did not pay much attention to the organization's performance appraisal system after obtaining the accreditation, so the IS09004 standard is still not widely used or even ignored in the company, leading to weak links in the quality management evaluation.

2.4.2.5 Jiangsu QMM evaluation model

Jiangsu local management maturity standard establishes a five-in-one evaluation model with "quality" as the core and with "leadership, innovation, brand, and efficiency" as the key elements. The evaluation elements can be divided into process and result (Wattanasap &

Shawyun, 2019). Process includes clauses such as leadership, innovation, quality, and brand. Result includes clauses in leader, innovation, quality, brand, and efficiency, as well as the output and effect. The result scoring needs to integrate the representativeness of performance indicators and the total performance based on the four result evaluation factors (Wuxi Quality and Technical Supervision Bureau, 2018). Jiangsu QMM evaluation model is presented in Figure 2.6.

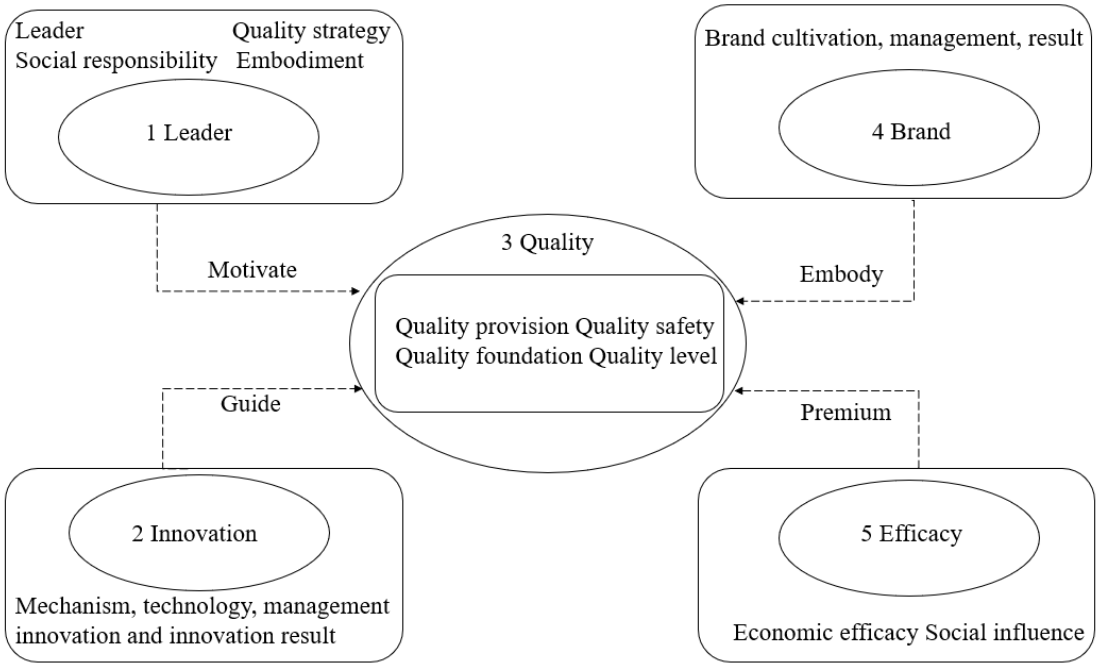


Figure 2.6 The QMM evaluation model

Source: Wuxi Quality and Technical Supervision Bureau (2018)

2.4.2.6 AQM^3

AQM^3 (Aerospace QMM model) is based on the international maturity theory and draws on the software capability maturity model (CMM) (T. C. Li et al., 2014; Q. Y. Yang, 2010). The basic framework of AQM^3 expresses maturity through five levels: basic, effective, stable, value-added, optimized (M. F. Yang, 2012).

The AQM^3 is presented in Figure 2.7.

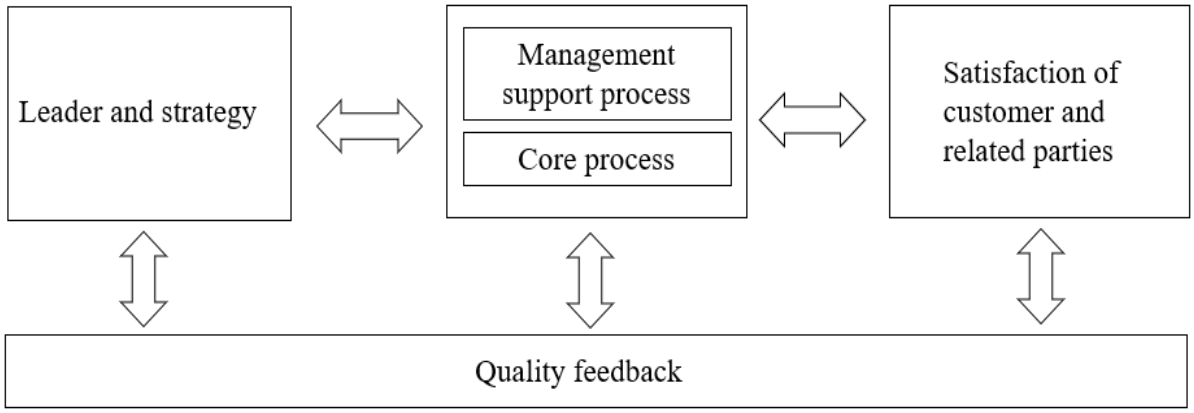


Figure 2.7 AQM^3

Source: Yang (2012)

The structure of AQM^3 is shown in Table 2.6.

Table 2.6 AQM^3

	Quality and strategic planning	Core process	Management support process	Quality feedback	Satisfaction of customer and related party
Basic level	All terms in GJB9001B-2009				
Effective level		Management related to product requirements; product design and development; process control; new product trial production control; production and service provision process control; production and service provision process confirmation; key process control; work environment control; test control; product delivery control; technical status management	Document control; recording control	Product monitoring and measurement; non-conforming product control	
Stable level	Duty and permission; human resources	Planning of product realization		Process monitoring and measurement	
Value-added	Continuous improvement of	Outsourcing process	Quality and economical		

level	leadership	management; procurement control	management		
Optimized level			Quality information	Data analysis	Satisfaction of customer and relevant party

Source: Yang (2012)

2.4.2.7 National quality awards

With economic globalization and the intensification of market competition, not only enterprises are faced with the practical problems of how to become better and stronger, but also countries need to consider how to guide and improve the management and industrial competitiveness of enterprises, thereby increasing the national competitiveness. Based on Japan's economic boom and management experience, 56 countries have successively set up national quality awards aimed at pursuing outstanding performance (Mark & Duncan, 2011). The world's three most famous quality awards are: Japanese Deming Award, Baldrige Quality Award, and European Quality Award. China also set up National quality award.

(1) The world's earliest quality award: Japan Deming Award

On June 15th, 1950, JUSE invited Deming (William Edwards Deming) to Japan to share about quality statistical control. JUSE then compiled and published *Dr. Deming on Quality Statistical Control*, which was based on Deming's courseware. Deming donated the copyright fee to JUSE, and Kenichi Koyanagi proposed using the fee to set up an award to thank Deming for his friendship with Japan (Smith, 2011). In 1951, the JUSE council approved the proposal and established the Deming Award.

The standards of the Deming Award mainly include leadership, planning and strategy, TQC management system, quality assurance system, business element management system, human resources, information utilization, TQC values, scientific methods, organizational activities, and contribution to achieving corporate goals (Mohit et al., 2012; Thandapani et al., 2012).

The evaluation criteria of the Deming Award consist of evaluation models and evaluation methods, which are both analyzed from three independent aspects: basic requirements, excellent TQM activities, and senior leaders (Suzuki et al., 2011).

1) Basic requirements

The senior management level formulates and implements management policies, focuses on innovating new products and work processes of the core quality system, and pays attention to the maintenance and improvement of product, operation quality, and management system. Operation and management are carried out combined with human resource development,

information analysis, and information technology.

2) Excellent TQM activities

Excellent TQM activities are extraordinary places, which refer to activities related to the organization's core quality and applied unique ideas and obtained excellent results. Enterprises applying for the Deming Award should have at least one distinguished activity, which can be promoted to other enterprises as a reference.

3) Senior leaders

The responsibility of senior leaders is to evaluate the role of senior managers in advancing TQM. The content and scoring of Deming Award are shown in Table 2.7.

Table 2.7 The content and scoring of Deming Award

Number	Category	Item	Score	Sum
1	Develop and implement quality management policy	Formulate business policies and strategic goals that actively meet customer requirements according to the actual needs of business philosophy, industry, scale, and business environment.	10	20
		All employees work together to carry out various improvement activities in order to achieve business policy goals.	10	
2	Develop new products and reform business	Actively develop new products (products and services) and implement business reforms.	10	20
		New products can meet customer needs, and business reforms can improve business efficiency	10	
3	Improve product quality and management quality	Daily management: after standardized training, there are few problems in daily business and the main business of each department operates stably.	10	20
		Continuous improvement: reduce the problems in market sales and product process through continuous improvement of quality, which can not only control the problems in market sales and product process at a minimum level, but also improve customer satisfaction.	10	
4	Establish and improve the management system in terms of quality, quantity, delivery, cost, safety, environment.	Establish and improve the above-mentioned effective management system for the stable operation of the company.	10	10
5	Use IT (information technology) tools to collect and analyze quality information	Systematically collect market and internal quality information, comprehensively use statistical methods and IT tools to improve the quality of products and services	15	15
6	Develop human resource	Develop and train human resources in a planned way, which can contribute to the improvement of product quality and business quality	15	15
Total score				100

Source: Qi (2012)

2) The world's most influential quality award: American Baldrige Quality Award

In the early 1980s, the United States' leadership in product and process quality is faced with strong challenges. The productivity growth of the U. S. lags behind competitors, with the poor-quality cost being 20% of the sales revenue. The economic circle in the U. S. began to recognize the serious outcome and started a quality revolution all over the country. The U.S. began to learn from Japan, and re-imported TQM. Baldrige became the U.S. Secretary of Commerce in 1981 and died in an accident in July 1987. During his tenure, Baldrige vigorously advocated quality management and spared no effort to promote the legislation of *Quality Improvement Law*. To commemorate Baldrige, the U.S. Congress established the Malcolm Baldrige Quality Award in 1987, the 26th Secretary of Commerce of the United States, and aimed to enhance the competitiveness and performance of the economy (K. D. Chen, 2019; Lee & Ooi, 2015).

According to the follow-up research of the American Institute of Standards and Technology, enterprises that have won Malcom Baldrige Quality Award in the U.S. have achieved excellent results in product and service quality, customer satisfaction, market share, labor productivity, and profit margins (W. R. Wang, 2020). Up to 2009, 80 enterprises including Motorola, Xerox, AT&T, IBM, and Boeing have won the quality awards, and these awards have played a huge role in improving the competitiveness and living quality in the U.S. The General Accounting Office of the United States has conducted research on Malcom Baldrige National Quality Award-winning companies and on-site review companies. By analyzing the relationship between the excellent performance model system management method and the success and profitability of the company, the research came to the conclusion that: the performance of the award-winning company is better than that of the Standard & Poor's 500 industrial stocks, with an earnings ratio of about 2.5:1 (Q. R. Zhang, 2009). Malcom Baldrige National Quality Award Foundation has conducted a survey of 2,500 companies in the United States with tax revenues of more than $100 million. In the survey, 79% of the companies believe that the Malcom Baldrige National Quality Award and its award criteria have greatly stimulated the quality of American companies, and 67% of companies believe that the Malcom Baldrige National Quality Award and its award criteria have greatly stimulated the competitiveness of American companies. According to the report of the American Enterprise Association, there are tens of thousands of companies that have applied the Malcom Baldrige National Quality Award standards for learning, implementation and self-evaluation. Through analysis, it is concluded that the success of national award derived from three aspects. Firstly, national quality awards have a high positioning, and pursue excellence performance. Secondly, the national quality award evaluation criteria are a set of standards for the pursuit of excellent performance. Thirdly,

the excellent performance model based on the national quality award evaluation criteria is a comprehensive and systematic management model, which is strongly promoted by the government.

Former U.S. President Clinton commented that the Baldrige Quality Award had played a major role in revitalizing the economy and improving the competitiveness and life quality in the U.S. Former U.S. President Bush commented that Baldrige National Quality Award is increasingly becoming a global standard, and the increasing number of similar awards in the world are the evidence (Liao, 2018). In the United States, there are only a few companies that can win the Baldrige National Quality Award each year, but there are hundreds of thousands of companies using the standard for self-assessment. The standard has become a guide for companies to pursue excellence, and the quality standards of many countries and regions worldwide have cited and referenced the standard.

Figure 2.8 presented the framework of Baldrige excellent performance criteria.

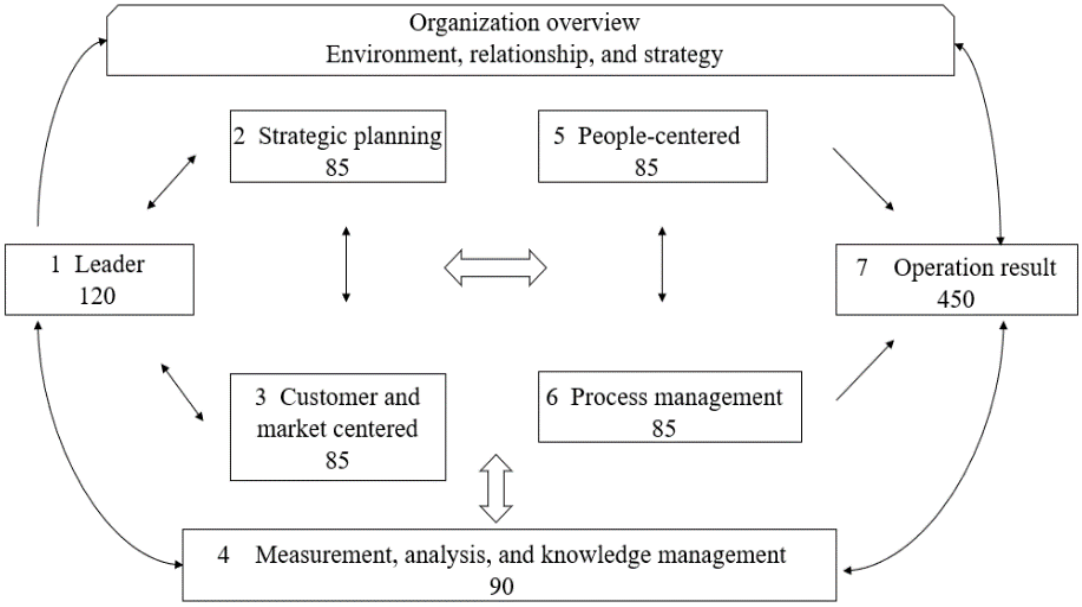


Figure 2.8 The framework of Baldrige excellent performance criteria

Source: Qi (2012)

3) European Quality Award

Baldrige Quality Award and the Japan Deming Award have made achievements in the quality and performance of manufacturing and service industries, which has inspired European companies. Jacques Deller, chairman of the European Commission (EC) at that time, pointed out that "For the success of enterprises and for the success of enterprises' competition, we must fight for quality." In 1988, 14 large European companies established the European Foundation for Quality Management (EFQM), which was intended to emphasize the importance of quality management in all activities and regard quality improvement as the basis for enterprises to

achieve excellence, thereby enhancing the efficiency of European enterprises. In October 1991, at the European Quality Fund Annual Forum held in Paris, Mr. Martin Bengeman, Vice President of the European Commission, formally proposed to establish the European Quality Award. In October 1992, at the European Quality Fund Annual Forum held in Madrid, Juan Carlos, the King of Spain, presented the first European Quality Award to the winners. In 2006, the European Quality Award was renamed as EFQM Excellence Award (Aydin et al., 2011). The purpose of EFQM Excellence Award is the same as that of the Baldrige National Quality Award in the United States and the Deming Award in Japan, all of which are aimed to promote quality improvement, increase the awareness of quality improvement as well as quality management techniques and methods, recognize enterprises with excellent performance, and improve the competitiveness of European companies in the global integrated market (Boulter et al., 2013). Since 1992, European countries and regions have gradually set up quality awards, with the evaluation criteria and process basically following the EFQM excellence model.

The EFQM Excellence Model was updated in 2010, which had modified the basic concepts, models and RADAR tools. As shown in Figure 2.9, the EFQM excellence model describes the process of an organization towards excellence from 9 aspects, which can be divided into driving factors and results. Driving factors are the means to achieve results, and results reflect the achievements of a particular business or business area. Among them, learning, creativity, and innovation can help to improve the driving factors, so as to achieve the improvement of results (Bohoris, 2013).

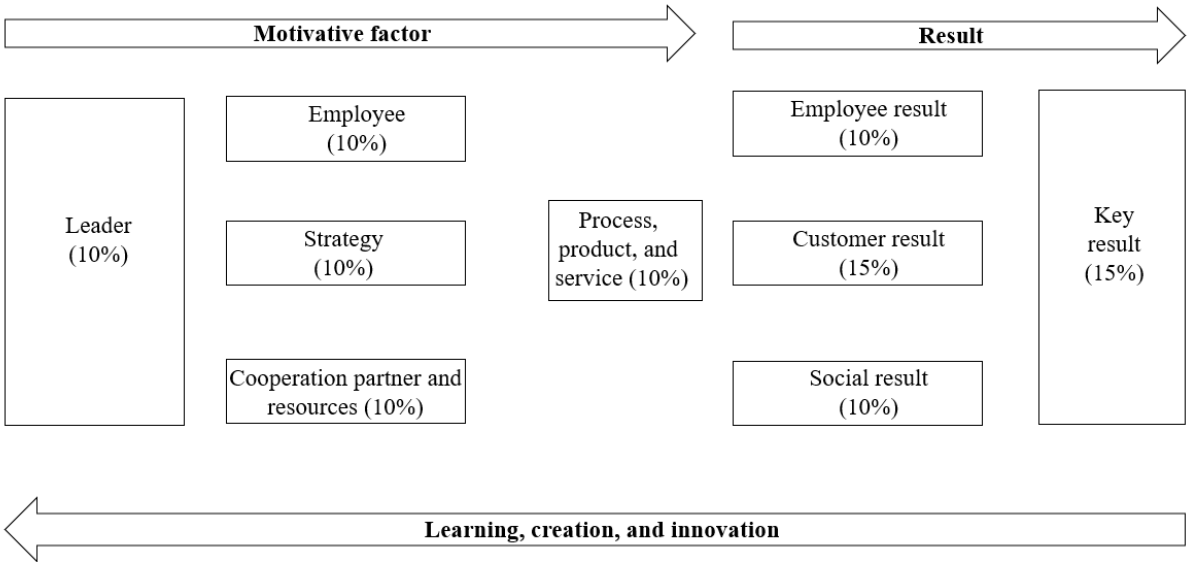


Figure 2.9 EFQM Excellence Model Criteria

Source: Qi (2012)

(4) China Quality Award

Established in 2001 and undertaken by the China Quality Association, the goal of the

National Quality Award was to encourage and guide Chinese enterprises to pursue excellent quality management, enhance organizations' overall competitiveness, adapt to economic globalization, and contribute to the overall management level and the quality of economic and social development. Since 2012, the Excellence Project Award has been set up in the National Quality Awards to commend key projects and projects that have achieved outstanding results in quality management and technological innovation using the excellent performance model. By 2014, enterprises from 30 provinces, autonomous regions, municipalities and special administrative regions have participated in the national quality award declaration, covering 13 industries and 54 major categories of the national economy. Eventually, 117 organizations won the award, including 7 organizations such as Qingdao Hisense and Shanghai Volkswagen who won this honor twice. Up to now, the National Quality Award has become a national quality award equal to the Japanese Deming Award in Japan, the Malcom Baldrige National Quality Award in the United States, and the EFQM Excellence Award in Europe. In the five years since BaoGang won the award, its profit doubled five times from ¥3.7 billion to ¥18.8 billion, which ranked among the top 3 in the world steel. In the five years since Haier won the award, its sales revenue rose from ¥60.2 billion to ¥103.9 billion, with the increase being 72%. Up to now, China national quality award has become the same-level award with other world-level award.

In 2004, China formulated GB/T 19580-2004 *Excellent Performance Evaluation Criteria* and GB/Z 19579-2004 *Excellent Performance Evaluation Criteria Implementation Guidelines*, which were released on August 31st, 2004 and implemented on January 1st, 2005. The release of Excellent Performance Evaluation Criteria as a national standard has promoted Chinese enterprises' awareness of pursuing excellence and improving the management level and the quality of products and services. The standard was revised in 2012, released on March 9th, 2012, and formally implemented on August 1st, 2012.

1) The framework of China Quality Award evaluation criteria is shown in Figure 2.10 (GB, 2012).

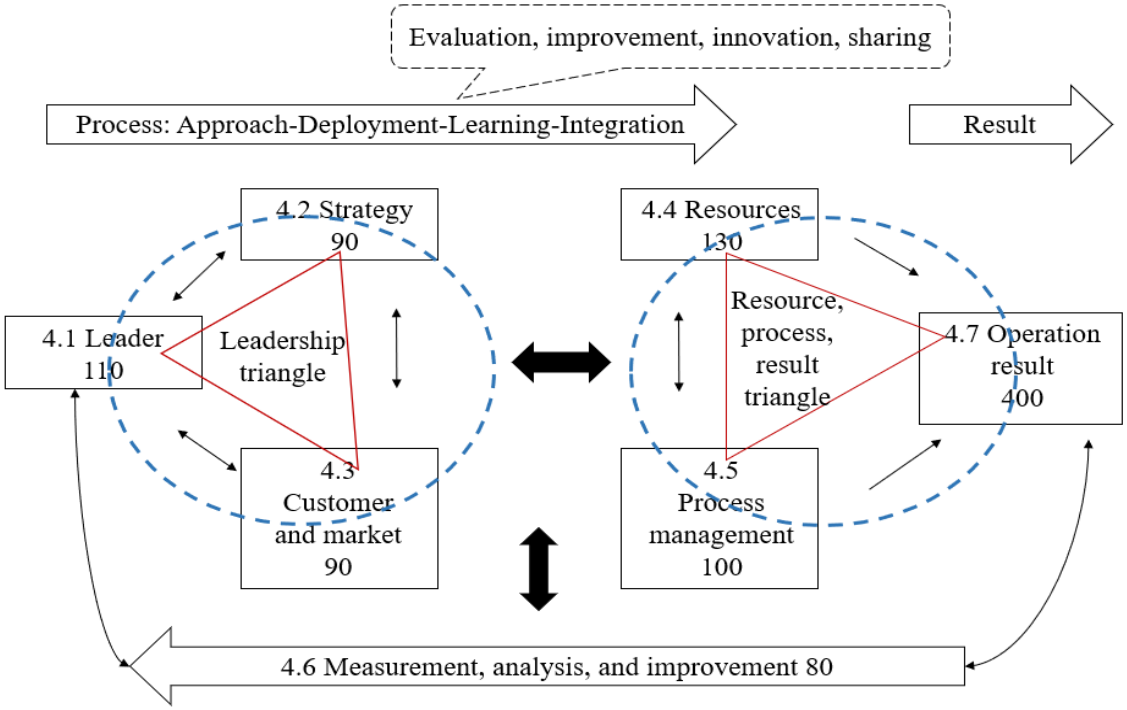


Figure 2.10 China Quality Award Evaluation Criteria Framework

Source: GB (2012)

2) Elements and scoring of China Quality Award

According to the provisions of GB/T19580-2012 *Excellent Performance Evaluation Criteria* and the information of the evaluated organization, the scoring clauses are divided into two categories: the process (17 scoring clauses in the standard 4.1-4.6) and the result (6 scoring clauses in standard 4.7) (W. M. Qi, 2012).

Process refers to the method and the corresponding development and improvement adopted by the organization regarding the requirements of scoring clause 4.1 to 4.6 in GB/T19580-2012 Excellent Performance Evaluation Criteria. The four elements are used to evaluate the maturity of the organization (GB, 2012).

Evaluation of approach:

a) The suitability of the approach, including the requirements for the standard scoring clauses and the suitability of the actual organization;

b) The effectiveness of the approach and whether it leads to good results;

c) The systematic nature of the approach, including repeatability.

Evaluation of deployment:

a) Whether the approach is continuously applied;

b) Whether the approach is applied in all applicable departments.

Evaluation of learning:

a) Continuously improve the method through cyclical evaluation and improvement;

b) Encourage breakthrough changes in methods through innovation;

c) Share method improvements and innovations in relevant departments and processes.

Evaluation of integration:

a) The method is coordinated with the organization needs defined in the organization overview and other scoring clauses;

b) The methods of each process and department are coordinated, integrated, complementary, and supportive to the realization of the organization's mission, vision, and strategic goals.

For the process, the final score is considered from the aspects of A-D-L-I and the evaluation score level is determined according to the principle of overall similarity (GB, 2012). Refer to Table 2.8 for the evaluation requirements and scores of A-D-L-I in the process.

Table 2.8 Guidance for the scoring of process

Score	Process
0% or 5%	There is no systematic approach and the information is fragmented and isolated. The approach is not deployed or slightly deployed. There is no improvement orientation and the existing improvements are merely reactive responses to problems. There lacks coordination and the departments do their own things.
10%,15%, 20 or 25%	Begin to have a systematic approach to deal with the basic requirements of the scoring clause. The approach is in the early stage of deployment in most aspects or departments, which hinders the realization of basic requirements. It is in the early stage of transition from "reactive response to problems" to "improvement orientation". Rely on joint problem solving to achieve coordination and agreement with other parties or departments.
30%,35%, 40 or 45%	There are systematic and effective approach to deal with the basic requirements of the scoring clause. The approach has been deployed, although it is still in the early stages of development in some aspects or departments. Systematic evaluation and improvement of key processes are started. The approach is initially coordinated with the basic organizational needs identified in the organizational overview and other process clause.
50%,55%, 60 or 65%	There are systematic and effective methods to deal with the overall requirements of the scoring clause. The method has been well deployed, although the deployment is different in some aspects or departments. Systematic evaluation improvements and some innovations are carried out based on the fact to improve the effectiveness and efficiency of key processes. The approach is coordinated with the organization's needs in response to the organization's overview and other process terms.
70%,75%, 80 or 85%	There are systematic and effective approach to deal with the detailed requirements of the scoring clause. The method has been well deployed without obvious gaps. Fact-based and systematic evaluation, improvement, and innovation have become key management tools. There is clear evidence proving that through organization-level analysis and sharing, the approach has been continuously improved. The approach is integrated with the organizational needs identified in response to the organizational overview and other process terms.

90%,95%, or 100%	There are systematic and effective approach to the detailed requirements of the scoring clauses. The approach has been completely deployed, and there are no obvious weakness and gap in any aspect or department. Fact-based and systematic evaluation, improvement, and innovation have become the key management tool in the organization. There are evidences showing that the approach has been constantly perfected and innovated in the whole organization. The approach has been greatly integrated with the organizational needs identified in response to the organizational overview and other process terms.

Source: GB (2012)

Result refers to the output and effect obtained by the organization in achieving the requirements of Standard 4.7. Levels, trends, comparisons, and integration (Le-T-C-I) are the four elements used to evaluate the maturity of organizational results (GB, 2012).

Evaluation of levels:

The current level of organizational performance.

Evaluation of trends:

a) The improvement speed of organizational performance (slope of trend data);

b) The breadth of organizational performance improvement (degree of deployment).

Evaluation of comparisons:

a) Comparative performance with suitable competitors or similar organizations;

b) Comparative performance with benchmarks or industry leaders.

Evaluation of integration:

a) The measurement indicators of organizational results correspond to the key performance requirement indicators determined in the “organizational overview” and “process”;

b) The results of the organization’s various processes and departments are coordinated to support the realization of the organization’s mission, vision and strategic goals.

For the result, the score clauses require performance level, improvement speed and breadth, and related comparable data. The score clause of the result is based on the current performance level, while taking into account the speed and breadth of improvement, the comparison with competitors and benchmarks, and the importance of the score clauses to the organization (echoing with the key requirements and performance in the organization overview and process clauses). The evaluation requirements and evaluation scores of the four elements of Le-T-C-I in the results are presented in Table 2.9.

Table 2.9 Guidance of scoring result

Scoring	Result
0% or 5%	The results are not described, or the results are poor. There is no data showing trends, or most data show bad trends. There is no comparative information. No results were reported in areas that are important for achieving the organization's mission, vision, and strategic goals. (I)
10%,15%, 20 or 25%	The results are few, and there is some early good performance in a few areas. There are some data showing trends, some of which show bad trends. No or little comparative information. The results are reported in few areas that are important for achieving the organization's mission, vision, and strategic goals.
30%,35%, 40 or 45%	The performance is good in most important aspects of the scoring clauses. There are some data showing trends, most of which are favorable. The organization is in the early stages of obtaining comparative information. The results are reported on most aspects important for achieving the organization's mission, vision and strategic goals.
50%,55%, 60 or 65%	The performance is good in most important aspects of the scoring clauses. There is a favorable trend in the important aspects of achieving the mission, vision and strategic goals of the organization. Comparing and evaluating with relevant competitors and/or benchmarks, some indicators have good comparative performance. The results correspond to the requirements of most customers, markets and processes.
70%,75%, 80 or 85%	In most aspects that are important to the scoring clauses, the performance is between good and excellent. The trends are sustainable favorable in most aspects that are important for achieving the organization's mission, vision and strategic goals. Comparing and evaluating with the relevant competitors and (or) benchmarks, most indicators have excellent comparative performance. The results correspond to the requirements of most key customers, markets, processes, and strategic implementation plans.
90%,95%, or 100%	The scoring clauses are excellent in most aspects that are important to the scoring clause. The trends are sustainable favorable in all aspects that are important for achieving the mission, vision, and strategic goals of the organization. In most respects, the organization is at the industry's leading position and benchmark level. The results fully correspond to the requirements of key customers, markets, processes, and strategic implementation plans.

Source: GB (2012)

3) The scoring terms and scores of China Quality Award are presented in Table 2.10.

Table 2.10 Evaluation criteria and scores of China Quality Award

First level indicator		Secondary level indicators	
Terms	Scores	Terms	Scores
4.1 Leadership	110	4.1.1 General principle	
		4.1.2 Senior leadership	50
		4.1.3 Organizational management	30
		4.1.4 Social responsibility	30
4.2 Strategy	90	4.2.1 General principle	
		4.2.2 Strategy formulation	40
		4.2.3 Strategy deployment	50
4.3 Customer and market	90	4.3.1 General principle	
		4.3.2 Customer and market	40
		4.3.3 Customer relationship and customer satisfaction	50
4.4 Resources	130	4.4.1 General principle	
		4.4.2 Human resources	60
		4.4.3 Financial resources	15
		4.4.4 Information and knowledge resources	20
		4.4.5 Technology resources	15
		4.4.6 Basic infrastructure	10
		4.4.7 Relationship with relevant parties	10
4.5 Process management	100	4.5.1 General principle	
		4.5.2 Process identification and design	50
		4.5.3 Process implementation and improvement	50
4.6 Measurement, analysis, and improvement	80	4.6.1 General principle	
		4.6.2 Measurement, analysis, and judgement	40
		4.6.3 Improvement and innovation	40
4.7 Result	400	4.7.1 General principle	
		4.7.2 Result of product and service	80
		4.7.3 Result of customer and market	80
		4.7.4 Financial result	80
		4.7.5 Resource result	60
		4.7.6 Effective result of process	50
		4.7.7 Result of leadership	50
Total	1000		1000

Source: GB (2012)

2.4.3 The comparison of QMM models

There are some similarities of QMM evaluation models at home and abroad. On the one hand, hierarchical structure is adopted in the models. Quality management has four or five hierarchies from low to high, and each model has an improvement path from the initial level to the optimization level (Crawford, 2006). On the other hand, the QMM model generally has two categories (Bohoris, 2013; L. Li, 2009): product quality and organizational quality. The Crosby model, McKinsey model, ISO9004, and AQM3 focus on the quality of the product or project process, while the excellent performance model (quality award) and Jiangsu Provincial Local Standard Quality Management Maturity Evaluation Guidelines focus on the organization's operational quality and management quality (W. J. Huang et al., 2011).

There are also differences between the QMM evaluation models. Crosby model and McKinsey quality models focus on the stages of quality management, ISO9004 focuses on QMS compliance, Japan Deming Award focuses on the application of TQM tools in products or projects, Baldrige quality awards is concerned about the organization's business quality and management quality (Q. Y. Yang & Fu, 2011). Moreover, the evaluation methods are different. The Crosby maturity grid is qualitative analysis, and other models combine qualitative and quantitative methods (R. Wang et al., 2019). The comparison of QMM evaluation models is summarized in Table 2.11.

Table 2.11 Comparison of QMM evaluation models

QMM models	Main features	Insufficiency	Applications
Crosby maturity grid	Simple model	Pure qualitative analysis	Applicable to simple self-evaluation of all companies
IQMM	Refer to the quality management model elements	Not highly targeted and has poor operability	Meaningful to the establishment of the QMM model
McKinsey Quality Model	Pay attention to the company's quality phases and focus on products or projects	Wide involvement range and heavy investigation workload	Various enterprises
IQMM	Combine the characteristics of ISO 9000 system and quality awards	The model evaluation system is not highly targeted and has poor operability due to the atypical business elements and sub-goals	Applicable to the evaluation of the company's QMS
ISO 9004	Concentrate on the process of quality system and focus on the compliance and standardization in the system	Not for the purpose of certification, and the attention from the enterprises is not enough. As a guideline standard, the system design is relatively broad and lacks intuitive and specific performance evaluation model design such as quality awards, which needs to be further refined in application.	Applicable to organizations that have established a QMS
Baldrige National Quality Award	Pay attention to the quality management advancement.	Much attention and high demands to performance.	Applicable to three types of organizations in the United States: products, services, and medical education.
European Quality Award	Focus on excellent enterprise benchmarks	Much attention and high demands to	Applicable to profitable companies

		performance.	in Europe.
Japan Deming Quality Award	Non-competitive and intended to promote the application of TQM tools in product realization or project promotion	The model evaluation system is not highly targeted due to the atypical business elements and sub-goals.	Applicable to enterprises, individuals, and projects with Japanese cultural background.
China Quality Award	Learn and adjust from the model of the Baldrige National Quality Award in the United States.	Pay more attention to and have higher requirements on performance.	Applicable to enterprises that apply for China quality award in comprehensively evaluating the enterprise operating performance.
Aerospace QMM model	Learn from American CMM based on GJB9001B standard	Not for the purpose of certification, so the attention is not enough. Due to its CMM model, the workload is large, which is not conducive to promotion.	Applicable to China's aerospace companies that have established a GJB9001B QMS
Jiangsu local QMM evaluation criteria	Focus on innovation and brand	Too much focus on business results and insufficient attention to product quality and process quality.	Applicable to enterprises and organizations in Wuxi, Jiangsu, China

2.5 Chapter summary

This chapter is the literature review, where quality, quality management, QMS, and QMM model are reviewed.

[This page is deliberately left blank.]

Chapter 3: Construction of the QMM Evaluation Model of Private Equipment Manufacturing Enterprises

3.1 Research design

3.1.1 Evaluation model construction

A model is abstracted from actual problems or objective laws, it is not only an organizational research method, but also a set of concepts and relationships (Schwarz, 1978; Z. Y. Wang & Sun, 2005). In order to explain these concepts and relationships, researchers would build models based on actual problems and construct cognitive frameworks. In this thesis, we aim to evaluate and explain the QMM of private equipment manufacturing enterprises. Therefore, a maturity evaluation model is needed, which could not only comprehensively and systematically reflect the quality elements in the management process of private equipment manufacturing enterprises, but also intuitively show the structural relationship between the elements.

The QMM evaluation model to be constructed in the thesis attempts to assess the quality management level of enterprises and improve the quality management of enterprises based on the evaluation results. Through the previous literature review, it is found that the existing theories cannot fully and effectively explain the quality management behavior of private equipment manufacturing companies. Therefore, the thesis bases on the quality management practices of private equipment manufacturing enterprises, uses the method of text analysis, and selects three domestic and foreign leading enterprises companies in quality management as the research objects. By analyzing the textual materials of enterprises through text analysis, the thesis explores the elements in the QMM model of private equipment manufacturing companies and builds a corresponding maturity model.

The scientificalness and effectiveness of the elements and indicators in the maturity model directly decides whether the evaluation results are authentic and correct. Therefore, during the construction of the QMM model (QMM) of private equipment manufacturing enterprises, we follow the basic requirements of “comprehensive content, prominent focus, scientific method, feasible evaluation, and wide adaptability”. Meanwhile, we also abide by the formulation principles, which include scientific principle, dynamics and stability unity principle, systematic principles, comparability principle, and practicality principle (L. Li, 2009).

(1) Scientific principle

Scientific principle means that the concepts of QMM evaluation indicators should be scientific, clear, and unambiguous. QMM evaluation indicators should have clear connotations and extensions, and can reflect the overall effect and operating characteristics of QMM. The established indicator system should objectively reflect the effects of QMS operation and reduce the subjective factors of evaluators.

(2) Dynamics and stability unity principle

With the continuous revision and upgrading of the QMS, the national military standard also needs constant revision. As a result, the QMM evaluation criteria need to be revised accordingly. The evaluation criteria are in dynamic development, but they are stable for a certain period of time.

(3) Systematic principle

The evaluation criteria are not static and unchanging documents, which should be selected based on the business strategy and product characteristics. Constructing a reasonable and hierarchical criteria system could highlight the key points and achieve the optimal purpose of the criteria system.

(4) Comparability principle

The established evaluation criteria should not only reflect the common attributes, but also promote the continuous improvement of QMM. The evaluation criteria and indicators should adopt uniform standards to ensure the evaluation indicators are definite, measurable and comparable.

(5) Practicality principle

The established evaluation criteria require numerical control specification and easy operation. Meanwhile, the criteria should in conformity with the actual status of the evaluated enterprise. Moreover, the indicator system needs to standardize the qualitative indicators reflecting QMM, and convert the indicators that cannot be directly measured into specific measurable indicators, so as to objectively and comprehensively respond to the reality of quality management capabilities.

3.1.2 Text analysis

Text analysis is an analysis process which could convert unstructured and chaotic text data into meaningful and logic data for analysis (Crabtree & Miller, 1992). Through interpreting and coding the qualitative data, text analysis can extract the conceptual composition and category structure of the research object. Generally, text analysis methods include thematic analysis,

content analysis, dictionary analysis, and bag-of-words (Carley, 1997; Shapiro, 1997).

While conducting text analysis, the thesis refers to the procedures of the grounded theory. When constructing the conceptual model through text analysis, the most important part is to encode the data level by level. The thesis adopts the three-level coding in qualitative analysis: open coding, axial coding, and selective coding. Due to the large amount of data generated in qualitative research (Popping, 2000), the thesis uses software to do the encoding. Scholars believe that computer software can aid to transform the qualitative research into a rigorous automated process, and computer analysis programs allow users to conduct complex analysis without understanding the technical principles (Andrew et al., 2010; Zamawe, 2015). NVivo is adopted in the thesis to do the qualitative research. NVivo is the abbreviation of Nudist Vivo, where Nudist is non-numerical unstructured data by techniques of indexing searching and theorizing, Vivo means freedom. The purpose of NVivo is to provide qualitative research with an efficient and fast analysis tool similar to SPSS in quantitative research (Bazeley & Jackson, 2013). NVivo, which is designed to have the ability to organize and analyze disordered information, is often used in qualitative research (especially in narrative analysis and grounded theory). The main functions of NVivo are: (1) processing interview manuscripts, literature contents, text contents, pictures and videos, questionnaires, web contents, social media information; (2) quickly retrieving data, automatically identifying key words and themes in the messy data, providing possible analysis ideas and directions; (3) automatically performing preliminary analysis and quick organization of data; (4) linking related contents and finding patterns in materials (Kuckartz & Udo, 2014). As shown in Appended Figure 1 (Annex), the specific operation steps of NVivo correspond to the three-level coding in qualitative study. After importing documents, pictures, audio, and video materials into the software, three-level coding can be conducted, during which the coder can add memos and notes according to his or her thoughts. In the process of coding, the coder first judges the content and forms a free node at the first level of encoding, then categorizes the free nodes to form a tree node. After which, the relationship is established by judging the nature of nodes and the connections between nodes (Azeem & Salfi, 2012). Finally, by analyzing the relationships, a model is finally formed (S. M. Liu & Li, 2017).

3.2 Research object and textual material

3.2.1 Research object

In this study, three domestic and foreign equipment manufacturing enterprises are selected for the research. The enterprises are Guizhou Dadongfeng Machinery Co. Ltd, Senhe Elevator Co., Ltd., and Missile and Fire Control Company.

Guizhou Dadongfeng Machinery Co., Ltd. (Dadongfeng), a company engaged in developing and producing of aero engine blades and gas turbine blades, was established in March 2011. Dadongfeng adheres to the development value of "making high-quality blades and casting a trustworthy enterprise" and the quality value of "creating first-class quality and promoting continuous improvement". Cooperating with domestic advanced engine blade manufacturers and scientific research institutes, Dadongfeng has high research and development ability, production capacity, and management level. Dadongfeng has obtained technological innovation projects from Guizhou Provincial Department of Science and Technology, Guizhou Provincial Development and Reform Commission. Moreover, Dadongfeng has declared 4 invention patents and been included in the "A Hundred Talents in Guizhou Province" project.

Senhe Elevator Co., Ltd. (hereinafter referred to as Senhe) is a professional and internationalized high-tech enterprise company established through investment, mergers and acquisitions. Senhe covers an area of 147,600 square meters, has an annual production capacity of 40,000, and has a product manufacturing center, a R&D and design center, and a customer service center. It is a modern large-scale manufacturing enterprise focus on equipment elevator, escalator and three-dimensional parking. Covering 46 countries and regions around the world and having 93 branches and 916 service outlets in China, Senhe is committed to becoming a manufacturer and service provider of safety elevators. Up to now, Senhe has been awarded the honors of National Machinery Industry Advanced Group, High-tech Enterprise. Moreover, its products have won the "U.S. Elevator World Engineering Award".

MFC is one of the subsets of Lockheed Martin, whose main business includes developing, manufacturing and supporting military systems in aerospace and space. With customers such U.S. army and dozens of product and service lines, MFC is an ideal supplier of products and services and has spread its business in over 50 countries.

There are three reasons why these three enterprises are selected in this study.

For the first reason, the three enterprises are consistent with the research objects. The

purpose of this research is to explore the quality management of private equipment manufacturing enterprises. Dadongfeng, Senhe and MFC are all enterprises engaged in equipment manufacturing, which is consistent with the research objects of this research.

For the second reason, all the three enterprises could produce aviation or aerospace products. Aviation or aerospace products have the characteristics of good quality, high technology, and strict requirements, which are of great significance to the national defense. Dadongfeng and Senhe have passed the GJB9001C-2017 standard certification, and MFC's own products serve the military. These three companies can all participate in national defense construction through their own technologies. Therefore, it is persuasive to use these three enterprises as the research object to extract the elements of QMM.

For the second reason, all the three enterprises have a high level of quality management. Dadongfeng have passed the GJB9001C-2017, GB/T 19001-2016/IS09001: 2015 standard quality system certification. Senhe have not only passed the national military standard certification, but also won the 2017 Huzhou Government Quality Award. MFC have won Baldrige Quality Award in 2012. Considering the high-quality management of these three enterprises, it is scientific to build the QMM model of private equipment manufacturing enterprises with these three enterprises as the research object.

3.2.2 Textual material

The textual materials used for encoding in this thesis are Dadongfeng's quality manual and procedure documents, Senhe's application material for Huzhou Government Quality Award, and MFC's application material for Baldrige Quality Award.

Quality manual is the first-level document of the company's quality system. It is a programmatic document that contains the enterprise introduction, organization chart, total quality target, quality policy and system requirements. Procedural document is the second-level document of the enterprise quality system, which is an extension of the quality manual. The main content of procedural document is the method to complete the introduction activity in the quality manual. Procedural document is the description of the specific implementation process. Through the quality manual and procedure documents, we can comprehensively understand the quality management situation of the enterprises.

Huzhou Government Quality Award is the highest quality award established by Huzhou City, Zhejiang Province in order to guide and encourage enterprises in the city to strengthen quality management and promote upgrading of efficiency. Every year, Huzhou Government

Quality Award is awarded to organizations engaged in product production, engineering construction, service provision, and environmental protection that have implemented excellent performance management and achieved significant economic and social benefits. When applying for awards, the organization needs to conduct self-evaluation according to the evaluation criteria of Huzhou Government Quality Award and form a self-evaluation report, which is then submitted to the evaluation team. By reading the organization's self-evaluation report, we can grasp the company's quality management situation from many aspects.

Baldrige Quality Award is a national quality award in the United States and one of the three major quality awards in the world. Awarded to companies that have made achievements in improving the quality of their products and services, the purpose of Baldrige Quality Award is to inspire and help American companies and to set an example. To apply for Baldrige Quality Award, enterprises need to submit a complete self-statement material. By reading the self-statement material of the organization, we can understand the process measures and behavior activities of the organization's quality management. There are only less than three companies or organizations in various fields that win Baldrige Quality Award each year, so the quality management level of the companies or organizations that win the award will inevitably play a demonstrative role in the industry.

The textual materials selected in this study can fully reflect the quality management situation of the enterprise and provide detailed practical data for the construction of the QMM model. The textual materials adopted in the encoding are about 190,000 words, which record and explain the quality management behaviors of the companies in detail. The textual materials of the three enterprises enable us to have a certain understanding about the quality management behavior structure of private equipment manufacturing enterprises, and also provide us with the elements and framework to extract and design QMM evaluation models for private equipment manufacturing enterprises.

3.3 Three-level coding

The thesis takes three domestic and foreign companies as the research object. Using the Quality Manual, Huzhou Government Quality Award, and Baldrige Quality Award as the text source, following the three principles of open coding, axial coding, and selective coding to extract the elements, and summarizing the connections and relationships between the elements, the thesis tends to form a model of the QMM of private equipment manufacturing enterprises.

3.3.1 Open coding

Open coding is a coding process where researchers should keep an open mind and dispose personal prejudices and the fixed mindset. The purpose of open coding is to discover concepts from the data, name the concepts, and determine the attributes and dimensions of the concepts in order to conceptualize the research phenomenon. The process of open coding can be shaped like a funnel where the beginning range is relatively wide, and then the range is continuously reduced until the code number is saturated. To keep deepening the analysis, researchers should often write analytical memos while doing the open coding, which could prompt the researchers to think about the theoretical issues that appear in the data, and gradually deepen the preliminary theory constructed during the writing (Anselm & Juliet, 2006).

The research has gone through three stages in the open coding process. The first stage is to randomly scatter the textual materials of the three enterprises. The purpose of this step is to prevent our judgment from being affected by the original structure of the text materials, which is conducive to the objective judgement of the text materials. At this stage, the important principle we follow is: believe in everything and nothing (Strauss & Corbin, 2014). The second stage is to name a concept from the text and do not miss any important information when coding. The more detailed the coding, the better it is. When naming the code, use the original text or our own words as the code number. The third stage is self-asking when analyzing the data line by line. In terms of relevant words, phrases, sentences, actions, meanings, and events, we ask ourselves: What is the relationship between the data and this research? What concepts can this event produce? What is the specific information provided by these materials? Why did these things happen?

After many cycles of "data collection, coding, analysis, re-coding", the thesis finally extracts 171 concepts, which is marked by "lowercase letter + serial number". After further abstracting and refining the concept, the thesis has obtained 42 categories, which is marked with "capital letter + serial number". Meanwhile, the thesis also explains the attributes of the category and the dimensions of the attributes. Table 3.1 presents the open coding records.

Table 3.1 Open coding record

Leadership				
	Open coding			
Original textual data	Concept	Category	Concept attribution	Attribution dimension
The chairman of the board is the first person in charge of the effectiveness of the company's QMS. The general manager assists the chairman to lead	a1 Responsible for the effectiveness of QMS	A1 Leadership and commitment	Degree of importance	Strong /Weak

the company's employees to supervise and monitor the implementation of the QMS. (a1)				
Provide the resources needed to meet the effective operation of the QMS based on the planning results. (a2)	a2 Ensure the resources required by QMS to be obtained			
Define department responsibilities, clarify and support the quality department to independently exercise its powers in quality management. (a3)	a3 Ensure the quality management department to conduct its work independently			
Responsible for the quality of final products and services. (a4)	a4 Responsible for the quality of final products and services			
Establish a quality information management system and a customer communication mechanism to ensure that customers can obtain information about product quality issues in a timely manner. (a5)	a5 Ensure that customers receive information about product and service quality issues			
Establish an integrity management system to enable the company and employees to uphold integrity and abide by the integrity promise. (a6)	a6 Ensure the quality integrity of the organization			
Actively promote the company's various improvements and provide resource guarantee for the improvement work. (a7)	a7 Promote improvement			
The chairman of the board formulated the company's quality policy after fully considering conditions such as the company's general management policy, customer requirements, laws and regulations, and available resources. (a8)	a8 Formulate quality policy	A2 Policy and goal management	Quality planning	suitable/unsuitable
Enable the related parties be informed or obtain the company's quality policy through company brochures, shareholder meetings, customer visits and seminars. (a9)	a9 Communication quality policy			
The chairman is responsible for organizing the formulation of the company's quality goals and ensuring that quality goals are established in relevant functional departments and levels. (a10)	a10 Quality goal planning			
Determine what to do, what resources are needed, who is responsible, when to complete, how to evaluate the results, and organize	a11 Quality goal implementation			

the implementation according to the plan. (a11)				
The methods of evaluating quality objectives include: qualitative analysis and quantitative analysis. (a12)	a12 Quality goal evaluation			
When making changes, consider: the purpose of the change and its potential consequences; the integrity of the QMS; the availability of resources; the assignment or reallocation of responsibilities and authorities. (a13)	a13 Quality goal revision			
The chairman of the board determines the settings of departments and positions of the company according to needs, and specifies responsibilities and authorities. (a14)	a14 Determine the responsibility of departments and positions	A3 Position responsibility and authority	Responsibility arrangement	Comprehensive/incomprehensive
The chairman of the board is the decision maker of QMS planning and changes. The chairman organizes the planning and changes of the QMS to ensure that the QMS meets the requirements of the GB/T190001-2016 and GJB9001C-2017 standards and maintains its integrity. (a15)	a15 Ensure the integrity of QMS when making changes			
Communicate with employees about the importance of meeting the requirements of customers and laws and regulations, and ensure that customer requirements are clear and met. (a16)	a16 Ensure the customer-oriented focus be promoted in organization			
Formulate the company's "Quality Reward and Punishment Management Regulations" to ensure that product quality duties are implemented in every position. (a17)	a17 Establish and implement quality accountability and incentive system			
Designate the chief engineer as the representative of the company's managers; the deputy chief engineer of quality is in charge of the QMS. (a18)	a18 Ensure that an executive is in charge of QMS			
The content of communication includes quality-related laws and regulations, customer complaints, product performance and price, schedule and delivery period, operational matters, responsibilities and interfaces, changes and other matters. (a19)	a19 Communication content	A4 Communication	Internal and external communication	sufficient/insufficient
Communication usually involves communication with customers	a20 Communication			

before contract signing, communication with relevant internal and external personnel when quality problems occur during operation, communication with customers in post-delivery activities, communication with the parties involved in complaint investigation and handling. (a20)	time			
Internal communication is carried out by quality meetings, party and government cadre meetings, ministerial meetings, meeting minutes, document delivery, training. External communication is carried out by seminars, telephone calls, faxes, letters, documents, and keeps communication records. (a21)	a21 Way of communication			
The objects of communication include internal leaders or employees, external customers, suppliers, partners, government agencies and higher-level agencies. (a22)	a22 Communication staff			
External communication takes the form of seminars, telephone calls, faxes, letters, documents, and keeps the communication records. (a23)	a23 Communication record			
The comprehensive management department is the central management department for quality awareness education, which is responsible for organizing and carrying out the company's internal quality awareness education and training. (a24)	a24 Quality awareness education	A5 Quality culture	Environmental guarantee	suitable/unsuitable
Enable employees to understand the importance and the relevance of the activities they are engaged in through organizational learning (e.g.: employee induction training, promotion examination, and obtaining of qualification certificates). (a25)	a25 New employee training			
Through case study, make employees understand that non-compliance with the QMS requirements will lead to the failure of the company's QMS, the loss of customers, and the consequences are extremely serious. (a26)	a26 Make clear the consequences of products and services that do not meet the requirements			
Standardize the ethical behavior of employees through the publicity and implementation of factory rules and regulations. (a27)	a27 The importance of ethical behavior			

Strategic management

Original textual data	Open coding Concept	Category	Concept attribution	Attribution dimension
Through analysis (PEST analysis) of domestic and foreign political and legal environment, economic environment, technological environment, social and cultural environment and other factors, grasp the direction of enterprise development. (b1)	b1 PEST analysis	B1 Strategy formulation	Action orientation	Clear /ambiguous
Organize multiple agencies to collect information on the internal and external environment through the Strategic Decision Committee. (b2)	b2 Obtain internal and external factors			
The continuity of domestic and foreign laws and regulations, taxation policies, preferential policies and industrial policies. (b3)	b3 Determine related laws and regulations			
Keep customer-oriented and market-oriented based on mission, vision and values. (b4)	b4 Consider the organizational value			
Synthesize the above-mentioned internal and external environment analysis to form a SWOT matrix and draw up alternative plans. (b5)	b5 Use SWOT analysis			
Senhe deploys the overall strategy layer by layer and implement it to basic units and individuals to ensure the effective implementation of the strategy. (b6)	b6 Implementation of strategic goals	B2 Strategic deployment	Practice behavior	in place/not in place
Coordinate and dispatch the allocation of resources from the three aspects of human, financial and material and through functional strategic planning, annual work task plan and comprehensive budget. (b7)	b7 Configuration resource guarantee			
The company has established a scientific KPI system and clarified key strategic target indicators to measure and evaluate the implementation and progress of the overall strategic plan. (b8)	b8 Track key performance indicators			
Propose suggestions for adjusting strategic plans, goals, and long-term and short-term plans after the summary analysis conducted by the Enterprise Development Department, which is then submitted to the Strategic Management Committee for approval and execution. (b9)	b9 Implement monitoring and review			

Risk management

Original textual data	Open coding Concept	Category	Concept	Attribution

			attribution	dimension
The quality department is responsible for quality risk management at all stages of the project (product). (c1)	c1 Establish a risk management agency	C1 Risk planning	Situation judgement	accurate/inaccurate
Determine the responsibilities, tasks and time of each department, and form a project risk management plan to guide each department to carry out risk assessment work. (c2)	c2 Clarify responsibility			
The risk management plan should include: risk management strategy, risk management organization and responsibilities, risk management process, risk criteria, risk communication and reporting, risk management cost and schedule. The plan should be approved by the person in charge of project management, and can be submitted to customers for confirmation if necessary. (c3)	c3 Formulate a risk management plan			
Risk identification methods include: checklist method, flow chart method, brainstorming method, and repeated correspondence inquiry method. (c4)	c4 Risk identification	C2 Risk evaluation	Practice behavior	in place/not in place
Risk analysis should be organized and implemented by the project leader, and risk analysis personnel should have equipment development experience and risk analysis capabilities. (c5)	c5 Risk analysis			
Determine the existing risk control measures and start-up mechanism based on the existing risk sources and the assessed risk value, and evaluate according to the risk acceptance criteria. (c6)	c6 Risk evaluation			
Organize and implement according to the determined work content and completion time to avoid risks or reduce the impact of risks. (c7)	c7 Risk avoidance	C3 Risk treatment	Check and evaluation	yes/no
Control risks within the acceptable range of business stakeholders. (c8)	c8 Risk control			
Find out the best method to avoid, accept, reduce and transfer risks. (c9)	c9 Risk transfer			
In the risk management process, the acceptable and unacceptable levels of risk should be determined. (c10)	c10 Risk acceptance			
Make a list of risk sources and a list of risk rankings, and if necessary, make recommendations for disposal measures for high-risk projects. (c11)	c11 Risk list			
Monitor the changes in the status of identified risks, residual risks or secondary risks, and relevant data should be continuously evaluated and checked to improve risk management.	c14 Evaluation of risk measures	C4 Risk monitoring	Action improvement	effective/ineffective

(c12) When necessary, risk response measures or risk response plans should be revised based on monitoring information. (c13)	c15 Establish a list of risk response measures			
Measurement, analysis and improvement				
Original textual data	Open coding			
	Concept	Category	Concept attribution	Attribution dimension
The quality department is responsible for determining the items and processes that the company needs to monitor and measure. (d1)	d1 Clarify what to monitor and measure	D1 Measurement, analysis and judgement	Evaluation check	effective/ ineffective
The quality department is responsible for customer satisfaction management, and implements the monitoring and measurement of customer satisfaction in accordance with the Customer Satisfaction and Communication Control Procedures to form a customer satisfaction analysis report. (d2)	d2 Customer satisfaction			
For customer complaints, the quality department is responsible for making records and circulate to the relevant departments. The responsible department formulates improvement measures and implements the improvement, and the quality department verifies the improvement effect and is responsible for notifying the customer of the processing result. (d3)	d3 Respond to customer complaints			
The production department and the quality department are responsible for collecting and analyzing information on product delivery progress, after-sales service, and product quality from the qualified suppliers to evaluate the performance of external suppliers. (d4)	d4 Performance of external providers			
Each department uses the information obtained from data analysis, management review, and quality objectives completion to evaluate the need for the QMS improvement. (d5)	d5 The need for QMS improvement			
The finance department is responsible for collecting and analyzing quality cost data to evaluate whether the quality economy meets the expected requirements. (d6)	d6 The economic analysis of quality			
Monitor the product quality characteristics and process capabilities to ensure that process capabilities meet requirements. (d7)	d7 Process capability analysis	D2 Statistical technolo	Quality tool	yes/no

Use index such as product qualification rate, reject rate, rework rate, process capability index, and quality loss rate to evaluate the effectiveness of the process. (d8)	d8 Effectiveness of process statistical quality methods	gy		
The quality information is managed in accordance with the Quality Information Management Process and the requirements for information collection, transmission, storage and application. (d9)	d9 Determine the need for quality information	D4 Internal audit	Check and evaluation	effective/ ineffective
Establish the company's quality information system, including the establishment of information classification method, information processing platform, and process controls such as retrieval, distribution, use, and confidentiality. (d10)	d10 Establish quality information management system			
According to the Quality Information Management Procedures..... (d11)	d11 Establish quality management information system			
Analyze quality information (d12)	d12 Analysis and processing of information			
Responsible for planning the internal audit program based on the QMS operation, the process and area to be audited, and the results of previous audits. (d13)	d13 Internal audit planning	D5 Management review	Check and evaluation	effective/ ineffective
Specify the audit criteria, scope, frequency and methods. (d14)	d14 Audit scope			
The internal auditors of the QMS should be trained by training institutions with internal auditor training qualifications and passed the examination, obtain an internal auditor qualification certificate or be qualified for the work determined by the assessment, and be authorized by the general manager to ensure the audit process objectivity and fairness. (d15)	d15 Auditor competence			
Based on the audit results, the quality department completes the quality audit report as an input for management review. (d16)	d16 Audit results			
The chairman presides over the management review. (d17)	d17 The top management presides over the management review			
The input materials for planning and implementing the management review include: the measures taken in the past management review; the changes of	d18 Management review input			

internal and external factors related to the QMS... (d18)				
Management review output includes: QMS and its process effectiveness improvement and customer-related product improvement decisions and measures; QMS changes required... (d19)	d19 Management review output			
The quality department is responsible for the centralized management of corrective measures implemented in accordance with the Non-conforming Product Control Procedure. (d20)	d20Establish failure report analysis and corrective action system	D6 Corrective action and make the five aspects to zero	Improvement mechanism	effective/ ineffective
Through review and analysis of the non-conformity, determine the reason for the non-conformity. (d21)	d21 Determine the reason for the non-conformity			
Through non-conformity review and analysis, determine the cause of non-conformity and whether there exist or may occur similar non-conformity activities. (d22)	d22 Non-conformity review and analysis			
When serious and major quality problems occur in products and services, the technical department and the quality department require the implementation of technical and management problems to be zeroed. (d23)	d23 Make the technology and management to be zero			
When the non-conformity is confirmed to be caused by the external supplier, the company requires the external supplier to take corrective measures and evaluate the effectiveness of the measures. (d24)	d24 Evaluate the effectiveness of corrective measures			
Through the party and government joint meeting, strategy seminars, annual work meeting analysis and discussion, combined with resource advantages, senior leaders determine the priority of specific improvements, implement responsible departments, formulate improvement measures, and look for innovation opportunities. (d25)	d25 Determine the need for innovation	D7 Innovation management	Improvement and innovation	effective/ ineffective
For major improvement projects involving the strategic adjustment, development and transformation, and process improvement of the company's overall interests, a work group is established to conduct multi-party investigations and studies, analyze opportunities and risks, and submit a demonstration report and improvement project application to the board of directors. (d26)	d26 Determine the innovation process			

Carry out various forms of innovation and improvement activities, promote the participation of all employees, and ensure orderly and effective development. (d27)	d27 Equipped with relevant resources			
Resources				
Original textual data	Open coding Concept	Category	Concept attribution	Attribution dimension
According to the strategy and human resource planning, the company regards strategic talents, international talents and professional talents as the key talents to introduce. Meanwhile, the type and number of employees needed is determined according to the employee flow and production needs. (e1)	e1 Identify the needs of employees	E1 Human resources	Staff guarantee	suitable/ unsuitable
The company uses methods such as target decomposition, job evaluation, and job analysis to determine job qualifications and job competency requirements. (e2)	e2 Determine the job requirements			
The company adheres to the principle of "simultaneous development of internal and external talents", analyzes and evaluates the needs of knowledge, skills, experience, academic qualifications, and professions, and adopts methods such as introduction and training to improve the ability and quality of the workforce. (e3)	e3 Improve employee quality			
Guided by the results of the identification of employee ability needs, the talent recruitment focuses on strategic, international, and professional talents, and recruits talents through high-level exchange meetings, university industry-university-research project discovery, and headhunting recommendations. The company analyzes the turnover situation of employees, classifies and summarizes the reasons for resignation, and provides targeted solutions and improvements to stabilize the workforce. (e4)	e4 Recruit and retain employees			
A diverse incentive system has been formulated as an important part of performance management, providing more incentive measures to promote employee performance, such as: winning bid award, year-end award, lean production award, suggestion award, outstanding employee, top ten Employees. Meanwhile, employees are provided with meal subsidies and	e5 Employee incentive			

welfare during important holidays. (e5) Extensively collect employees' concerns and suggestions through the above multiple channels, and determine the key factors that affect employees' rights, satisfaction, and enthusiasm through analysis and evaluation. (e6)	e6 Employee satisfaction			
According to the needs of strategy, key process management and the existing infrastructure, the scale, type and quantity of infrastructure construction are determined according to the sales plan and production outline. (e7)	e7 Reasonable configuration of infrastructure	E2 Basic infrastructure	Equipment guanrantee	suitable/ unsuitable
The company strictly abides by preventive maintenance and overhaul, supplemented by troubleshooting afterwards, implements a "three-level maintenance" preventive maintenance system, and configures an online early warning control system for key quality and production control equipment to ensure the integrity and normal operation of the infrastructure. (e8)	e8 Develop and implement equipment maintenance			
In accordance with the requirements of strategy, annual plan goals, product market demand, production automation, labor intensity reduction, elimination of outdated production capacity, and energy conservation and environmental protection, the infrastructure is continuously updated and transformed. (e9)	e9 Equipment renovation			
In contrast to traceable international or domestic measurement standards, calibration and/or verification should be performed at specified time intervals or before use. When the above standards do not exist, the records used as the basis for calibration should be kept. (e10)	e10 Regular calibration/verification	E3 Monitoring and measuring equipment	Statistical management	effective/ ineffective
The monitoring and measurement equipment resources provided by the organization should ensure that the products and services are required. (e11)	e11 Configure reasonable monitoring and measurement resources			
In order to prevent deviation from the original applicable state and ensure the continued suitable use of monitoring and measurement resources, these monitoring and measurement resources should be maintained. (e12)	e12 Maintain monitoring and measurement resources			
When the measurement equipment is found not meet the intended use, the organization shall determine the validity of the previous measurement results. (e13)	e13 Traceability of measurement products			

The company's technical department determines and provides the required process operating environment to run the process and obtain qualified products. (e14)	e14 Determine and provide a suitable process operating environment	E4 Process operating environment	Process environment	reasonable/ unreasonable
The environmental factors that need to be monitored are: social factors, psychological factors, physical factors. (e15)	e15 The content of the process operating environment			
According to strategic needs, the company has established a complete hardware network system and software management and control system to ensure unimpeded information channels.		E5 Information and knowledge resources	Platform construction	good/bad
The company's central computer room is a data center, using advanced international brand equipment to provide a fast and stable hardware support platform for information systems such as finance, personnel, and the company's official website. (e16)	e16 Configure information system			
In terms of software, the company has successively updated OA system, which enables internal personnel to share information conveniently and efficiently, and work together efficiently. The company also changes the complicated and inefficient manual office methods in the past, and realize rapid and comprehensive information collection and information processing. (e17)	e17 Information software			
The company's information construction is reasonably deployed based on the company's development scale. In the future, the company will assess and introduce a storage system to make the production and delivery of materials more accurate, reduce the professionalism of personnel and increase the speed of receiving and sending materials. After the company develops to a certain scale, it will combine the current MES and ERP system with the machine, and control the production of the automated assembly line on the basis of the automated assembly line to move closer to a modern factory of intelligent manufacturing. (e18)	e18 Development direction of information system			
The company identifies internal and external explicit/invisible knowledge, confirms and transforms it into company standards. (e19)	e19 Knowledge recognition			
Employees browse by authority:	e20 Knowledge			

corporate standards, analysis reports, summaries, successful cases, professional knowledge, experience skills, employee production, maintenance and management. (e20)	Sharing			
Carry out corporate culture promotion education and theme activities, organize labor skill competitions, encourage employees to learn from top ten employees and outstanding workers, and create a working atmosphere of "comparing, learning, helping and surpassing". (e21)	e21 Knowledge learning and application			
Encourage employees to summarize successful practice and innovation experience at work, encourage cross-departmental cooperation, form project teams, carry out management and technological innovation projects, integrate resources with external enterprises, research institutions, universities and other resources, and carry out joint R&D cooperative innovation projects. (e22)	e22 Knowledge innovation			
The organization shall determine the requirements of related parties related to the QMS. (e23)	e23 Determine the requirements of related parties	E6 Relationship of related parties	Relationship management	good/bad
The organization shall establish the monitoring and review of the relevant parties and their requirements of the QMS. (e24)	e24 Monitoring and review of related parties and their requirements			
Methods such as brainstorming, networking, level comparison, active investigation, and monitoring of customer needs can be used to determine the requirements of related parties. (e25)	e25 Relevant methods to determine the requirements of related parties			
Documented information control				
Original textual data	Open coding Concept	Category	Concept attribution	Attribution dimension
In order to determine that the documented information is appropriate and sufficient, review and approve the documented information. (f1)	f1 Approval of documents	F1 Document control	Document content	sound/ unsound
In order to control documented information, the company should carry out the following activities: change control (such as version control). (f2)	f2 File change management			
Prevent the unintended use of obsolete documents. (f3)	f3 Control of invalid documents			
The quality records retained as evidence of conformity shall be protected to prevent unexpected changes. (f4)	f4 Prevent unexpected changes to quality records	F2 Record control	Record content	sufficient/ insufficient
The retention period of records should	f5 Control record			

meet customer requirements, laws and regulations, and be compatible with the life cycle of products and services. (f5)	retention period			
Design and development of products and services				
Original textual data	Open coding Concept	Category	Concept attribution	Attribution dimension
When accepting customer orders, the customer service department should identify and determine customer requirements, including modifications to contracts and orders, and agree with customers to ensure the consistency of understanding and implementation of customer requirements. In the whole process of product realization, the comprehensive management department is responsible for reporting the actual situation of product realization to customers, collecting customer feedback information (including customer complaints and complaints), and processing and improving by the technical department, quality department, and production department according to the division of responsibilities to obtain customer understanding and support. (g1)	g1 Communicate with customers	G1 Product and service requirement	Communication	strong/weak
The technical department and the comprehensive management department are respectively responsible for organizing the identification, determination and centralized management of product requirements in accordance with the *Determination of Product and Service Requirements and Review Control*. The quality department cooperates to complete the determination of product-related requirements. Product-related requirements are put forward by the comprehensive management department through market surveys, contracts, assignments, agreements, bids, or obtained through communication between the technical department and customer service department and customers, and organize related departments to discuss and determine. (g2)	g2 The determination of product and service			
The comprehensive management department should organize relevant personnel to review the following requirements before the product development contract and product batch production contract are signed: the contract, order and/or technical agreement requirements provided by the customer, including the requirements for delivery and	g3 Review of product and service requirements			

post-delivery activities; risks and control measures. (g3)				
If changes in product and service requirements have an impact on the realization of customer requirements, the technical department should communicate with the customer in a timely manner and obtain the customer's consent before implementing the change. If product and service requirements are changed, ensure that relevant documented information is revised, and ensure that relevant personnel are aware of the changed requirements. If changes in product and service requirements affect the fulfillment of customer requirements, the changes should be approved by the customer. (g4)	g4 Changes in products and services			
According to the needs of the new product development task book, the technical department established a new product development team composed of personnel from technical, quality, production field to prepare new product design and development related documents. The documents and content include: the determination of the development stage in (new product design and development project), analyze the quality characteristics of the product according to the requirements. (g5)	g5 Design, development and planning	G2 Design and development process of product and service	Design and development	suitable/ unsuitable
Design input can be reviewed through document review or conference review to ensure that the input is sufficient and appropriate, and the design input review form should be filled in. (g6)	g6 Design and development input			
The review, test, verification and confirmation process and results of each stage of design and development shall be approved and documented in accordance with regulations. Customers should be invited to participate in the confirmation of design and development. Measures should be taken to track the issues raised by the review, verification and confirmation. (g7)	g7 Design and development control			
The output of design and development should meet the requirements of the input. (g8)	g8 Design and development output			
The technical status documents are respectively numbered in accordance with the requirements of military and civil aircraft as well as cold and hot processing technology, and are managed in accordance with the *Document Control Procedure*. (g9)	g9 Technical status indicator	G3 Technology management	Professional techniques	effective/ ineffective
After receiving the technical status change documents such as the design drawing	g10 Technical status control			

modification sheet, technical decision sheet, test card and deviation document issued by the design department, the technical department's data room, after confirming the scope of knowledge, should notify the technician to change the technical status and track the change condition. (g10)				
After the technical department fills in the *Technical Status Change Implementation Report Form*, the key records will be notified on the management account and pass the report to the relevant departments. (g11)	g11 Technical status documentary			
The technical status audit work consists of an audit team formed by the customer, the designer, and the company to conduct physical and technical status audits. (g12)	g12 Technical status review			
Develop a general quality characteristic work plan, clarify personnel, responsibilities, work procedures, content, methods and schedule requirements. (g13)	g13 General quality characteristic planning	G4 General quality characteristic management	Professional techniques	effective/ ineffective
The general quality characteristics of the product are reviewed while designing and developing the review. (g14)	g14 General quality characteristics review			
The general quality characteristic design report should be completed in accordance with the work plan. (g15)	g15 General quality characteristic design report			
The organization shall establish and operate a product failure reporting and corrective action system. (g16)	g16 Implement failure report and corrective action system			
The overall equipment and systems and equipment should carry out failure mode and impact analysis (FMEA). (g17)	g17 Carry out failure mode and impact analysis			
Before product trial production, check the preparation status of product trial production. (g18)	g18 Check the production preparation status of the product trial	G5 New product trial production	Product trial	suitable/ unsuitable
Perform process review to meet the requirements of GJB1269. (g19)	g19 Process review			
Compile the first article appraisal catalog and conduct the first article appraisal to meet the requirements of GJB908. (g20)	g20 First Article Appraisal			
After the product trial production is completed, the product quality review will be carried out to meet the requirements of GJB907. (g21)	g21 Product quality review			
Prepare and review the test program or test plan. For the tests that are of concern to customers, the test program or test plan shall be approved by the customer. (g22)	g22 Trial planning	G6 Trial control	Evaluation check	yes/no
Prepare for the test and implement the readiness check. (g23)	g23 Trial preparation			

Organize the test in accordance with the test program or test plan. (g24)	g24 Test implementation			
Take effective corrective measures for the failures and defects found in the test, and perform the test or verification again. (g25)	g25 Trial problem handling			
Provision of products and services				
Original textual data	Open coding			
	Concept	Category	Concept attribution	Attribution dimension
The production department is responsible for organizing the technical department, quality department and other related departments to evaluate the supplier's quality assurance ability and evaluate the ability of qualified suppliers to provide products. The production department compiles the *List of Qualified Suppliers* based on the evaluation results. (h1)	h1 Supplier selection evaluation	H1 External provision process	Supplier management	suitable/ unsuitable
Clarify verification requirements, methods and qualification criteria, implement verification as required, and keep verification records. (h2)	h2 Verification of the purchased products			
The information provided to external suppliers can be in the form of written information such as contracts, agreements, orders, bids, and assignments, or the form of verbal requirements. (h3)	h3 Information about the purchased products			
Provide design drawings, specifications, technical conditions, work instructions and other production operation documents, such as: process specifications, flow cards and inspection documents. (h4)	h4 Provide working files	H2 Control of products and services provision	Practice behavior	in place/not in place
Equip with and use monitoring and measurement resources suitable for monitoring and measurement activities, including: personnel engaged in monitoring and measurement, monitoring and measurement equipment, working materials, methods, and environmental and guarantee conditions. (h5)	h5 Provide monitoring and measurement resources			
According to the *Human Resources Management Control Procedures* and the requirements of human resources planning, qualified personnel shall be allocated. Employees in the positions that have qualification requirements, they should obtain the qualification certificates. (h6)	h6 Human resource allocation			
Provide suitable equipment and production environment according to the requirements of planning output, including tools, clamps, molds, and measuring tools related to product processing. (h7)	h7 Equipment and environmental management			
For processes where the output results cannot be verified by subsequent monitoring or	h8 Special process			

measurement (such as the blade casting process), according to the requirements of the *Special Process Control Procedure*s, the ability of the production and service provision process to achieve planned results is confirmed and reconfirmed regularly. (h8)	confirmation			
According to the requirements of the process technical documents, use the raw materials and auxiliary materials that have passed the re-inspection of the factory. (h9)	h9 Control of raw materials and auxiliary materials			
Monitoring and measurement activities are implemented on process parameters and product characteristics at the stages determined by relevant quality control and process technical documents to verify compliance with process or output control criteria and product and service acceptance criteria. (h10)	h10 Acceptance of products and services			
Identify the output status in accordance with the monitoring and measurement requirements during the entire process of product production and service provision. (h11)	h11 Identification of production and service	H3 Identification, protection and traceability	Practice behavior	in place/not in place
Establish records according to batches, record in detail the quantity, quality, operators and inspectors of feeding, processing, assembly, commissioning, inspection, and delivery, and keep the records as required. (h12)	h12 Implement batch management			
The company uses batch management to uniquely identify products and retain the traceable information formed. (h13)	h13 Ensure product traceability			
The production department is responsible for organizing and implementing the protection management of the product production process and the handling, packaging, storage and protection of the product during the delivery process, and taking appropriate protection such as moisture, vibration, and rust prevention measures. (h14)	h14 Product protection			
Identify and mark the key processes, stamp “key parts” or “important parts” mark on the cover of the process specification, and stamp the “key process” marks on the corresponding process diagrams. (h15)	h15 Key process identification	H4 Key process control	Practice behavior	in place/not in place
Set up quality control points to monitor and control key process parameters and key or important characteristics of products; implement the three rules of “fixed equipment (production equipment, testing equipment), designated personnel (operators, designated inspectors), and designated process methods” system, fill in three fixed tables, and effectively monitor and control process parameters and key or important characteristics of products. (h16)	h16 Critical process control			

Implement 100% inspection on key or important characteristics. If 100% inspection cannot be implemented, the specified inspection or verification method shall be approved by the customer. (h17)	h17 Critical process inspection			
Fill in and keep key process quality records to maintain traceability. (h18)	h18 Key process records			
According to *Inspection Work Requirements*, product verification requirements are specified. (h19)	h19 Product acceptance requirements	H5 Release of products and services	Release control	effective/ ineffective
When implementing product release and delivering services, relevant personnel should be authorized. (h20)	h20 Authorized acceptance personnel			
When the product does not complete the required verification activities and requires an exception (emergency) release, the approval procedures shall be fulfilled in accordance with the regulations, and the customer's consent shall be obtained to identify and keep records of the exception release product and software data to ensure that the product can be recovered and replaced. (h21)	h21 Controlled exception (emergency) release			
When the product is delivered, the company provides a signed product certificate and final inspection record according to the regulations. (h22)	h22 Provide the conformity certificate and finished product acceptance record			
The non-conforming product reviewer shall be qualified and approved by the customer or customer representative, authorized by the chairman, to review the non-conforming product within the scope of their respective duties and provide review opinions. (h23)	h23 Authorization of non-conforming product reviewer	H6 Non-conforming product management	Check and evaluation	yes/no
The company takes appropriate measures based on the nature of the nonconformity and its impact on the conformity of products and services, including nonconforming products and services discovered after the products are delivered to customers or started to be used. (h24)	h24 Disposal of non-conforming product			
After the nonconforming product is corrected, the product needs to be verified again to confirm compliance with the requirements. (h25)	h25 Verification of rework or repair			
The quality department maintains records of nonconforming product review and measures taken. (h26)	h26 Non-conforming product record management			
Prepare service plans and key customer visit plans, notify relevant departments to provide resource guarantees, implement services,	h27 Develop after-sales service plan	H7 After-sales	Service guarantee	effective/ ineffective

verify and report, and be responsible for conducting customer satisfaction surveys. (h27)		service		
Assign technical service personnel to the site to provide services; collect and analyze product usage and service information; when problems are found after delivery, take measures such as investigation, handling and reporting, and verify their effectiveness. (h28)	h28 Implement after-sales service			
Collect all kinds of information to confirm customer needs; be responsible for the sorting and filing of original records of pre-sales, in-sales and after-sales services. (h29)	h29 After-sales service information management			
Quality management result				
Original textual data	Open coding			
	Concept	Category	Concept attribution	Attribution dimension
Senhe conducts customer satisfaction evaluation every year, and the results show that Senhe's customer satisfaction is at a relatively high level. See Chart 2.7-7 Senhe Customer Satisfaction (i1)	i1 Index level and trends of customer satisfaction	I1 Customer satisfaction results	Check and evaluation	yes/no
Through surveys on trade associations and joint customer, on-site visits, understand the comparison results with major competitors and benchmarks. It shows that Senhe is better than competitors and benchmark companies. See Chart 2.7-8 Overall Satisfaction Comparison. (i2)	i2 Customer satisfaction comparison results			
Senhe transforms customer satisfaction into customer loyalty through quality and value. The survey shows that Senhe's customer loyalty is at an excellent level and is superior to major competitors in the industry. See chart 2.7-9 Senhe customer loyalty. (i3)	i3 Index levels and trends of customer loyalty			
In the past three years, Senhe has effectively implemented the research and development process, and the research and development of high-end products has gradually increased, which has provided technical support for the smooth realization of the company's strategy of becoming stronger and larger. Such as the number of new product research and development, research and development cycle. (i4)	i4 The result of the development process	I2 QMS results	Check and evaluation	yes/no
Senhe has always attached importance to the win-win cooperation with suppliers, continuously strengthened the relationship management with suppliers, and strengthened the control of raw material procurement, supply quality and warehousing management, and achieved good results. Such as inspection pass rate, purchase cost achievement rate, purchase plan completion rate. (i5)	i5 The result of the procurement process			

In the past three years, Senhe has continuously improved the production process, scientifically organized production management, and achieved remarkable results, with stable quality improvement and effective cost control. Such as timely delivery rate, cost control rate, rework rate, production plan. (i6)	i6 The result of the production process			
In the process of marketing services, Senhe has a stable performance in terms of customer, market, and internal operations. Such as domestic market share, timely delivery rate, and capital recovery rate. (i7)	i7 The result of the marketing process			
Senhe implements enterprise standards higher than national standards in product development, manufacturing and testing, ensuring stable quality and outstanding performance. (i8)	i8 Product performance	I3 Products and services results	Check and evaluation	yes/no
Senhe provided installation and maintenance services in accordance with systems and procedures such as *Customer Satisfaction Monitoring Procedures* and *Maintenance Service Procedures*. The track and the improvement of customer complaints show that customers have expressed satisfaction with the company's main service results. (i9)	i9 Service performance			
Compared with other similar domestic products, Senhe products have excellent main product performance indicators and a small control range of fluctuation indicators. (i10)	i10 Comparison results of key performance indicators of products and services			
In terms of products and services, Senhe has won honors such as *Zhejiang Famous Brand Products*, *Zhejiang Famous Export Brands*, *National Customer Satisfaction Products*, *Customer Satisfaction Service Company*, *Zhejiang Green Enterprises*, *National High-tech Enterprises*, and *Zhejiang Famous Brand Products*, *National Torch Program Industrialization Demonstration Project*, *Zhejiang Province Excellent Industrial New Product (New Technology) Third Prize*. (i11)	i11 Features and innovation of product and service			

3.3.2 Axial coding

Axial coding is the second-level coding which intends to discover and set up relationships between concepts and categories to show the relationship between the data parts. These relationships can be causal relation, chronological relation, semantic relation, contextual relation, similar relation, difference relation.

In the process of axial coding, the researcher merely conducts in-depth analysis on one

category once, and uses this category as the axis to find relevant relationships around this category. As the analysis continues to deepen, the relationships between the categories should become more and more specific (X. D. Wang, 2020).

The thesis has gone through three stages in the axial coding. The first stage is to explore the category of concepts. At this stage, we not only consider the relationship between the concepts, but also explore the intentions and motivations behind these concepts. The second stage is to distinguish the priority of the category. After establishing the relationship between each group of concepts and categories, we also distinguish the main category and the secondary category. When different levels of categories are identified, we link the lower-level categories to the higher ones to establish relationships. The third stage is to establish a prototype of theoretical construction. After the completion of the first two stages, we tried to explore the category relationships and initially formed a theoretical construction prototype guided by action orientation or interaction orientation. This theoretical prototype will play a vital role in dealing with real problems in the later stage.

Through axial coding, 4 main categories are formed in the thesis, namely: management process, support process, customer-oriented process and result. 9 sub-categories are formed, among which, leadership, strategic management, risk management, measurement, analysis and improvement belong to the management process, resources and documented information control belong to the support process, design and development of product and service, and provision of product production belong to the customer-oriented process, and the quality management result belongs to the result. The axial coding of quality management of private equipment manufacturing enterprises is summarized in Table 3.2.

Table 3.2 Axial coding record

Categories extracted in open coding	Sub-category	Main category
A1 Leadership and commitment	Leadership	Management process
A2 Policy and goal management		
A3 Position responsibility and authority		
A4 Communication		
A5 Quality culture		
B1 Strategy formulation	Strategic management	
B2 Strategy deployment		
C1 Risk planning	Risk management	
C2 Risk evaluation		
C3 Risk treatment		
C4 Risk monitoring		
D1 Measurement, analysis and judgement	Measurement, analysis and improvement	
D2 Statistical technology		
D3 Quality information		
D4 Internal audit		
D5 Management review		
D6 Corrective action and make the five aspects to zero		
D7 Innovation management		
E1 Human resources	Resources	Support process
E2 Basic infrastructure		
E3 Monitoring and measuring equipment		
E4 Process operating environment		
E5 Information and knowledge resources		
E6 Relationship of related parties		
F1 Document control	Documented information control	
F2 Record control		
G1 Product and service requirement	Design and development of products and services	Customer-oriented process
G2 Design and development process of product and service		
G3 Technology management		
G4 General quality characteristic management		
G5 New product trial production		
G6 Trial control		
H1 External provision process	Provision of products and services	
H2 Control of products and services provision		
H3 Identification, protection and traceability		
H4 Key process control		
H5 Release of products and services		
H6 Non-conforming product management		
H7 After-sales service		
I1 Customer satisfaction results	Quality management result	Result
I2 QMS results		
I3 Products and services results		

3.3.3 Selective coding

Selective coding, also known as core coding, requires selecting a “core or main category” after systematically analyzing all categories. Compared with other categories, the core category must be repeatedly proved to be commanding and can include most of the research results in a

relatively broad theoretical range. Like the pull of a fishing net, the core category can guide all the other categories. As the core categories are analyzed, the theory will naturally develop forward.

In the process of core coding, we often ask ourselves: “At what level can this conceptual category(s) belong to a larger social analysis category? Can these conceptual categories summarize a more important core? How do I put these conceptual categories together to form a systematic theoretical framework?” The specific steps for core coding in this thesis are as follows:

(1) Make clear the story line of the information. Through in-depth analysis of the materials and coding levels of the three enterprises, quality management of private equipment manufacturing enterprises began to appear as the core category. The quality management of private equipment manufacturing enterprises is inseparable from the guiding role of leadership, strategic management, risk management, measurement, analysis and improvement in the management process, as well as the supporting role of resources and documented information control in the supporting process. The business of the enterprise is the design and development of product and service, and the provision of product and service in the customer-oriented process. The aim to achieve the quality management result.

(2) Further compare the main categories, secondary categories and the corresponding attributes and dimensions. Through comparison and analysis, the study finds that quality management of private equipment manufacturing enterprises occupies a central position in these categories, has the highest frequency of occurrence, and can establish connections with all categories. Leadership, resource management, design and development of product and service, and quality management result are all manifestations of the quality management activities of private equipment manufacturing enterprises in different aspects.

(3) Establish a systematic connection between the core category and other categories. In this thesis, the connotation and relationship of all-level categories are discussed deeply through constant comparison. In the end, the maturity model is established, with the core element being quality management of private equipment manufacturing enterprises, with the main category being management process, support process, customer-oriented process and results, with the secondary category being leadership, strategic management, risk management, measurement, analysis and improvement, resources management, documented information control process, design and development of product and service, provision of product and service, and quality management results. The final evaluation model is shown in Figure 3.1.

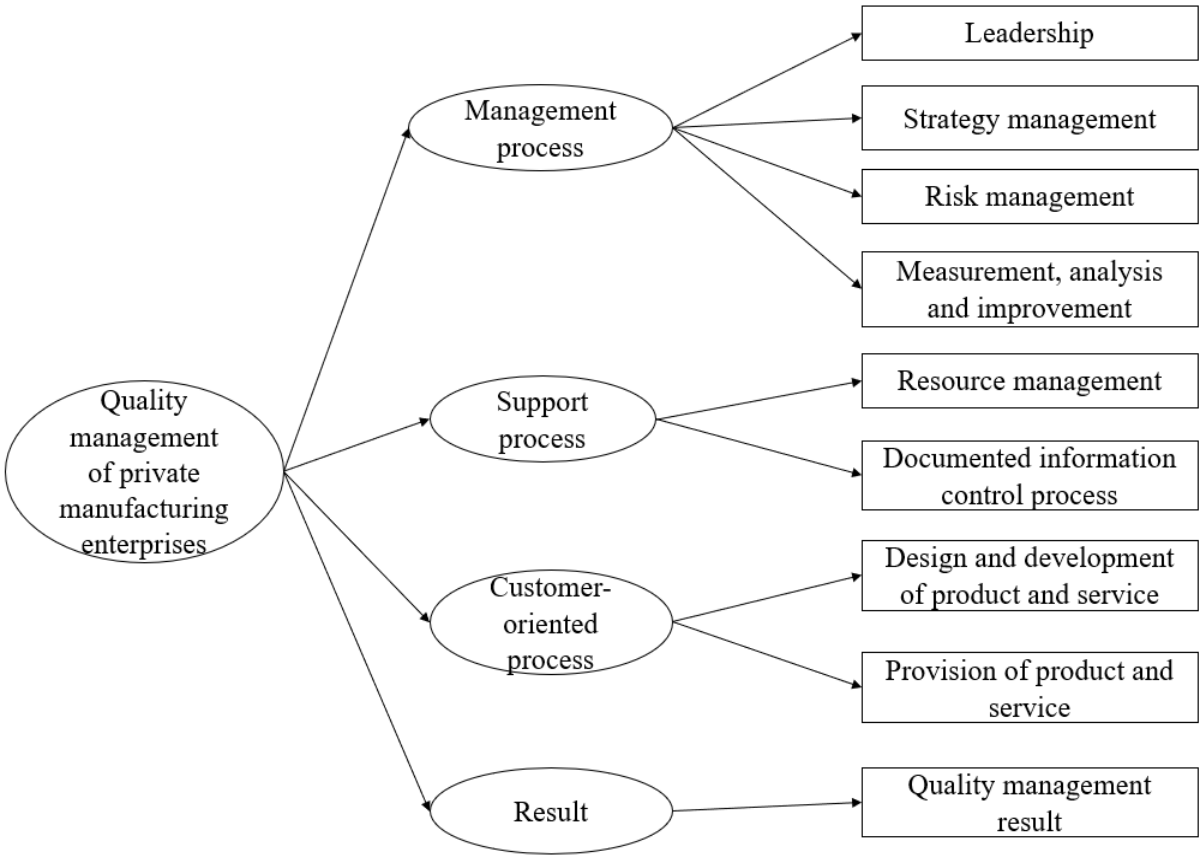


Figure 3.1 The QMM model of private equipment manufacturing enterprises

3.3.4 Model evaluation

The main purpose of this chapter is to identify the key elements in the quality management of private equipment manufacturing enterprises and obtain the logical structure between the elements. Using the three-level coding method, we coded and analyzed the textual materials of three domestic and foreign equipment manufacturing companies. The analysis results suggest that the quality management of private equipment manufacturing companies is a systematic concept, which is composed of management process, support process, customer-oriented process and result.

To evaluate the model we have obtained, we refer to Corbin and Strauss's opinion and use the seven criteria they proposed to evaluate the text analysis result.

Criteria 1: Has new concepts been created? This study conducted an in-depth analysis of the original data of three domestic and foreign equipment manufacturing companies, and extracted the concepts and categories in quality management of private equipment manufacturing companies, such as leadership, strategic management, resource management, design and development of product and service, quality management result. Among these elements, some were often neglected before, such as SWOT analysis, risk management plan,

technical status management, general quality characteristic management.

Criteria 2: Are the concepts systematically related? During the process of coding, we use as many code numbers as possible. Meanwhile, we repeatedly compare the extracted concepts to ensure that these concepts are logically and practically related, so that we can further extract secondary category.

Criteria 3: Does the category draw from the concepts and have sufficient closeness? In this study, 9 sub-categories and 3 main categories were extracted, all of which were extracted from bottom to top, indicating that the categories are close and the concepts are related.

Criteria 4: Does the theory construction process have enough variation? This research extracts the key elements and construct the theory bases on the original data of the enterprise. Therefore, the development of each concept and each category has a good foundation and can accommodate enough variation in the theory construction.

Criteria 5: Can the research explain the boundary conditions of the phenomenon? The theory, concepts, and categories in this model can explain the data well, so the boundary conditions of the phenomenon can be covered.

Criteria 6: Have the procedures of the research been considered? In the process of coding, continuous coding, analysis and comparison are carried out. Therefore, every concept and category can withstand test.

Criteria 7: How important is the theoretical discovery? The QMM model of private equipment manufacturing enterprises constructed in this study can provide enterprises with the direction of evaluating quality management. Meanwhile, the construction of this model also lays the foundation for the development of questionnaires and evaluation scales in the later stage of the study.

Compared with other quality management models, this model has three privileges. For the first privilege, the model is highly systematic. Most of the previous quality management models only focused on the process or the results of quality management. However, the elements extracted from the original data of the enterprise in this study include not only process elements but also result elements, which is comprehensive. For the second privilege, the model has strong operability. Compared with the theoretical model developed from top to bottom, the bottom-up model constructed in this study through grounded theory can integrate with reality more easily and have stronger operability. For the third privilege, the model echoes with the development. Quality management is a dynamic process, and the evaluation indicators may lose effectiveness with time going by. The text materials we used are new and have high timeliness.

3.4 Maturity level

Standards are required in any evaluation, because standards can provide a reference system. The QMM evaluation model developed in this research should also be carried out according to certain standards. Only when the standards are established, can the QMM level of private equipment manufacturing enterprises be evaluated and judged. In that way, we could help enterprises diagnose and improve the QMS.

The QMM level in the study refers to the level of Capacity Maturity Model (CMM). CMM provides a stepped improvement structure for the process capability of software enterprises. CMM defines 5 different maturity levels. The maturity level represents the management level from chaos to maturity, and the upgrading of maturity represents the process of upgrading management level and the corresponding maturity capability (Qin & Zhao, 2017).

Based on the application of CMM in enterprises, QMM of private equipment manufacturing enterprises also adopts a five-level structure. The QMM levels describe the gradual improvement of private equipment manufacturing enterprises' QMM, as shown in Appended Figure 2 (Annex).

The maturity levels define the stages in the process towards a mature management organization. Each maturity level lays a foundation for management process improvement and promotes the new development of organizational management capability. In this thesis, we refer to the existing maturity levels, and describe the characteristics of the five maturity levels of private manufacturing enterprises as follows.

Level 1: Initial level

The initial level is the minimum requirement for an enterprise to establish a QMS, and it is the first stage of the QMS from low-level to high-level. The standard of initial level is to pass the third-party QMS certification (GJB9001C-2017 standard) which is recognized by customers, and accept the supervision and audit as required (G. J. Zhu, 2008).

The characteristic of enterprises in the initial level is that GJB9001C-2017 standard system is initially established, and internal audits and management reviews are conducted as required. However, the understanding of QMS is not deep enough, and there is still a gap between the standards and the actual operations. Enterprises of initial level need to firstly strengthen the publicity and implementation of standards, secondly improve the QMS documents, thirdly clarify department responsibilities, job requirements, and process flow, and fourthly be strict on the process discipline to achieve "write what I do, do what I write".

Level 2: Repeatable level

After meeting the requirements of initial level, the enterprise begins to reach the repeatable level by initially establishing a continuous improvement mechanism. Enterprises of repeatable level have the following characteristics. Firstly, the responsibilities and authorities of each department are clear. Secondly, the quality objectives are effectively decomposed and implemented, with the focus being the product realization process as well as the design, production, procurement, and supplier management that play a decisive role in the actual product. Thirdly, effective corrective measures are taken through the PDCA cycle to meet the improvement needs of the enterprise and ensure product compliance. Fourthly, leaders and employees at all levels understand the role of quality management. Most management elements can be implemented, the quality of key processes and activities can be controlled, and management work can be systematic, disciplined, and repeatable.

Level 3: Defined level

After meeting the requirements of repeatable level, the enterprise could make efforts to reach the defined level. Enterprises of repeatable level have the following characteristics. Firstly, the corporate structure and the quality management responsibilities at all levels are further standardized, and a complete QMS document is established. Secondly, each element of corporate quality management has been effectively implemented, and employees are capable of job knowledge and skill requirements. Thirdly, the predetermined QMS goals are achieved, but some aspects of the QMS performance are not be satisfactory, which needs further standardization to continuously ensure product compliance.

Level 4: Managed level

After meeting the requirements of repeatable level, the enterprise could reach the managed level by further improving management and achieving quantitative management. To be specifically, the quality management content has clear measurement, and the enterprise has established quantitative goals to measure various quality activities. Meanwhile, quality information is established and used to analyze the management process and take corresponding corrective measures for the purpose of improving the QMS. Moreover, risks are effectively managed and most quality management elements are managed independently, making system management a conscious behavior in business operations.

Level 5: Optimizing level

After meeting the requirements of the managed level, the enterprise could reach the optimizing level, which is the industry benchmark level. For enterprises of this level, systematic method is established to collect, analyze, and review the existing information, and determine the need to update and understand the organizational environment, policies, strategies, and

goals, and identify opportunities for improving, learning, and innovation in organizational leadership activities.

Comprehensive analysis of organizational performance is conducted to determine the potential advantages and weaknesses in the organizational leadership, including: policy formulation and communication; management process; resource management; improving, learning and innovation. A clear framework is used in the analysis to show the impacts of leadership and activities on organizational performance.

3.5 Chapter summary

Based on the literature review, this chapter uses the three-level coding in the qualitative study to analyze the text materials of three domestic and foreign equipment manufacturing enterprises: Dadongfeng, Senhe Elevator, and MFC. In this chapter, the QMM elements of private equipment manufacturing companies are extracted, and the maturity evaluation model is established.

Through the analysis of the text materials, we have a clearer understanding about the QMM of private equipment manufacturing enterprises. Research shows that the quality management activities of private equipment manufacturing enterprises are composed of four subsystems: management process, support process, customer-oriented process, and result. Each subsystem contains a series of key process areas and key processes. The management process includes four key process areas: leadership, strategic management, risk management, measurement, analysis, and improvement, which further includes 18 key processes. The support process includes two key process areas: resource management and documented information control process, which further includes 8 key processes. Customer-oriented process includes two key process areas: design and development of product and service, provision of product and service, which further includes 13 key processes. Result includes one key process area: quality management result, which further includes 3 key processes. The elements abstracted can fully reflect the connotation and connection of the QMM of private equipment manufacturing enterprises, which lay a foundation for our subsequent development of questionnaire and scale.

[This page is deliberately left blank.]

Chapter 4: Empirical Analysis of the QMM Evaluation Model

In Chapter 3, we analyzed the textual materials of three foreign and domestic enterprises using text analysis method and constructed a QMM evaluation model for private equipment manufacturing enterprises. The result of text analysis shows that the QMM evaluation model of private equipment manufacturing enterprises consists of 4 subsystems: management process, support process, customer-oriented process and result. To enhance the scientificalness and operability of the model, this chapter tends to verify the evaluation model through empirical research. Firstly, the research designs a questionnaire based on the constructed maturity evaluation model. Secondly, the research adopts the questionnaire to carry out a pre-survey and conducts an EFA using the data collected. Thirdly, the research uses the adjusted questionnaire to carry out a formal survey and conducts a CFA using the data collected. Lastly, the research proposes research hypotheses and research model on the relationship of the four subsystems, and then tests the hypotheses.

4.1 Research design

4.1.1 Questionnaire design

This research objects to study the QMM of private equipment manufacturing enterprises. However, the relevant data cannot be acquired from the public information. Therefore, the research decides to obtain the data using questionnaire. On the one hand, questionnaire can test the relationship between the elements of the evaluation model, and verify the maturity evaluation model constructed in the previous chapter. On the other hand, questionnaire can help us to grasp the quality management situation of the private equipment manufacturing industry and lay a foundation for the improvement of quality management.

The study uses the evaluation model proposed in the previous chapter as the framework to form the QMM questionnaire. In the evaluation model, QMM is divided into management process, support process, customer-oriented process, and result.

The management process includes 4 key process areas (leadership, strategic management, risk management, measurement, analysis, and improvement), which further includes 18 key processes. The support process includes two key process areas (resource management and documented information control process), which further includes 8 key processes. The

customer-oriented process includes two key process areas (design and development of product and service, provision of product and service), which further includes 13 key processes. The results include one key process area (quality management result), which further includes 3 key processes. In total, there are 42 key processes, which are the source of questionnaire items. Each questionnaire item is the description of the corresponding key process. Referring to the division standard in GB/T19580-2012, we divide management process, support process, and customer-oriented process as the process, and divide result as the result (see Annex B for the complete questionnaire) (Bi et al., 2019).

To provide a standard for making judgments and scoring while filling out the questionnaire, we add the illustration of the scoring guide for the management process, support process and customer-oriented process as well as the scoring guide for result at the beginning of the corresponding items (S. D. Lu, 2016). The scoring guide for the process is shown above in Appended Table 1 (Annex), and the scoring guide for the result is shown above in Appended Table 2 (Annex).

As for the content of the item, we invited 6 experts to fill in the questionnaire and then improve the expression and format of the questionnaire referring to the experts' opinions to ensure that all the items are clear, understandable, and unambiguous. As for the questionnaire-filling method, this research adopts anonymous filling to clear up the doubts and give an objective answer.

Since the questionnaire used in this study are not from mature scales, this study conducts a small sample pre-survey before the formal large-sample survey, and test the questionnaire through EFA.

4.1.2 Sample selection

Focusing on private equipment manufacturing enterprises, the thesis collects data by investigating the employee's evaluation of the enterprises' QMM. During the pre-survey, we selected 6 private equipment manufacturing enterprises located in Guizhou province as the research objects, including BYZH company, KHHD company, DDF company, GXTF company, HHDL company, and HFKJ company. During the formal survey, we selected 80 private manufacturing enterprises located in Beijing, Zhejiang province, Guizhou province, Hunan province, and Sichuan province as the research objects. To ensure that the collected data can truly reflect the quality management of the enterprises, we select employees who are familiar with the QMM situation of the enterprise to fill in the questionnaire.

4.1.3 Data collection

Data collection is carried out in the pre-survey and the formal survey, both using online questionnaire. After entering the questionnaire on Wenjuanxing.com, a professional platform for survey, we sent the link and QR code of the questionnaire to the person in charge of the company. The person in charge of the company specified the employees who were familiar with the company's QMM to fill in the questionnaire. Before filling out the questionnaire, the researcher would not only explain the importance and anonymity of the questionnaire, but also explain the structure of the questionnaire, so that the employees could be clear about the questionnaire and answer objectively. 120 valid questionnaires and 240 valid questionnaires were collected separately during the pre-survey and formal survey, which were then used for EFA and CFA and hypothesis test.

4.1.4 Analysis method

To test the QMM evaluation model of private equipment manufacturing enterprises proposed in the previous chapter, the thesis adopts a large sample questionnaire survey to conduct the empirical research. Using statistical software such as SPSS22.0 and Mplus8.0, the thesis explores the relationship between the elements of the model by proposing and analyzing the hypotheses. The analysis methods in this study mainly include descriptive analysis, reliability analysis, validity analysis, and structural equation modeling (SEM).

Statistical description is a method to describe the characteristics of the sample. In this study, the basic information of the sample is described, including gender, age, education, position, and working years.

Reliability analysis is an effective method to evaluate whether the questionnaire is stable and reliable. As the most frequently used method in reliability analysis, Cronbach's α can reflect the internal consistency of the items. When Cronbach's α is greater than 0.7, the reliability is good. In this study, SPSS22.0 is used to analyze the reliability of the questionnaire.

Validity analysis, a method to analyze the validity and accuracy of the questionnaire, is used to measure whether the items are reasonable. Validity includes content validity, construct validity and criterion validity, among which content validity and structure validity are more common. Content validity is the validity of the words and content of the questionnaire, which can be improved by referring to authoritative sources such as books and research paper. Construct validity is the relationship between measurement items and measurement dimensions. As for the content validity, we have consulted the experts for multiple times about the content

of the items, which is a guarantee for a high content validity. As for the construct validity, the study would test construct validity through EFA and CFA. EFA is intended to find out the number of factors that influences the subsystems and the correlations between the factors and subsystems. SPSS22.0 is used to conduct the EFA. CFA is intended to explore the degree to which the factor model matches with the actual data. In this study, Mplus8.0 is used to test whether the number of factors and factor loadings of the four subsystems are consistent with our expectations.

SEM includes measurement model and path model. SEM can not only measure the internal structure and the correlations of the factors, but also measure the relationship between multiple independent variables and dependent variables. In this study, Mplus8.0 is used to explore the relationships between the four subsystems and test the proposed research hypotheses.

4.2 EFA (pre-survey sample)

In order to ensure the validity and reliability of the QMM evaluation questionnaire, the thesis conducts a pre-survey in 6 private manufacturing enterprises in Guizhou province. A total of 120 valid questionnaires are collected in the pre-survey, which is then used for the EFA on the four dimensions of quality management.

In this research, the EFA of each dimension is carried out in three steps. The first step is the sufficiency test. Before the EFA, the sufficiency test of the sample is required to determine whether the data is suitable for factor analysis. The criteria for sufficiency test are KMO value and Bartlett sphere examination result. KMO>0.9 indicates very suitable; 0.8<KMO<0.9 indicates suitable for EFA; 0.7<KMO<0.8 indicates generally suitable; 0.6<KMO<0.7 indicates barely suitable; KMO<0.6 indicates not suitable. Meanwhile, the value of Bartlett sphere examination result should be significantly different from 0, and the larger the chi-square approximation is, the more suitable the data is for factor analysis. The second step is to conduct EFA on each subsystem of the questionnaire. In this research, principal component analysis is used to extract factors, and the maximum variance method is selected as the rotation method. The principal factors are extracted according to the requirement that the characteristic root should be greater than 1 and the factor loading should be greater than 0.5. The larger the factor loading is, the higher the construct validity is. The third step is to analyze the reliability of each subsystem to determine the internal consistency and stability among the items of each dimension. In this thesis, Cronbach's α is used for the reliability test. The larger Cronbach's αis, the stronger the internal consistency is. Generally, Cronbach's α greater than 0.7 indicates a

good consistency between items.

4.2.1 Management process

For the first step, the sufficiency test of each variable in the management process is carried out. The results show that the KMO value is 0.943, and the probability of Bartlett's sphere test significance is 0.000, which indicates that the data is suitable for EFA.

For the second step, the thesis extracts the factors using the principal component analysis method. 4 factors are extracted under the requirement of characteristic root greater than 1 and factor loading greater than 0.5. As shown in Appended Table 3 (Annex), the results of factor analysis generally correspond with our expectations. Factor 1 represents "measurement, analysis and improvement", factor 2 represents "leadership", factor 3 represents "strategic management", and factor 4 represents "risk management". From the principal component factor analysis, it can be seen that the factor loading of LD1 and LD2 are both greater than 0.5 in factor 1 "measurement, analysis and improvement" and factor 2 "leadership". Considering the approximate factor loading on the two factors, we invited the experts to judge the item content and found that the content of LD1 and LD2 are more inclined to be leadership. Therefore, LD1 and LD2 are finally attributed to factor 2. It can be seen from the principal component factor analysis that the factor loading of FX1 is less than 0.5 on any factor, so in the follow-up questionnaire, we deleted the item FX1. The accumulative explained variance of the 4 factors is 74.78%.

For the third step, the reliability test of the variables in the management process is carried out. The Cronbach's α of each variable is greater than 0.7. Specifically, the Cronbach's α of "leadership" is 0.91, the Cronbach's α of "strategic management" is 0.96, the Cronbach's α of "risk management" is 0.88, and the Cronbach's α of "measurement, analysis and improvement" is 0.97. Therefore, the EFA result of the management process is ideal.

4.2.2 Support process

For the first step, the sufficiency test of each variable in the support process is carried out. The KMO value is 0.920, and the probability of Bartlett's sphere test significance is 0.000, which indicates that the data is suitable for EFA.

For the second step, the factors are extracted using the principal component analysis method. 2 factors are extracted under the requirement of characteristic root greater than 1 and factor loading greater than 0.5. As shown in Appended Table 4 (Annex), the results of factor analysis

generally correspond with our expectations. Factor 1 represents “resource management” and factor 2 represents “documented information control process”. The accumulative explained variance of the two factors is 77.48%.

For the third step, the reliability test of the variables in the support process is carried out. The Cronbach’s α of each variable is greater than 0.7. Specifically, the Cronbach’s α of “resource management” is 0.92, the Cronbach’s α of “documented information control process” is 0.86. Therefore, the EFA result of the support process is ideal.

4.2.3 Customer-oriented process

For the first step, the sufficiency test of each variable in the customer-oriented process is carried out. The result shows that the KMO value is 0.917, and the probability of Bartlett’s sphere test significance is 0.000, which indicates that the data is suitable for EFA.

For the second step, we extract the factors using the principal component analysis method. 2 factors are extracted under the requirement of characteristic root greater than 1 and factor loading greater than 0.5. As shown in Appended Table 5 (Annex), the results of factor analysis generally correspond with our expectations. Factor 1 represents “design and development of product and service” and factor 2 represents “provision of product and service”. The accumulative explained variance of the two factors is 77.48%.

From the principal component factor analysis, it can be seen that the factor loading of TF1 and TG2 are both greater than 0.5 in factor 1 “design and development of product and service” and factor 2 “provision of product and service”. Considering the approximate factor loading on the two factors, we invited the experts to judge the item content and found that the content of KF5 is more inclined to be design and development of product and service and TG5 are more inclined to be provision of product and service. Therefore, KF5 is finally attributed to factor 1 and TG2 is finally attributed to factor 2. The accumulative explained variance of the two factors is 76.36%.

For the third step, the reliability test of the variables in the support process is carried out. The result shows that the Cronbach’s α of each variable is greater than 0.7. Specifically, the Cronbach’s α of “design and development of product and service” is 0.93, the Cronbach’s α of “provision of product and service” is 0.93. Therefore, the EFA result of the customer-oriented process is ideal.

4.2.4 Result

For the first step, the sufficiency test of each variable in the result is carried out. The result shows that the KMO value is 0.917, and the probability of Bartlett's sphere test significance is 0.000, which indicates that the data is suitable for EFA.

For the second step, the research extracts the factors using the principal component analysis method. 1 factor is extracted under the requirement of characteristic root greater than 1 and factor loading greater than 0.5. As shown in Appended Table 6 (Annex), the results of factor analysis generally correspond with our expectations. Factor 1 represents "quality management result". The accumulative explained variance of the factors is 77.48%.

For the third step, the reliability test of the variables shows that the Cronbach's α of each variable is greater than 0.7. Specifically, the Cronbach's α of "quality management result" is 0.93, the Cronbach's α of "product production and service provision" is 0.93. Therefore, the EFA of the result is ideal.

4.3 CFA (large sample)

After obtaining the ideal results of the EFA in the pre-survey, the thesis conducted a formal survey. Using the data collected from the formal survey, we first used SPSS22.0 for the statistical description. After that, we used Mplus8.0 to perform CFA on the four sub-systems of quality management to test the construct validity. In terms of construct validity, X^2/df, CFI, TLI, RMSEA, and SRMR are adopted as the model fit indexes. The standards of each index are as follows: $X^2/df > 5$ indicates poor model fit; $2 < X^2/df < 5$ indicates acceptable model fit; $X^2/df < 2$ indicates good model fit. RMSEA >0.1 indicates poor model fit; 0.05<RMSEA<0.08 indicates acceptable model fit; RMSEA<0.05 indicates good model fit. SRMR<0.05 indicates good model fit. CFI>0.9 indicates good model fit, and the closer CFI to 1, the better the model fit is. TLI>0.9 indicates good model fit, and the closer TFI to 1, the better the model fit is.

4.3.1 Statistical description

During the formal survey, we collected 240 valid questionnaires from 80 private manufacturing companies in Beijing, Jiangsu province, Guizhou province, and Sichuan province.

As shown in the statistical description in Appended Table 7 (Annex), in terms of the gender, 45% are men and 55% are women, indicating an even proportion of men and women. In terms of the age, 74.6% are over 30 years old, indicating that most of the sample are middle-aged. In

terms of the education, 57.4% have a bachelor's degree or below, and 42.5% have a bachelor's degree or above, indicating an even educational background distribution. In terms of the position, 6.7% are senior managers, 11.7% are middle-level managers, 36.7% are R&D/technical staff, 73.4% are quality management staff, 8.3% are user representatives, indicating that the samples are all in the positions that are familiar with quality management. In terms of working years, 44.6% have been working for more than 9 years, indicating that most of the samples have long working years and have a wide knowledge about the enterprise.

4.3.2 Management process

The EFA shows that the management process is composed of four dimensions: leadership, strategic management, risk management, measurement, analysis and improvement. In order to further test the division of dimensions, we use CFA to test the construct validity.

As shown in Appended Table 8 (Annex), $X^2/df=2.968$, CFI=0.957, TLI=0.935, RMSEA=0.091, SRMR=0.036, indicating that the CFA result of management process is ideal.

4.3.3 Support process

The EFA shows that the support process is composed of two dimensions: resource management and documented information control process. In order to further test the division of dimensions, we use CFA to test the construct validity.

As show in Appended Table 9 (Annex), $X^2/df =2.459$, CFI =0.942, TLI=0.915, RMSEA=0.049, SRMR=0.037, indicating that the CFA result of support process is ideal.

4.3.4 Customer-oriented process

The EFA shows that the customer-oriented process is composed of two dimensions: design and development of product and service, provision of product and service. In order to further test the division of dimensions, we use CFA to test the construct validity.

As shown in Appended Table 10 (Annex), $X^2/df=3.132$, CFI=0.910, TLI=0.878, RMSEA=0.033, SRMR=0.063, indicating that the CFA result of customer-oriented process is ideal.

4.3.5 Result

The EFA shows that the result is composed of one dimension: quality management result. In order to further test the division of dimensions, we use CFA to test the construct validity.

As shown in Appended Table 11 (Annex), $X^2/df=0.000$, CFI=1, TLI=1, RMSEA=0.000, SRMR=0.000. Since there are only 3 items, the model fit index is not very representative. However, it can be seen from the path coefficient that the CFA result is ideal.

4.4 Research hypotheses and hypothesis test

4.4.1 Research hypothesis

As shown in the evaluation model proposed in the last chapter, QMM evaluation model of private equipment manufacturing enterprises consists of four subsystems: management process, support process, customer-oriented process, and result. In order to further understand the relationship between the quality management elements, a path analysis of the relationship between the four subsystems is conducted. In GB/T19580-2012 Excellent Performance Evaluation Criteria, the quality management is divided into process category and result category. Therefore, we refer to the division logic of GB/T19580-2012 during constructing the research model. In the QMM evaluation model, the management process, support process, and customer-oriented process can be categorized as process, and the quality management result can be categorized as result. Therefore, there is a causal relationship in the QMM evaluation. In the quality management process of private equipment manufacturing enterprises, the management process occurs first, followed by the support process. The maturity of the management process and the support process will affect the customer-oriented process and ultimately affect the quality management results. Meanwhile, the support process also has an impact on the management process. Therefore, the thesis proposes the research model and research hypotheses. The research model is shown in Figure 4.1.

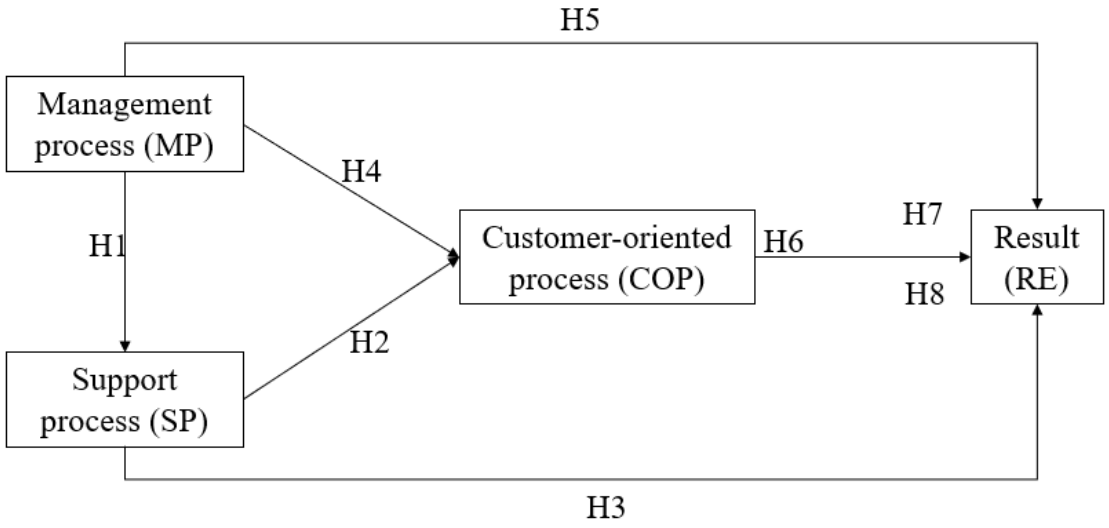


Figure 4.1 Research model

H1: Management process positively affects support process.

H2: Management process positively affects customer-oriented process.

H3: Management process positively affects result.

H4: Support process positively affects customer-oriented process.

H5: Support process positively affects result.

H6: Customer-oriented process positively affects result.

H7: Customer-oriented process mediates the effect of management process on result.

H8: Customer-oriented process mediates the effect of support process on result.

4.4.2 Hypothesis testing

(1) The impact of the management process on the support process

The management process is composed of four dimensions: leadership, strategic management, risk management, measurement, analysis and improvement. The support process is composed of two dimensions: resource management and documented information control process. Therefore, we explore the impact of the four dimensions of the management process on the two dimensions of the supporting process, and test the following set of hypotheses.

H1-1: Leadership positively affects resource management.

H1-2: Strategic management positively affects resource management.

H1-3: Risk management positively affects resource management.

H1-4: Measurement, analysis and improvement positively affects resource management.

H1-5: Leadership positively affects documented information control process.

H1-6: Strategic management positively affects documented information control process.

H1-7: Risk management positively affects the documented information control process.

H1-8: Measurement, analysis and improvement positively affects the documented information control process.

As shown in Appended Table 12 (Annex), leadership has a significant positive impact on resource management ($\beta=0.349$, $p<0.05$); measurement, analysis and improvement have a significant positive impact on resource management ($\beta=0.904$, $P<0.001$); measurement, analysis and improvement have a significant positive impact on documented information control process ($\beta=1.990$, $p<0.001$). Therefore, H1-1, H1-4 and H1-8 are supported. That is, strategic management and risk management have no positive effect on resource management, but leadership and measurement, analysis and improvement have a significant positive impact on resource management. Meanwhile, measurement, analysis and improvement have a significant positive impact on the documented information control process. Therefore, we can say that management process as a whole positively affects the support process.

(2) The impact of management process on customer-oriented process

The management process consists of four dimensions: leadership, strategic management, risk management, measurement, analysis and improvement. The customer-oriented process consists of two dimensions: design and development of product and service, provision of product and service. Therefore, we explore the impact of the four dimensions of the management process on the two dimensions of the customer-oriented process, and tested the following set of hypotheses.

H2-1: Leadership positively affects the design and development of product and service.

H2-2: Strategic management positively affects the design and development of product and service.

H2-3: Risk management positively affects the design and development of product and service.

H2-4: Measurement, analysis and improvement positively affects the design and development of product and service.

H2-5: Leadership positively affects the provision of product and service.

H2-6: Strategic management positively affects the provision of product and service.

H2-7: Risk management positively affects the provision of product and service.

H2-8: Measurement, analysis and improvement positively affects the provision of product and service.

As shown in Appended Table 13 (Annex), measurement, analysis and improvement has a

significant positive impact on the design and development of products and services (β=1.535, p<0.001); risk management has significant negative impact on the provision of product and service (β=-0.560, p<0.001); measurement, analysis and improvement have a significant positive impact on the provision of product and service (β=1.346, p<0.001). Therefore, H2-4 and H2-8 are supported. That is, the impact of leadership, strategic management, and risk management on the design and development of products and service as well as the provision of product and service are not significant. Measurement, analysis and improvement has a significant positive impact on the design and development of product and service as well as the provision of product and service. Therefore, we can say that part of management process positively affects customer-oriented process.

(3) The impact of management process on result

The management process consists of four dimensions: leadership, strategic management, risk management, measurement, analysis and improvement. The result consists of one dimension: quality management results. Therefore, we explore the impact of the four dimensions of the management process on one dimension of the result, and tested the following set of hypotheses.

H3-1: Leadership positively affects quality management result.

H3-2: Strategic management positively affects quality management result.

H3-3: Risk management positively affects quality management result.

H3-4: Measurement, analysis and improvement positively affects quality management result.

As shown in Appended Table 14 (Annex), leadership has a significant positive impact on the quality management results (β=0.839, p<0.001). Therefore, H3-1 is supported. Leadership has a significant positive impact on the quality management result. Therefore, we can say that part of management process positively affects the result.

(4) The impact of support process on customer-oriented process

The support process consists of two dimensions: resource management and documented information control process. The customer-oriented process consists of two dimensions: design and development of product and service, provision of product and service. Therefore, we explore the impact of the two dimensions of the support process on the two dimensions of the customer-oriented process, and test the following set of hypotheses.

H4-1: Resource management positively affects the design and development of product and service.

H4-2: The documented information control process positively affects the design and

development of product and service.

H4-3: Resource management positively affects the provision of product and service.

H4-4: The documented information control process positively affects the provision of product and service.

As shown in Appended Table 15 (Annex), resource management has a significant positive impact on the design and development of product and service (β=0.688, $p<0.001$); documented information control process has a significant positive impact on the design and development of product and service (β=0.340, $p<0.001$); resource management has a significant positive impact on provision of product and service (β=0.818, $p<0.001$). Therefore, H4-1, H4-2 and H4-3 are supported, and H4-4 is unsupported. Therefore, we can say that support process as a whole positively affects customer-oriented process.

(5) The impact of support process on result

The support process consists of two dimensions: resource management and documented information control process. The result consists of one dimension: quality management result. Therefore, we explore the influence of the two dimensions of the support process on one dimension of the result, and tested the following set of hypotheses.

H5-1: Resource management positively affects quality management result.

H5-2: The documented information control process positively affects the quality management result.

As shown in Appended Table 16 (Annex), resource management has a significant positive impact on the quality management results (β=0.980, $p<0.001$). Therefore, H5-1 is supported. Therefore, we can say that support process as a whole positively affects customer-oriented process.

(6) The impact of customer-oriented processes on result

The customer-oriented process consists of two dimensions: design and development of product and service, provision of product and service. The result consists of one dimension: quality management result. Therefore, we explore the impact of the two dimensions of the customer-oriented process on one dimension of the result, and tested the following set of hypotheses.

H6-1: The design and development of product and service positively affects quality management result.

H6-2: The provision of product and service positively affects quality management result.

As shown in Appended Table 17 (Annex), the provision of product and service have a significant positive impact on the quality management result (β=0.984, $p<0.001$). Therefore,

H6-2 is supported. The impact of the design and development of product and service on the quality management result is not significant. It is may because the provision of product and service can affect the quality management result more directly, while the design and development of product and service can actually positively affect the provision of product and service. Therefore, we can say that customer-oriented process as a whole positively affects the result.

(7) The mediating role of customer-oriented processes between management process and result

The customer-oriented process consists of two dimensions: design and development of product and service, provision of product and service. The management process consists of four dimensions: leadership, strategic management, risk management, measurement, analysis and improvement. The result consists of one dimension: quality management result. Therefore, we explore the impact of the two dimensions of the support process on the four dimensions of the management process, as well as the mediating effect. Therefore, we put forward the following set of hypotheses.

H7-1: The design and development of product and service mediate the positive impact of leadership on quality management result.

H7-2: The design and development of product and service mediate the positive impact of strategic management on quality management result.

H7-3: The design and development of product and service mediate the positive impact of risk management on quality management result.

H7-4: The design and development of product and service mediate the positive impact of measurement, analysis and improvement on quality management result.

H7-5: The provision of product and service mediate the positive impact of leadership on quality management result.

H7-6: The provision of product and service mediate the positive impact of strategic management on quality management result.

H7-7: The provision of product and service mediate the positive impact of risk management on quality management result.

H7-8: The provision of product and service mediate the positive impact of measurement analysis and improvement on quality management result.

It can be seen from the previous hypothesis test that the impacts of leadership and strategic management on customer-oriented process are not significant, and the impact of design and development of product and service on result is not significant, which means H7-1, H7-2, H7-

3, H7-4, H7-5, and H7-6 are not valid in the first place. Therefore, we only test H7-7 and H7-8.

Referring to the Bootstrap method proposed by Preacher and Hayes (2004), we obtained the 95% and 97.5% confidence intervals after 5000 times of Bootstrap. As shown in Appended Table 18 (Annex), the mediating results in H5.7 do not include 0 (Lower 2.5%=-0.0151, Upper 2.5%=-0.023), indicating that the mediating effect of the provision of product and service in the relationship between risk management and quality management result is significant. The mediating results in H5.8 do not include 0 (Lower 2.5%=0.165, Upper 2.5%=0.396), indicating that the mediating effect of the provision of product and service in the relationship between measurement, analysis and improvement and quality management result is significant. Therefore, H7-7 and H7-8 are supported.

(8) The mediating role of customer-oriented processes in the impact of support process on result

The customer-oriented process consists of two dimensions: design and development of product and service, provision of product and service. The support process consists of two dimensions: resource management and documented information control process. The result consists of one dimension: quality management result. Therefore, we explore the impact of the two dimensions of the support process on the four dimensions of the management process and the mediating effects. Therefore, we put forward the following set of hypotheses.

H8-1: The design and development of product and service mediate the positive impact of resource management on the result.

H8-2: The design and development of product and service mediate the positive impact of the documented information control process on the result.

H8-3: The provision of product and service mediates the positive impact of resource management on result.

H8-4: The provision of product and service mediates the positive impact of the documented information control process on the result.

It can be seen from the previous hypothesis test that the design and development of product and service have no significant impact on the result, so H8-1 and H8-2 are not valid in the first place. Therefore, we test H8-3 and H8-4 below.

Referring to the Bootstrap method proposed by Preacher and Hayes (2004), we obtained the 95% and 97.5% confidence intervals after 5000 times of Bootstrap. As shown in Appended Table 19 (Annex), the mediating results in H8.3 do not include 0 (Lower 2.5%=0.297, Upper 2.5%=0.537), indicating that the mediating effect of the provision of product and service in the

relationship between resource management and quality management result is significant. The mediating results in H8-4 do not include 0 (Lower 2.5%=0.011, Upper 2.5%=0.129), indicating that the mediating effect of the provision of product and service in the relationship between documented information control process and quality management result. Therefore, H8-3 and H8-4 are supported.

4.4.3 Discussion

The quality management of private equipment manufacturing enterprises is a hierarchical system, with the subsystems having certain internal connections. Through the logic from "process" to "result", we construct a research model and put forward the research hypotheses, that is: management process and support process affect result through customer-oriented process. Table 4.1 is a summary of the hypotheses supported after the hypothesis test.

From the hypothesis test result, it can be seen that in each relationship between the subsystems, there are hypothesis being supported. Therefore, there is an internal connection among the various subsystems of the QMM model of private equipment manufacturing enterprises. The model we have constructed has practical meaning.

Table 4.1 Summary of supported hypotheses

Impact path	No.	Hypotheses
MP-SP	H1-1	Leadership positively affects resource management.
	H1-4	Measurement, analysis and improvement positively affects resource management.
	H1-8	Measurement, analysis and improvement positively affects the documented information control process.
MP-COP	H2-4	Measurement, analysis and improvement positively affects the design and development of product and service.
	H2-8	Measurement, analysis and improvement positively affects the provision of product and service.
MP-RE	H3-1	Leadership positively affects quality management result.
SP-COP	H4-1	Resource management positively affects the design and development of product and service.
	H4-2	The documented information control process positively affects the design and development of product and service.
	H4-3	Resource management positively affects the provision of product and service.
SP-RE	H5-1	Resource management positively affects quality management result.
COP-RE	H6-2	The provision of product and service positively affects quality management result.
MP-COP-RE	H7-7	The provision of product and service mediates the positive impact of risk management on quality management result.
	H7-8	The provision of product and service mediates the positive impact of measurement analysis and improvement on quality management result.
SP-COP-RE	H8-3	The provision of product and service mediates the positive impact of resource management on result.
	H8-4	The provision of product and service mediates the positive impact of the

documented information control process on the result.

It is worth noting that although H2-7 is not supported, the result shows that risk management has a significant negative impact on the provision of product and service. The reason for the negative impact may be: too much emphasis on risk in the provision of product and service may cause companies to not dare try and challenge, resulting in insufficient innovation capabilities and lagging behind in the same industry. Due to the lack of innovation and progress, the customer's experience of the product production and service has decreased.

4.5 Chapter summary

Based on the QMM evaluation model of private equipment manufacturing enterprises constructed in the previous chapter, in this chapter, we firstly compile a questionnaire and revise the questionnaire after consulting the experts for multiple times. Then, we conduct a pre-survey and use the data from the pre-survey to perform an EFA. After that, we conduct a formal survey and use the data from the formal survey to conduct a CFA. Meanwhile, research hypotheses are proposed, tested and discussed in this chapter.

[This page is deliberately left blank.]

Chapter 5: The Application of the QMM Model of Private Equipment Manufacturing Enterprises on GXTF Company

5.1 Design of the QMM evaluation scale

In the previous model verification stage, a questionnaire on the quality maturity of private equipment manufacturing enterprises has been prepared. However, QMM questionnaire can only provide a general description of the quality management status of private equipment manufacturing enterprises, but cannot give the enterprises more guidance on maturity evaluation. In order to truly reflect the quality status of private equipment manufacturing enterprises and find the problems and deficiencies in enterprises' quality management, it is necessary to develop the relevant evaluation scale based on the questionnaire to measure the quality maturity level of private equipment manufacturing enterprises.

Based on the framework of the maturity evaluation model, the development and design of the QMM scale draws on the self-assessment content in the ISO9004.2018 standard and the scoring guide in *GB/T 19001-based QMM Evaluation Criteria* by China Quality Association. After discussing with the quality management experts of Beijing Tianyizheng Certification Center Co., Ltd., an evaluation scale that can measure the quality management process and quality result of private enterprises was formed. The design of the scale has reflected the PDCA principles, risk-based thinking principle and process method principle (Z. D. Ma et al., 2018). Ultimately, the 41 key processes in the model are further decomposed into 205 key process factors.

To ensure the applicability of the maturity scale, two rounds of expert discussion are conducted on the maturity evaluation scale to make revision and improvement.

In July 2021, experts from Beijing Tianyizheng Certification Center Co., Ltd, KHHD company, and GXTF company were invited to conduct expert discussions on the framework and content of the maturity evaluation scale. At the beginning of the discussion, the researcher introduced to experts the purpose and significance of evaluating the QMM of private equipment manufacturing enterprises, illustrated the process of constructing the QMM evaluation system of private equipment manufacturing enterprises, and then explained the design of the maturity evaluation scale. After the introduction, the experts participating in the discussion agreed that the QMM evaluation of private equipment manufacturing enterprises is of great significance. Meanwhile, the experts held that compiling the quality maturity evaluation criteria in

accordance with the excellent performance evaluation criteria might be difficult for organizations to grasp the evaluation content and evaluation standards. The experts recommended to detail the evaluation items and further clarify the scoring rules, which could not only facilitate the self-evaluation of the organization, but also convenient the second-party or third-party evaluation.

The maturity evaluation scale was revised and improved according to the suggestions of the experts. In August 2021, quality audit experts from Beijing Tianyizheng Certification Center Co., Ltd, experts from KHHD company and GXTF company were invited to review the revised version of the maturity evaluation scale. At this time, all of the experts agreed with the revised maturity evaluation scale. Moreover, the experts recommended to add evaluation opinions after scoring each evaluation item. If the maturity level was lower than 3, the existing deficiencies of the organization should be pointed out.

After two rounds of expert discussions, the maturity evaluation scale was refined based on the opinions of the experts. The QMM evaluation scale for private equipment manufacturing enterprises was formed (see Annexes C) (Gong, 2016; ISO, 2018).

5.2 Determination of the evaluative indicator weights of the maturity scale

5.2.1 Research method

The methods of weight determination include Delphi method (expert survey method), weighted average method, frequency distribution weight determination method, fuzzy coordinated decision method, AHP and other methods. The maturity evaluation system of private equipment manufacturing enterprises is a complex indicator system composed of quantitative indicators and qualitative indicators. Therefore, the contribution rate of each indicator to the overall goal is different, that is, the weight of each indicator is different. The maturity evaluation system of private equipment manufacturing enterprises is composed of various systems. Interacting and restricting, each system is affected by many factors, so the systems can be decomposed into different sub-indicators, thus forming a complex tree-shaped system. Considering the construct and flexibility of the tree-shaped system, this study uses AHP to determine the weight of each indicator.

AHP, a method which combines qualitative analysis and quantitative analysis, is effective in making decisions on complex issues. It is proposed by Saaty in the 1970s. According to the problem analysis, AHP is divided into three levels: target level G, criterion level C and plan

level P (Saaty, 1994). Using the method of paired comparison, the importance of the decision plans is determined, that is, the weight of the decision plan to target level G to is determined. In that way, a satisfactory decision can be obtained.

AHP has advantages, for example, AHP can help the evaluator to determine the importance level of paired comparison by looking up in the relative importance table. Therefore, AHP has high reliability and low possibility of error. Moreover, AHP digitizes and systematizes people's thinking, making it easy to accept and calculate. More importantly, AHP has strong compatibility and can be combined with methods such as Delphi method and factor analysis method, which provides good technical support for the establishment of the quality maturity evaluation system of private equipment manufacturing enterprise.

Therefore, AHP is a method which is relatively complete, easy to calculate, and suitable for multi-objective and multi-criteria evaluation. AHP has many privileges, so it is suitable for establishing and evaluating the quality maturity system of private equipment manufacturing enterprises.

AHP generally includes the following steps:

(1) Construct hierarchical structural model

(2) Construct a judgment matrix

To construct the judgement matrix, we need to make a paired comparison of the relative importance of the criterion at each level and give a judgment. The commonly used meaning of the judgment matrix elements are shown in Appended Table 20 (B. Huang, 2018; M. Qi, 2021).

Value 1 means that element i is as important as element, Value 3 means that Element i is slightly more important than element j,value 5 means that Element i is obviously more important than element j,value 7 means that element i is strongly more important than element j, value 9 means that element i is absolutely more important than element j. For 2, 4, 6, 8, the meanings of them are between the meanings of the values of 1, 3, 5, 7, 9.

(3) Calculate the eigenvector of the judgment matrix and the corresponding maximum eigenvalue

(4) Consistency check of the judgment matrix

Consistency check is needed for hierarchical single sort and hierarchical total sort. A correct order of importance of judgment matrix has certain logical rules. If it is assumed that supply is more important than quality, but quality should be more important than supply logically, then the judgment matrix violates the consistency criterion and is logically unreasonable. Therefore, in practice, the judgment matrix is required to meet the general consistency, which requires consistency test. The steps of consistency check are as follows:

① Calculate the C.I., as in formula (5.1).

$$\boldsymbol{C.I.} = \frac{\boldsymbol{\lambda_{max} - n}}{\boldsymbol{n - 1}} \tag{5.1}$$

② λ_{max} is the maximum eigenvalue of the matrix, calculate the consistency index C.R., as in formula (5.2)

$$\boldsymbol{C.R.} = \frac{\boldsymbol{C.I.}}{\boldsymbol{R.I.}} \tag{5.2}$$

R.I. is the average random consistency index, as in Appended Table 21.

When C.R.<0.1, the consistency of the judgment matrix is considered to be acceptable, otherwise the elements in the matrix should be adjusted until the judgment matrix has satisfactory consistency.

(5) Calculate the weight

If the consistency test is passed, then the feature vector obtained is the weight of each element. Using the weight of each level, we could calculate the total weight of the bottom plan to the top target.

Yaahp is an AHP assistant software that provides modeling, calculation, and analysis assistance for decision making using Analytic Hierarchy Process. Yaahp software can be used to accomplish the multi-criteria decision analysis task of AHP, fuzzy comprehensive evaluation method and the combination of AHP and fuzzy comprehensive evaluation method conveniently. In this paper, Yaahp software is used for analytic hierarchy process.

5.2.2 Determination of the indicator weights

(1) Construct hierarchical structural model

Using the AHP method, the hierarchical structure model is divided into three levels, where the first level is the target level. The second level is the criterion level, which includes 10 key process areas such as leadership, strategic management, risk management, measurement, analysis and improvement, resources. The third level is the indicator level (also called measure level or program level), which is the evaluation indicators, measures, or programs to achieve the goals. In this research, the indicator level includes the 41 key processes in the quality management of the private equipment manufacturing enterprises, such as leadership and commitment, policy and goal management, job responsibilities and authority, communication, quality culture. As shown in Table 5.1.

Table 5.1 Hierarchical structure model of QMM evaluation for private equipment manufacturing enterprises

Goal level A	Criterion level B	Indicator C
QMM of private manufacturing enterprises A	Leadership B1	Leadership and commitment C1
		Policy and goal management C2
		Position responsibility and authority C3
		Communication C4
		Quality culture C5
	Strategic management B2	Strategy formulation C6
		Strategy deployment C7
	Risk management B3	Risk evaluation C8
		Risk treatment C9
		Risk monitoring C10
	Measurement, analysis and improvement B4	Measurement, analysis and judgement C11
		Statistical technology C12
		Quality information C13
		Internal audit C14
		Management review C15
		Corrective action and make the five aspects to zero C16
		Innovation management C17
	Resources B5	Human resources C18
		Basic infrastructure C19
		Monitoring and measuring equipment C20
		Process operating environment C21
		Information and knowledge resources C22
		Relationship of related parties C23
	Documented information control B6	Document control C24
		Record control C25
	Design and development of products and services B7	Product and service requirement C26
		Design and development process of product and service C27
		Technology management C28
		General quality characteristic management C29
		New product trial production C30
		Trial control C31
	Provision of products and services B8	External provision process C32
		Control of products and services provision C33
		Identification, protection and traceability C34
		Key process control C35
		Release of products and services C36
		Non-conforming product management C37
		After-sales service C38
	Quality management result B9	Customer satisfaction results C39
		QMS results C40
		Products and services results C41

(2) Construct a judgment matrix

To ensure the application, representativeness and authority of the constructed matrix, the experts participate in the matrix construction should not only have many years' experience in enterprise quality management or technical management, but also have senior engineer qualifications. Meanwhile, these experts should have been engaged in the GJB9001C-2017

certificate and have deep understanding about the quality management activities of private equipment manufacturing enterprises, so that they could give objective judgement on quality management activities. Based on the above requirements, the thesis selected 7 audit experts from Beijing Tianyizheng Certification Center to score.

To show the calculation process of the specific weight and the total weight, we present expert ZGJ's scoring results of the "leadership" dimension in quality management as an example. Appended Table 22 (Annex) is the paired judgment matrix of the importance of the indicators to leadership.

(3) Calculate the eigenvector of the judgment matrix and the corresponding maximum eigenvalue

Using the above paired judgement matrix, the geometric mean of each row is calculated:

The product of the first row is 1×2×2×3×3=36

The product of the second row is 1/2×1×1×2×2=2

The product of the third row is 1/2×1×1×2×2=2

The product of the fourth row is 1/3×1/2×1/2×1×1=1/12

The product of the fifth row is 1/3×1/2×1/2×1×1=1/12

Then, calculate the m root of the above data (m=5) times to get:

$a_1=\sqrt[5]{36}$=2.0477

$a_2=\sqrt[5]{2}=1.1487$

$a_3=\sqrt[5]{2}=1.1487$

$a_4=\sqrt[5]{1/12}=.6084$

$a_5=\sqrt[5]{1/12}=.6084$

Next, calculate the proportion after summing up the a_i data and get:

W_1=2.0477/(2.0477+1.1487+1.1487+.6084+.6084)=.3682

W_2=1.1487/(2.0477+1.1487+1.1487+.6084+.6084)=.2065

W_3=1.1487/(2.0477+1.1487+1.1487+.6084+.6084)=.2065

W_4=.6084/(2.0477+1.1487+1.1487+.6084+.6084)=.1094

W_5=.6084/(2.0477+1.1487+1.1487+.6084+.6084)=.1094

Then, the relative weight vector of the five secondary indicators under the "leadership" dimension is obtained:

W=(.3682, .2065, .2065, .1094, .1094)

To test the relative weight obtained above, the largest characteristic root of the judgment matrix R, λ_{max} is required.

λ_{max}=5.0133

(4) Consistency test of the judgment matrix

The consistency index is C.I.=(5.0133.5)/(5.1)=.003325

Through the consistency index value, find that when the judgment matrix n=5, R.I.=1.12, then the consistency ratio is:

C.R.=C.I./R.I.=.003325/1.12=.00297

C.R. <.1 indicating that the relative weight judgment of the five secondary indicators under the “leadership” dimension has a high degree of reliability.

(5) Calculate the weight

Later, the relative weights of 5 secondary indicators under the “leadership” dimension is obtained, as shown in Appended Table 23. Among which, λ_{max}=5.0133， C.R.= .00297

Following the same procedure, the paired judgment matrix and the relative weight of the importance of the indicators to the strategic management is obtained (see Appended Table 24 for details). Among which, λ_{max}=2.0000, C.R.= .0000

The paired judgment matrix and relative weights of the importance of index-level factors to risk management is obtained, as shown in Appended Table 25. Among which, λ_{max}=3.0092, C.R.= .0079

The paired judgment matrix and the relative weight of the importance of indicators to measurement, analysis and improvement is obtained, as shown in Appended Table 26. Among which, λ_{max}=7.0000, C.R.= .0000

The weights of 41 process indicators under 9 key process areas are gradually obtained. Then, we average and normalize the weights obtained by 7 experts, and test the consistency of each group of weights.

Using the AHP yaahp software to establish a hierarchical structure model. The experts scored in turn to establish a judgment matrix. Regarding the scores given by the experts, group decision-making calculations are used to obtain the weight of the entire index system (Zhou, 2021). See Appended Table 27 for summary.

5.3 Determination of the maturity level

When evaluating the quality maturity of private equipment manufacturing enterprises in this thesis, the maturity level is divided into initial level, repeatable level, defined level, managed level, and optimized level. The maturity level can only be subjectively judged based on the

organization's self-assessment materials or on-site observations. In order to objectively judge the maturity and come to a definite conclusion, the thesis applies the fuzzy comprehensive evaluation method to the maturity level.

In 1965, Zadeh, a professor in the Department of Electrical Engineering and Computer Science at the University of California Berkeley and an expert in automatic control, published a paper titled with *Fuzzy Sets* (Zadeh, 1965). For the first time in the history, fuzzy concepts were described using precise mathematical methods, which also marks the birth of fuzzy mathematics (Y. L. Ma, 2017).

Fuzzy sets are objective reflections of the existing fuzzy concepts. Fuzzy concepts are concepts with unclear boundaries. For example, "tall man" is a fuzzy concept, because it is impossible to tell how tall is "tall". How to determine the relation of an element to a fuzzy set? The method is to use a certain number in the closed interval [0,1] to define the degree to which the element subordinates to the fuzzy set, which is called "subordinating degree". For example, the subordinating degree of the fuzzy set of "tall man" can be determined as .7 based on the common sense and experience. There are many fuzzy concepts and phenomena in the objective world, and fuzzy mathematics is an attempt to solve fuzzy problems by using mathematical tools. Fuzzy comprehensive evaluation method is a comprehensive evaluation problem that applies fuzzy mathematics to practice. Specifically, fuzzy comprehensive evaluation method is a kind of quantitative evaluation method based on fuzzy mathematics and fuzzy relation comprehensive principle. It is a method to evaluate the subordinate degree of the object to be evaluated comprehensively from each element.

As for how to conduct the fuzzy comprehensive evaluation method, there are five steps (S. X. Zhu, 2016).

Step 1: Determine the evaluation factor set

Suppose $U = \{u_1, u_2, \cdots, u_n\}$ is a set of n evaluation factors (evaluation indicators) describing the evaluated object. Where, n is the number of evaluation factors determined by a specific index system. In order to facilitate weight distribution and evaluation, evaluation factors can be divided into several categories according to attributes. If each category is treated as a single evaluation factor and a first-order evaluation factor, the second-order factor can be set as a subordinate of the first-order factor. In addition, tertiary factors can be set as secondary factors to secondary factors.

Step 2: Determine the comment set of the evaluation object

Suppose $V = \{v_1, v_2, \cdots, v_n\}$ to be an evaluation set composed of various levels that the evaluator may evaluate the object. Among them, v_j represents the j-th evaluation, j=1, 2, ...,

n. Meanwhile, n is the total number of the evaluations. The evaluation levels are generally divided into 3.5 levels, and the specific level can be described based on the evaluation content.

Step 3: Determine the weight vector of the evaluation factor

A is the weight or weight coefficient vector of the evaluation indicators, which reflects the importance. Define the fuzzy subset of the factor set as $A = \{a_i\}$, i=1,2...n, then a_i represents the weight of the i-th factor, A reflects the importance of the factors.

Specifically, the steps of AHP include clarifying the problem, establishing a hierarchical structure, constructing a judgment matrix, making a single-level ranking and its consistency test, and making a total-level ranking and its combination consistency test.

Step 4: Single factor fuzzy evaluation is carried out to establish fuzzy relation matrix R

One-factor fuzzy evaluation is called one-way evaluation to determine the subjection degree of evaluation object to evaluation set V.

After the hierarchical fuzzy subset is constructed, it is necessary to quantify the evaluated objects one by one from each factor UI, that is, to determine the membership degree of the evaluated objects to the hierarchical fuzzy subset from a single factor, and then obtain the fuzzy relation matrix, as in formula (5.3):

$$\boldsymbol{R} = \begin{pmatrix} \boldsymbol{r_{11}} & \boldsymbol{r_{12}} & \boldsymbol{\Lambda} & \boldsymbol{r_{1n}} \\ \boldsymbol{r_{21}} & \boldsymbol{r_{22}} & \boldsymbol{\Lambda} & \boldsymbol{r_{2n}} \\ \mathbf{M} & \mathbf{M} & \mathbf{O} & \mathbf{M} \\ \boldsymbol{r_{m1}} & \boldsymbol{r_{m2}} & \boldsymbol{\Lambda} & \boldsymbol{r_{mn}} \end{pmatrix} \tag{5.3}$$

In matrix R, r_{ij} represents the subordinating degree of a certain evaluated object to the hierarchical fuzzy subset v_j from the factor u_i. The performance of an evaluated object in a certain factor u_i is characterized by a fuzzy vector r_i, which is called a one-factor evaluation matrix. r_i can be regarded as a fuzzy relationship between the factor set U and the evaluation set V, that is, a reasonable relationship between the influencing factors and evaluation objects. In the matrix R, r_i=(r_{i1}, r_{i2}, …, r_{in}), after normalization, Σr_{ij}=1.

Step 5: Perform fuzzy synthesis and make a comprehensive evaluation

In the fuzzy evaluation matrix R, each row reflects the subordinating degree of the evaluated object to the evaluation level on different indicators. When making a comprehensive judgment on the evaluated object as a whole, it is needed to combine the weight vector A with the fuzzy evaluation matrix R to obtain the subset B, which is the fuzzy subset of the overall evaluation result to the comment set V. Meanwhile, B= (b_1, b_2, …, b_m), and B is also called a decision set.

The final evaluation decision set is obtained using the matrix multiplication method, that is

B=A·R. As for the decision set B, there are usually two ways to interpret the comprehensive evaluation result.

The first way is to make comprehensive evaluation according to the principle of maximum subordination. The evaluation level with the highest subordinating degree of decision set B to comment set V is selected as the final level of the evaluation object, that is, the evaluation level of the maximum value in b_1, b_2, …, b_m is taken as the overall result. The second way is to assign different values to v_1, v_2, ..., v_m in the comment set V, that is, firstly convert the comment set V into a parameter vector C, C=(c_1, c_2, …, c_m)T, and then combine with the decision set B to calculate the overall score of the evaluation object.

5.4 Maturity evaluation of GXTF company

5.4.1 GXTF company

GXTF company was registered and established in Guiyang High-tech Zone in April 2006. Focusing on the design and manufacturing of complete aircraft, the production and sales of precision parts and standard parts, GXTF company is a high-tech private enterprise with independent legal entity. Up to December 31, 2020, the company has a registered capital of 5 million yuan and a total asset of 42 million yuan. Covering an area of 10,000 square meters, the company has 80 technical experts and skilled workers and a total of more than 150 advanced processing equipment and testing equipment.

Since 2009, the company has successively passed the ISO9001 standard QMS, GJB 9001C standard QMS certification. The company has 57 patents (including 1 invention and 56 utility models) and mainly engaged in the development, production and maintenance of mobile helicopter landing pads, fasteners, and aircraft structural parts. The organizational structure of the company is shown in Appended Figure 3 (Annex).

5.4.2 Maturity level of GXTF company

10 experts from Beijing Tianyizheng Certification Center Co., Ltd. and Guizhou Quality Association were invited to evaluate the maturity of GXTF company's quality management. Evaluation experts are composed of 6 auditors engaged in national military standard certification, 2 quality experts engaged in excellent performance review, and 2 customer representatives. These experts have many years of work experience in the field of enterprise quality management, and all have the title of senior engineer.

Before the evaluation, a communication was organized among the experts. To facilitate the experts' understanding and implementation, the author introduced the construction of the QMM evaluation index of private equipment manufacturing enterprises, the maturity evaluation scale, the weight of the QMM evaluation index of private equipment manufacturing enterprises.

5.4.2.1 Determine the factor set

For the QMM evaluation index system of private equipment manufacturing enterprises, there are two sets of evaluation factor set. The first-level factor set U consists of 9 first-level indicators in the maturity evaluation system, namely U1 leadership, U2 strategic management, U3 risk management, U4 measurement, analysis and improvement, U5 resources, U6 documented information control, U7 the design and development of product and service, U8 product production and service provision, and U9 quality management. For the second-level factor set, U1 is composed of 5 secondary indicators in the maturity evaluation system, namely U11 leadership and commitment, U12 policy and target management, U13 job responsibilities and authority, U14 communication, and U15 quality culture. U2 is composed of 2 secondary indicators in the maturity evaluation system, namely U21 strategy formulation and U22 strategy deployment. U3 is composed of 3 secondary indicators in the maturity evaluation system, namely U31 risk assessment, U32 risk treatment, and U33 risk monitoring. U4 is composed of 7 secondary indicators in the maturity evaluation system, namely U41 measurement, analysis and evaluation, U42 statistical technology, U43 quality information, U44 internal audit, U45 management review, U46 corrective measures and double five points to zero, U47 Innovation management. The two-level factors can be show as:

First-level: $U = \{U_1, U_2, U_3, U_4, U_5, U_6, U_7, U_8, U_9\}$

Second-level: $U_1 = \{U_{11}, U_{12}, U_{13}, U_{14}, U_{15}\}$

$U_2 = \{U_{21}, U_{22}\}$

$U_3 = \{U_{31}, U_{32}, U_{33}\}$

$U_4 = \{U_{41}, U_{42}, U_{43}, U_{44}, U_{45}, U_{46}, U_{47}\}$

$U_5 = \{U_{51}, U_{52}, U_{53}, U_{54}, U_{55}, U_{56}\}$

$U_6 = \{U_{61}, U_{62}\}$

$U_7 = \{U_{71}, U_{72}, U_{73}, U_{74}, U_{75}, U_{76}\}$

$U_8 = \{U_{81}, U_{82}, U_{83}, U_{84}, U_{85}, U_{86}, U_{87}\}$

$U_9 = \{U_{91}, U_{92}, U_{93}\}$

5.4.2.2 Comment set and comment standard

The five levels in the maturity evaluation model are transformed into the indicator comment set to determine the range of the QMM of private equipment enterprises. According to the determined maturity evaluation model, a comment set V={V1, V2, V3, V4, V5}={initial level, repeatable level, defined level, managed level, optimized level}.

After clarifying the levels, it is necessary to determine the numerical standard of the evaluation to digitize the evaluation result and convert the comment set V into a parameter vector. Set the initial level to be 1, the repeatable level to be 2, the defined level to be 3, the management level to be 4, and the optimization level to be 5, then C=(1,2,3,4,5)T, which can be combined with the decision set B to calculate the comprehensive score of the evaluated object. Appended Table 28 is the standards for dividing the comprehensive score of maturity (W. W. Yin, 2021), that is 1≤P＜1.5 represents initial level, 1.5≤P＜2.5 represents repeatable level, 2.5≤P＜3.5 represents defined level, 3.5≤P＜4.5 represents managed level, 4.5≤P＜5 represents optimized level.

5.4.2.3 Determine the maturity level

U1 consists of 5 secondary indicators, namely U11 leadership and commitment, U12 policy and goal management, U13 job responsibility and authority, U14 communication, and U15 quality culture. For U11 leadership role and commitment, among the 10 experts, 4 experts judged as defined level (3 points), 5 experts judged as managed level (4 points), and 1 expert judged as optimized level (5 points). Therefore, the single factor evaluation set of U11 is R11=(0, 0, 4/10, 5/10, 1/10)=(0, 0, .4, .5, .1). Similarly, the single factor evaluation set of U12 is R12=(0, 2/10, 7/10, 1/10, 0)=(0, .2, .7, .1, 0); the single factor evaluation set of U13 is R13=(0, 0, 6/10, 3/10, 1/10)=(0, 0, .6, .3, .1); the single factor evaluation set of U14 is R14=(0, 1/10, 6/10, 3/10, 1/10)=(0, .1, .6, .3, .1); the single factor evaluation set of U15 is R15=(0, 1/10, 8/10, 1/10, 0)=(0, .1, .8, .1, 0). In this way, we could obtain the subordinating degree of the indicators in the “leadership” factor set in GXTF company, as shown in Appended Table 29.

On this basis, we construct the fuzzy evaluation matrix R_1 corresponding to U_1 “leadership” factor set:

$$R_1=\begin{bmatrix} R11 \\ R12 \\ R13 \\ R14 \\ R15 \end{bmatrix}=\begin{bmatrix} 0 & 0 & .4 & .5 & .1 \\ 0 & .2 & .7 & .1 & 0 \\ 0 & 0 & .6 & .3 & .1 \\ 0 & .1 & .6 & .3 & .1 \\ 0 & .1 & .8 & .1 & 0 \end{bmatrix}$$

Using the fuzzy evaluation matrix R_1 and the weight vector W_1 obtained by the analytic

hierarchy process (keep two decimal places), matrix multiplication and normalization are performed to obtain the comprehensive evaluation set B_1 of the U_1 "leadership" factor set, namely:

$$B_1=W_1 \bullet R_1=(.3463, .2105, .1210, .0755, .2466) \bullet \begin{bmatrix} 0 & 0 & .4 & .5 & .1 \\ 0 & .2 & .7 & .1 & 0 \\ 0 & 0 & .6 & .3 & .1 \\ 0 & .1 & .6 & .3 & .1 \\ 0 & .1 & .8 & .1 & 0 \end{bmatrix}$$

$B_1=(0, .0743, .6011, .2778, .0543)$

Similarly, we obtained the comprehensive evaluation set of U_2 "strategic management" factor set:

$$R_2=\begin{bmatrix} .1 & .7 & .2 & 0 & 0 \\ .1 & .8 & .1 & 0 & 0 \end{bmatrix}$$

$$B_2= W_2 \bullet R_2=(.3929, .6071) \bullet \begin{bmatrix} .1 & .7 & .2 & 0 & 0 \\ .1 & .8 & .1 & 0 & 0 \end{bmatrix}$$

$B_2=(.1, .7607, .1393, 0, 0)$

The comprehensive evaluation set of U_3 "risk management" factor set:

$$R_3=\begin{bmatrix} 0 & .4 & .5 & .1 & 0 \\ .3 & .5 & .2 & 0 & 0 \\ .5 & .3 & .2 & 0 & 0 \end{bmatrix}$$

$$B_3= W_3 \bullet R_3=(.2419, .4494, .3087) \bullet \begin{bmatrix} 0 & .4 & .5 & .1 & 0 \\ .3 & .5 & .2 & 0 & 0 \\ .5 & .3 & .2 & 0 & 0 \end{bmatrix}$$

$B_3=(.2892, .4141, .2726, .0242, 0)$

The comprehensive evaluation set of U_4 "measurement, analysis and improvement" factor set:

$$R_4=\begin{bmatrix} 0 & .1 & .7 & .1 & .1 \\ .1 & .6 & .2 & .1 & 0 \\ 0 & 0 & .5 & .4 & .1 \\ 0 & 0 & .4 & .5 & .1 \\ 0 & 0 & .7 & .2 & .1 \\ 0 & .1 & .6 & .2 & .1 \\ .1 & .3 & .5 & .1 & 0 \end{bmatrix}$$

$$B_4=W_4 \bullet R_4=(.1455, .1161, .1048, .2070, .2012, .0820, .1433) \bullet \begin{bmatrix} 0 & .1 & .7 & .1 & .1 \\ .1 & .6 & .2 & .1 & 0 \\ 0 & 0 & .5 & .4 & .1 \\ 0 & 0 & .4 & .5 & .1 \\ 0 & 0 & .7 & .2 & .1 \\ 0 & .1 & .6 & .2 & .1 \\ .1 & .3 & .5 & .1 & 0 \end{bmatrix}$$

$B_4=(.0259, .1353, .5218, .2425, .0741)$

The comprehensive evaluation set of U_5 "resources" factor set:

$$R_5=\begin{bmatrix} 0 & .1 & .6 & .2 & .1 \\ 0 & 0 & .8 & .2 & 0 \\ 0 & 0 & .8 & .2 & 0 \\ 0 & 0 & .3 & .6 & .1 \\ 0 & .1 & .6 & .2 & .1 \\ 0 & 0 & .2 & .6 & .2 \end{bmatrix}$$

$$B_5=W_5 \bullet R_5=(.2926, .1825, .0826, .0821, .1933, .1670) \bullet \begin{bmatrix} 0 & .1 & .6 & .2 & .1 \\ 0 & 0 & .8 & .2 & 0 \\ 0 & 0 & .8 & .2 & 0 \\ 0 & 0 & .3 & .6 & .1 \\ 0 & .1 & .6 & .2 & .1 \\ 0 & 0 & .2 & .6 & .2 \end{bmatrix}$$

$B_5=(0, .0486, .5617, .2997, .0902)$

The comprehensive evaluation set of U_6 “documented information control” factor set:

$$R_6=\begin{bmatrix} 0 & .1 & .5 & .4 & 0 \\ 0 & .2 & .5 & .3 & 0 \end{bmatrix}$$

$$B_6= W_6 \bullet R_6=(.5714, .4286) \bullet \begin{bmatrix} 0 & .1 & .5 & .4 & 0 \\ 0 & .2 & .5 & .3 & 0 \end{bmatrix}$$

$B_6=(0, .1429, .5, .3571, 0)$

The comprehensive evaluation set of U_7 “design and development of products and services” factor set:

$$R_7=\begin{bmatrix} 0 & .1 & .6 & .2 & .1 \\ 0 & 0 & .9 & .1 & 0 \\ 0 & .2 & .7 & .1 & 0 \\ 0 & .1 & .8 & .1 & 0 \\ 0 & .1 & .8 & .1 & 0 \\ 0 & .1 & .5 & .4 & 0 \end{bmatrix}$$

$$B_7=W_7 \bullet R_7=(.1702, .3106, .0894, .0894, .1702, .1702) \bullet \begin{bmatrix} 0 & .1 & .6 & .2 & .1 \\ 0 & 0 & .9 & .1 & 0 \\ 0 & .2 & .7 & .1 & 0 \\ 0 & .1 & .8 & .1 & 0 \\ 0 & .1 & .8 & .1 & 0 \\ 0 & .1 & .5 & .4 & 0 \end{bmatrix}$$

$B_7=(0, .0805, .7134, .1818, .0244)$

The comprehensive evaluation set of U_8 “product production and service provision” factor set:

$$R_8=\begin{bmatrix} 0 & .1 & .7 & .2 & 0 \\ 0 & .1 & .8 & .1 & 0 \\ 0 & 0 & .8 & .2 & 0 \\ 0 & .3 & .6 & .1 & 0 \\ 0 & .2 & .6 & .2 & 0 \\ 0 & .1 & .8 & .1 & 0 \\ 0 & 0 & .4 & .3 & .3 \end{bmatrix}$$

$$B_8=W_8 \bullet R_8=(.1318,.1555,.0642,.2257,.1186,.0809,.2233) \bullet \begin{bmatrix} 0 & .1 & .7 & .2 & 0 \\ 0 & .1 & .8 & .1 & 0 \\ 0 & 0 & .8 & .2 & 0 \\ 0 & .3 & .6 & .1 & 0 \\ 0 & .2 & .6 & .2 & 0 \\ 0 & .1 & .8 & .1 & 0 \\ 0 & 0 & .4 & .3 & .3 \end{bmatrix}$$

B_8=(0, .1283, .6286, .1761, .067)

The comprehensive evaluation set of U_8 "quality management result" factor set:

$$R_9=\begin{bmatrix} 0 & 0 & .5 & .4 & .1 \\ 0 & .2 & .6 & .2 & 0 \\ 0 & .2 & .5 & .2 & .1 \end{bmatrix}$$

$$B_9= W_9 \bullet R_9=(.2338, .3032, .4630) \bullet \begin{bmatrix} 0 & 0 & .5 & .4 & .1 \\ 0 & .2 & .6 & .2 & 0 \\ 0 & .2 & .5 & .2 & .1 \end{bmatrix}$$

B_9=(0, .1532, .5303, .2468, .0697)

B_1-B_9 are the first-level index evaluation set, see Appended Table 30 for details.

Fuzzy evaluation matrix R corresponding to the GXTF company's QMM factor set U is obtained:

$$R=\begin{bmatrix} B1 \\ B2 \\ B3 \\ B4 \\ B5 \\ B6 \\ B7 \\ B8 \\ B9 \end{bmatrix}=\begin{bmatrix} .0000 & .0743 & .6011 & .2778 & .0543 \\ .1000 & .7607 & .1393 & .0000 & .0000 \\ .2892 & .4141 & .2726 & .0242 & .0000 \\ .0259 & .1353 & .5218 & .2425 & .0741 \\ .0000 & .0486 & .5617 & .2997 & .0902 \\ .0000 & .1429 & .5000 & .3571 & .0000 \\ .0000 & .0805 & .7134 & .1818 & .0244 \\ .0000 & .1283 & .6286 & .1761 & .0670 \\ .0000 & .1532 & .5303 & .2468 & .0697 \end{bmatrix}$$

Combine the first-level weight to obtain the GXTF company's QMM decision set B:

B= W•R=(.0235, .1668, .5539, .2037, .0526)

According to the maximum degree of membership, the QMM level of GXTF company is judged to be at the defined level.

The comprehensive score of GXTF company's QMM is:

$$P=C^T \bullet B=(1, 2, 3, 4, 5)^T \bullet \begin{bmatrix} .0235 \\ .1668 \\ .5539 \\ .2037 \\ .0526 \end{bmatrix}=3.10$$

The first-level indicator leadership score = $B \bullet C^T$ =(0, .0743, .6011, .2778, .0543)•(1, 2, 3, 4, 5)^T=3.33

Among which, strategic management score 2.04, risk management score 2.03, measurement, analysis and improvement score 3.20, resources score 3.43, documented

information control score 3.21, product and service design and development score 3.15, product production and service provision score 3.18, quality management results score 3.23. Figure 5.1 presents the quality maturity score of the first-level indicators of GXTF company's quality management.

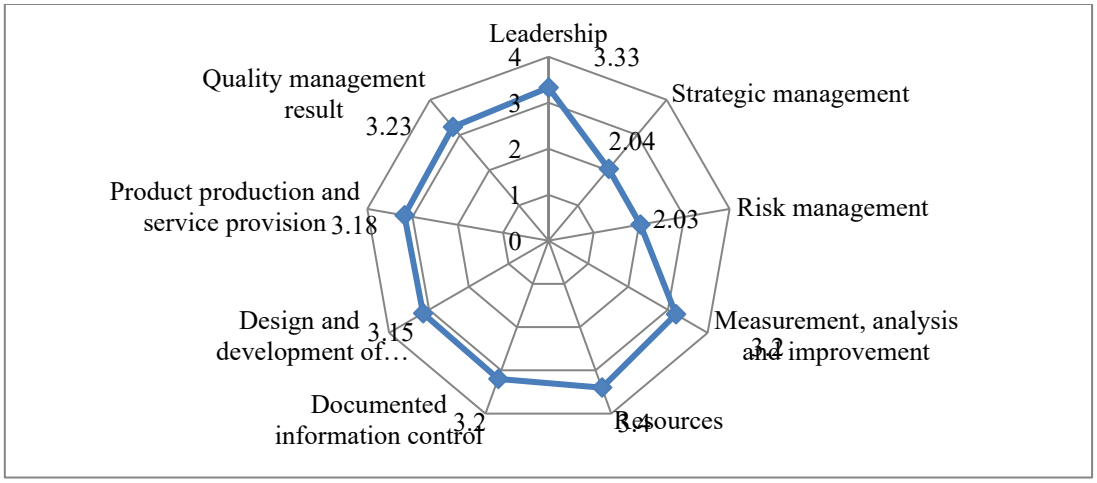


Figure 5.1 The maturity of each key process area of the first-level indicators in GXTF company's quality management

From Figure 5.1, it can be seen that strategic management and risk management are at a repeatable level, 7 items such as leadership are at the defined level.

5.5 Analysis of GXTF company's maturity evaluation results

Through the maturity evaluation by the maturity evaluation scale, we can see that the GXTF company's QMM level is at the defined level. Carrying out quality improvement requires further analysis based on the evaluation scores and weights to clarify the priority of improvement.

Based on the comprehensive consideration of the above factors and drawing upon the Kraljic matrix combination model, we attempt to construct the quality maturity evaluation and improvement positioning model from the quality maturity scores of GXTF company's process indicators and from the weight of the private equipment manufacturing enterprises' quality maturity process indicators.

(1) Improvement positioning model

The improvement positioning model helps companies determine the priority of quality management process improvement and implement targeted improvement strategies. The improvement positioning model is shown in Figure 5.2 (S. X. Zhu, 2016).

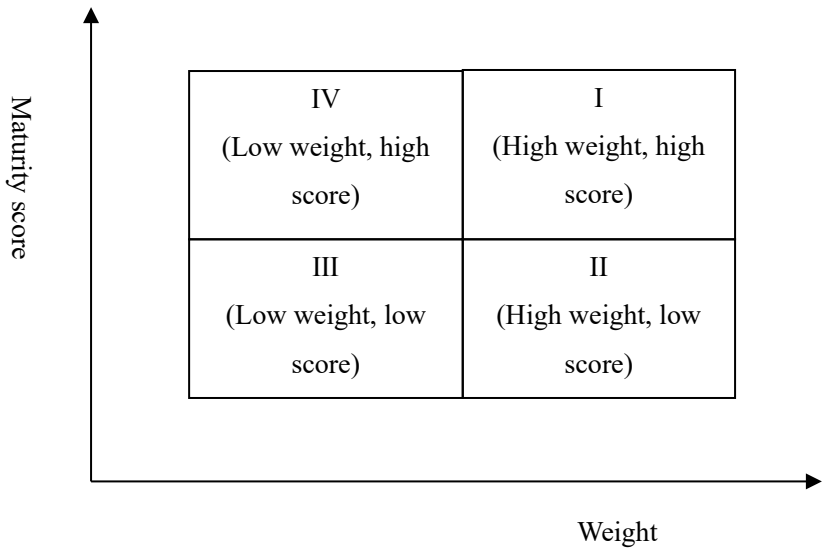


Figure 5.2 Improvement positioning model for maturity evaluation results

(2) Classification of maturity evaluation results

To classify the maturity evaluation results, a two-dimensional analysis chart is needed. The first thing of the chart is designing the coordinate scale. We calculate the average of the weights. Suppose the average to be a, then we can get the abscissa (X axis), which is the weight of the process indicator's maturity. The abscissa of quadrant III is [0, a] and the abscissa of quadrant II is (a, 1]. As for the Y-axis the quality maturity score, the ordinate of quadrant III is [0, 2.5] and the ordinate of quadrant IV is (2.5, 5].

Quadrant I (high weight, high score):

Companies whose maturity is located in this quadrant has high weight in the process indicators of the QMM, and has high score in the quality management process and result. This area is the advantages of the enterprise QMM, which need to be maintained.

Quadrant II (high weight, low score):

Companies whose maturity is located in this quadrant has high weight in the process indicators of the QMM, but has low score in the quality management process and result. This quadrant is the weakness of the enterprise QMM, which need to be focused on and improved.

Quadrant III (low weight, low score):

Companies whose maturity is located in this quadrant has low weight in the process indicators of the QMM, and has low score in the quality management process and result. This quadrant is also the weakness of the enterprise QMM, but due to the low weight, it can be a secondary improve part.

Quadrant IV (low weight, high score):

Companies whose maturity is located in this quadrant has low weight in the process

indicators of the QMM, but has high score in the quality management process and result. This quadrant is the part that need not be focused on. Instead, the company should focus on the quadrant II.

According to the fuzzy evaluation matrix and parameter vector of each key process area of GXTF company, we calculate the maturity score of each key process of GXTF company's quality management, and then analyze the quality management process, support process, and customer-oriented process.

(1) The maturity of GXTF company's management process

In the management process, strategy formulation ZL1, strategic deployment ZL2, risk processing FX2, risk monitoring FX3, and statistical technology CL2 are at the repeatable level; leadership and commitment LD1, job responsibility and authority LD3, communication LD4, and quality information CL3 are at the management level; measurement, analysis and evaluation CL1, internal audit CL4, management review CL5, corrective actions and double-five-point zeroing CL6, innovation management CL7. are all at the defined level. Appended Figure 4 (Annex) presents the maturity level of each key process indicator of the management process.

Taking the total weight coefficient of management process indicators in the entire maturity evaluation as the X axis, and taking the maturity score of management process indicators as the Y axis, the priority matrix of each key process indicator of the GXTF company's management process is drawn, as shown in Appended Figure 5 (Annex).

As shown in Appended Figure 5 (Annex), leadership role and commitment LD1 is in the quadrant I; strategy formulation ZL1, strategic deployment ZL2, risk processing FX2 are in the quadrant II; statistical technology CL2, risk monitoring FX3 are in the quadrant III; job responsibility and authority LD3, communication LD4, quality culture LD5, risk assessment FX1, measurement, analysis and evaluation CL1, quality information CL3, internal audit CL4, management review CL5, corrective measures and double-five-point zeroing CL6, innovation management CL7 in the quadrant IV.

Therefore, strategy formulation ZL1, strategic deployment ZL2, and risk management FX2 priority should be given priority to during the improvement. Meanwhile, statistical technology CL2 and risk monitoring FX3 should be in the secondary improvement list.

(2) The maturity of the GXTF company's support process

The overall maturity score of the support process is relatively high, all reaching the defined level. Among which, the process operating environment as well as the relationship between related parties have reached the managed level. Appended Figure 6 (Annex) is the maturity

level of the key process indicators.

Taking the total weight coefficient of the support process indicators in the entire maturity evaluation as the X axis, and taking the maturity score of the support process indicators as the Y axis, the priority matrix of each key process indicator of the GXTF company's support process is drawn, as shown in Appended Figure 7 (Annex).

Monitoring and measuring equipment ZY3, process operating environment ZY4, infrastructure ZY2, information and knowledge resources ZY5, related party relations ZY6, record control XX2 are in the quadrant IV; document control XX1 and human resources ZY1 are in the quadrant I.

(3) The maturity of GXTF company's customer-oriented process

The overall maturity score of the customer-oriented process is relatively high, all reaching the defined level, among which the after-sales service has reached the managed level. Appended Figure 8 (Annex) presents the maturity level of the key process indicators.

Taking the total weight coefficient of the customer-oriented process indicators in the entire maturity evaluation as the X axis, and taking the maturity score of the customer-oriented process indicators as the Y axis, the priority matrix of each key process indicator of the GXTF company's customer-oriented process is drawn, as shown in Appended Figure 9 (Annex). Identification, protection and traceability TG3, technical status management KF3, and general quality characteristics management KF4 are in the quadrant IV; product and service requirements KF1, product and service design and development process KF2, new product trial production KF5, test control KF6, externally provided process TG1, product production and service provision control TG2, key process control TG4, product and service release TG5, non-conforming product management TG6, and after-sales service TG7 are all in the quadrant I.

From the result, we can see that the weights of the process indicators in the customer-oriented process are high. GXTF company pays more attention to the customer-oriented process, so the overall control situation is relatively good and has all reached the defined level, among which the after-sales service has reached the managed level. Meanwhile, it is recommended to pay attention to the key process control TG4. Although the key process is in the quadrant I, it is the closest to the quadrant II, which should be paid attention to. If not, it may fall to the quadrant II.

(4) The maturity of GXTF company's result

The maturity of GXTF's result scores high, all reaching the defined level. The customer satisfaction result reaches the managed level, among which the maturity of customer satisfaction result JG1 maturity scores 3.6, the maturity of QMS JG2 scores 3, and the maturity

of product and service JG3 scores 3.2. The maturity score of the result is already high, so we could pay less attention to the result this time.

5.6 QMM improvement strategy for GXTF company

Through the previous analysis, it is confirmed that strategic management (strategy formulation ZL1, strategic deployment ZL2) and risk management FX2 are priority improvement items.

5.6.1 Improvement strategies for strategic management

5.6.1.1 Problems in strategy formulation

Regarding the strategy formulation, the experts have proposed four problems.

(1) The strategic management mechanism and strategic management process of the GXTF company are not clear. Moreover, the company has not clarified the requirements such as main steps, participants, and work content, which is not conducive to the orderly development of strategy formulation.

(2) GXTF companies is insufficient in strategic analysis. For example, in their "14th Five-Year Plan" industrial strategic planning, SWOT has not been used. Meanwhile, the company's analysis of key success factors in the industry has deviations, which is not conducive to the scientific formulation of the company's strategy.

(3) There are limitations in the overall development plan of the GXTF company. There is a lack of connection between the strategic goal and the vision, and strategic indicators do not support strategic positioning. For example, the supporting processing of aviation composite parts has not been determined, which is not conducive to the realization of the vision and the strategic positioning.

(4) GXTF company's strategic positioning and strategic objectives are insufficient to cope with the identified strategic challenges. For example, strategic challenges such as the unreasonable structure of the workforce identified in the "14th Five-Year" development plan have not been dealt with in the strategic positioning and overall goals of the development plan.

5.6.1.2 Problems in strategic deployment

Regarding the strategy deployment, the experts have proposed three problems.

(1) GXTF company can be further improved in the strategic deployment. The strategic planning system in the "14th Five-Year Plan" is not perfect. For example, the standard fastener industry plan only proposes the "14th Five-Year" plan, and lacks a strategic implementation

plan to achieve the goals. At present, the content of the "14th Five-Year" strategic plan has not been effectively implemented in the company's 2021 comprehensive production and operation plan. Moreover, the department's annual performance indicators are insufficient in supporting the company's strategic planning, which is not conductive to effectively support the realization of strategic goals through the strategic implementation plan.

(2) GXTF company lacks the systematic identification of the resources required to ensure the realization of strategic deployment, and fails to identify and allocate resources based on the determined strategic measures as well as the long-term and short-term plans. For example, the company has determined the seal industry plan, but there is no special allocation plan for talents related to seal manufacturing in the allocation of human resources, and no clear requirement for the configuration of related equipment and testing equipment for seal manufacturing in the basic equipment configuration. This is not conducive to ensuring the strategy through effective resource allocation.

(3) In GXTF company's strategic planning system, there is no comparison with the competitors and benchmarks in terms of the key performance prediction results.

5.6.1.3 Improving strategy

To improve the above shortcomings and deficiencies of strategic management proposed by the experts, the following strategies are proposed to the company, and the company has made targeted improvement.

(1) Enhance the organizational structure of the company's strategic planning

The company leaders attached great importance to the problems and held a special meeting instantly. In this meeting, the strategy committee of GXTF company was established, assigning the general manager as the director and other senior leaders as the team members. The committee is responsible for the overall coordination and leadership of the implementation of corporate strategy, with the comprehensive management department as a permanent institution to organize the functional departments to carry out strategy formulation. Moreover, third-party experts are hired to participate to ensure the scientific accuracy of strategy formulation, and the technical quality department is responsible for the adaptive modification of the quality manual.

(2) Sort out the strategy formulation process

The company has sorted out the strategic management process, as shown in Appended Figure 10 (Annex).

(3) Compile a three-level management system for the company's strategic management

On the one hand, the company clarified the responsibilities of each department as well as

the internal and external information collection regulations. On the other hand, the company conducted the macro-environment analysis (PEST analysis) and industry environment analysis (five forces model analysis), and used SWOT analysis to form and determine the strategic plans.

(4) Re-formulate the "14th Five-Year Plan" strategy

The strategy committee of GXTF company organized a strategy seminar. During this seminar, in response to the problems in strategic management, the "14th Five-Year Plan" strategy was re-formulated combined with the company's vision and mission.

(5) Resource allocation

From the human resources, financial resources and material resources, through functional strategic planning and annual work task plan, the company established a complete talent recruitment and training mechanism to ensure the effective resource allocation and usage, and achieve the matching of strategic goals and resources.

(6) Assessment and evaluation

The company has established key strategic target indicators, clarified the monitor before management review, evaluate the implement effect of the strategy planning, formulated the improvement measures for uncompleted indicators, identified innovation opportunities, and implemented improvements. Each functional department regularly measures and analyzes the implementation of the strategic plan, and puts forward suggestions for improvement and adjustment. After making a summary, the comprehensive management department puts forward suggestions for adjusting the strategic plan, goals, and long-term and short-term plans, which are then submitted to the strategic management committee for approval. When approved by the general manager, the strategic plan could be implemented.

In the management review input report, the comparisons of the key performance prediction results between the competitors and benchmarks are clarified.

5.6.2 Improvement strategies for risk management

5.6.2.1 Problems in the risk treatment

(1) GXTF company's risk treatment mechanism and process are unclear. Moreover, requirements such as the main steps, participants, and work content are not clarified, which is not conducive to the orderly development of risk treatment.

(2) The designers of GXTF company did not strictly follow the requirements of failure mode, impact and hazard analysis guidelines to carry out FMECA analysis, which led to the failure of effective decomposition of the risk measure plan and the closed-loop management of

risk treatment.

(3) The process personnel of GXTF company failed to effectively carry out PFMEA work, which is not conducive to the development of risk treatment.

Risk-based thinking is the core concept of the 2015 QMS (A. L. Zhang, 2020). Risk management is helpful for organizing activities that encourage improvement and help improve performance (Jin & Xu, 2021).

5.6.2.2 Improving strategy

(1) Implement management departments and clarify management responsibilities

Clarify the technical quality department as the department responsible for risk management (Jin & Xu, 2021).

The department responsibilities of the technical quality department include: responsible for advancing comprehensive risk management, deciding the major issues of risk management, and coordinating and solving major problems in the process of comprehensive risk management; responsible for the internal and external environments as well as the needs of related parties; responsible for the identification, analysis, response, review, monitoring, evaluation, transmission, and record-keeping of the risks.

The relevant functional departments are responsible for the internal and external environments of each department, the needs of related parties, and the identification, analysis, response, review, monitoring, evaluation, transmission, and record-keeping of the risks.

The designer and technologist are systematically responsible for the risk management of the product realization process.

(2) Sort out the risk treatment steps

Based on the risk assessment report, the technical quality department organizes the relevant departments to formulate corresponding plans and measures for the research project risks. Risk treatment is mainly to control risks within an acceptable range by selecting and implementing appropriate risk response measures. Generally, risk treatment includes the following four steps:

Step 1: Choose risk treatment measures

Risk treatment measures are divided into: risk aversion, risk taking, eliminating risk sources, changing the possibility or consequences of risks, sharing risks, and retaining risks.

Step 2: Develop a risk treatment plan

Step 3: Implement the approved risk treatment measures or plans

Follow up and inspect the implementation of risk treatment measures based on the risk management plan, risk assessment report, and risk treatment measure plan. When there is a

problem with the implementation of the measures, the risk management plan and risk treatment measure plan should be adjusted in time.

Step 4: Record the risk treatment process and result

The main inputs and outputs of risk treatment are shown in Appended Table 31.

(3) Personnel training

Conduct risk management knowledge training. After the training, the comprehensive management department will issue an anonymous training evaluation form to the trainees to evaluate the training content, training process and training lecturers and put forward reasonable suggestions in a timely manner (A. L. Zhang, 2020). Cultivate and retain talents to come up with scientific and effective measures when responding to risk management. Do well in DFMEA, PFMEA, and enhance the company's risk management capabilities (Hao, 2018).

Step 4: Carry out risk management work around specific R&D projects

The risk management of equipment development projects needs to start from two aspects: system management and risk management. The system management obtain management element improvement plans through system comparison and analysis, which could effectively improve its quality risk management level and reduce the quality risk of the enterprises.

The risk management conducts quality risk control through identifying, evaluating, disposing, monitoring and early warning of the specific quality risk points of the equipment development projects, which could guarantee the implementation of the projects (Y. Zhi, 2017).

5.7 Chapter summary

This chapter has developed a mature scale suitable for the quality management evaluation of private equipment manufacturing enterprises. To ensure the scale feasibility, two rounds of expert discussions were organized, and then the scale was revised referring to the experts' suggestions. Using AHP, the thesis constructed the weight coefficients of the maturity evaluation indicators and used the fuzzy comprehensive analysis to evaluate the maturity of GXTF company. Through evaluation, the weak links as well as the priority improvement items and the secondary improvement items of GXTF company's quality management were identified. Regarding the priority improvement items, the targeted measures were implemented to lay a foundation for improving the QMM of private equipment manufacturing enterprises.

Chapter 6: Conclusions

6.1 Research conclusions

In this thesis, the domestic and foreign theories, elements and methods of QMM are reviewed. By analyzing the text materials of Dadongfeng, Senhe Elevator, and MFC, three private equipment manufacturing companies at home and abroad, the thesis extracted the basic elements of the quality management of private equipment manufacturing enterprises. Basing on the analysis results, the QMM evaluation model and the indicator system of private equipment manufacturing enterprises were constructed. The QMM evaluation model of private equipment manufacturing enterprises are composed of four subsystems: management process, support process, customer-oriented process, and result. Each subsystem contains a series of key process areas and key processes. The management process includes four key process areas: leadership, strategic management, risk management, measurement, analysis, and improvement, which further includes 18 key processes. The support process includes two key process areas: resource management and documented information control process, which further includes 8 key processes. Customer-oriented process includes two key process areas: design and development of product and service, provision of product and service, which further includes 13 key processes. Result includes one key process area: quality management result, which further includes 3 key processes.

Adopting statistical software such as SPSS22.0 and Mplus8.0, the thesis firstly conducted the model verification and hypothesis testing, and then explored the relationship between the elements in the maturity model. The analysis methods of this thesis mainly include: statistical description, reliability analysis, validity analysis, and SEM. Obtaining a good result of the preliminary investigation, the thesis conducted a formal investigation. Using the data collected in the formal survey, the thesis used SPSS22.0 for the statistical description, and then used Mplus8.0 for the CFA on the four sub-systems of quality management to test the structural fit.

Based on the QMM of private equipment manufacturing enterprises, the thesis proposed the research model and research hypotheses. The path analysis research results show that: Leadership positively affects resource management; measurement, analysis and improvement positively affects resource management; measurement, analysis and improvement positively affects the documented information control process; measurement, analysis and improvement positively affects the design and development of product and service; measurement, analysis

and improvement positively affects the provision of product and service; leadership positively affects quality management result; resource management positively affects the design and development of product and service; documented information control process positively affects the design and development of product and service; resource management positively affects the provision of product and service; resource management positively affects quality management result; the provision of product and service positively affects quality management result; the provision of product and service mediates the positive impact of risk management on quality management result.

The thesis developed a scale suitable for the quality management evaluation of private equipment manufacturing enterprises. In order to ensure the feasibility of the scale, two rounds of expert discussion were organized to revise the scale. Using the AHP method, the thesis constructed the weight coefficients of the maturity evaluation indicators and used the fuzzy comprehensive analysis method to evaluate the maturity of GXTF company. Through the evaluation, the weak links as well as the priority improvement items and the secondary improvement items of GXTF company's quality management were identified. Regarding the priority improvement items, the targeted measures were implemented to lay a foundation for improving the QMM of private equipment manufacturing enterprises.

6.2 Research innovations

For the first innovation, the research develops a maturity evaluation questionnaire and a QMM evaluation scale based on the QMM evaluation model. The questionnaire and the scale provide a framework for the evaluation, diagnosis, and QM improvement, which is conducive to improving the quality of the private equipment manufacturing enterprises. Meanwhile, the research also provides an upgraded version of the GJB9001C QMS for the certification institution, which could provide enterprises with value-added services, improve the enterprise's QM level, and enhance the enterprise's core competitiveness.

For the second innovation, the research explores the path relationships between the QMM of private equipment manufacturing enterprises, and clarifies the role of different processes in the enterprise QMS. Using the result model and hypothesis testing, the research initially realized the QM research of private equipment manufacturing enterprises from the appearance explanation to the mechanism analysis, which provides a reference for improving the QM level.

6.3 Research prospects

The thesis explores the basic elements in the QM of private equipment manufacturing enterprises. However, the scale and development of different enterprises would lead to different QM status. Therefore, in the future research, the corresponding evaluation factors such as brand management and benchmarking should be introduced according to the actual QM status of the private enterprise, which could make the QMM evaluation model correspond more to the specific practices of different private enterprises (Y. Li, 2014).

When conducting case studies on the evaluation model and evaluation method, the thesis mainly adopts the AHP yaahp software to establish hierarchical structure models. To better apply and promote the thesis, in the future research, a software system integrating evaluation, diagnosis, and decision-making analysis could be adopted to make the QMM evaluation more convenient.

Due to the limited resources and energies, the evaluation results of the QMM of private manufacturing enterprises could be more or less affected by the experts' personal experiences and cognition. Therefore, in the future research, the research conclusion should be further explored and optimized (L. Yang, 2018).

6.4 Chapter summary

This chapter is a summary and prospect of the thesis. In this chapter, the research work of this thesis is firstly summarized. Then, the research conclusions and the innovations of the thesis are summarized. After that, the prospects of the maturity evaluation of private equipment manufacturing enterprises are proposed. Lastly, this chapter puts forward research problems to be focused on and paid attention to.

[This page is deliberately left blank.]

Bibliography

Andrew, J. H., Lynne, H. J., & Jeff, D. B. (2010). Using QSR-NVivo to facilitate the development of a grounded theory project: an account of a worked example. *International Journal of Social Research Methodology*, *4*(13), 283-302.

Anselm, S., & Juliet, C. (2006). Basics of qualitative research: grounded theory procedures and techniques. *Modern Language Journal*, *2*(77), 267-268.

Aydin, S., Kahraman, C., & Kaya, H. (2011). A new fuzzy multicriteria decision making approach: An application for European quality award assessment. *Knowledge-Based Systems*, *32*(8), 37-46.

Azeem, M., & Salfi, N. A. (2012). Usage of Nvivo software for qualitative data analysis. *Academic Research International*, *1*, 262-266.

Bao, Y. H. (2016). *Research on management maturity evaluation and improvement opportunities of knowledge-based SMEs* [Master's thesis], Beijing Jiaotong University.

Bazeley, P., & Jackson, K. (2013). *Qualitative data analysis with Nvivo*. Sage publications.

Bi, P. X., Liu, Z., Guo, J., & Wei, J. X. (2019). 卓越绩效模式过程与结果评价要素 [Process and result evaluation elements of excellent performance model]. *Standardization Science*, (05), 136-139.

Bohoris, G. A. (2013). A comparative assessment of some major quality awards. *International Journal of Quality & Reliability Management*, *12*(9), 30-43.

Boulter, L., Bendell, T., & Dahlgaard, J. (2013). Total quality beyond north America a comparative analysis of the performance of European excellence award winners. *International Journal of Operations & Production Management*, *1*(33), 197-215.

Carley, K. M. (1997). *Network text analysis: the network position of concepts*. Sage Publications.

Chen, C. (2020). 风电制造企业质量管理成熟度评价研究及应用 [Research and application of quality management effectiveness evaluation for wind power manufacturing enterprises]. *Euquipment Manufacturing Technology*, (11), 171-174.

Chen, K. D. (2019). 卓越绩效模式在企业管理中的应用研究—以TS公司为例 [Research on the application of excellent performance model in enterprise management——Taking TS company as an example]. *China Economic & Trade Herald*, (07), 74-76.

Chen, Q. H. (2006). *Research on the relationship between total quality management and performance* [Master's thesis], Nanjing University of Aeronutics and Astronautics.

Chen, Y. (2019). *The application research of six sigma in S700C wireless communication module embedded software project quality management* [Master's thesis], Donghua University.

Chikati, R., & Mpofu, N. (2014). IJSTR-1113-7725 combining TQM, SQM and TOE to attain educational excellence. *International Journal of Scientific & Technology Research*, *11*(2), 223-227.

Crabtree, B. F., & Miller, W. F. (1992). A template approach to text analysis: developing and using codebooks. *Doing Qualitative Research*, *1*, 93-109.

Crawford, J. K. (2006). The project management maturity model. *Journal of Information Systems Management*, *23*, 50-58.

Crosby, P. B. (1980). *Quality is free: the art of marketing quality certain*. McGraw-Hill Book Company.

Crosby, P. B. (2006). *Quality free*. China Renmin University Press.
De Cerio, M. J. (2003). Quality management practices and operational performance: Empirical evidence for Spanish industry. *International Journal of Production Research*, *12*(41), 2763-2786.
Derming, W. E. (2003). *Deming on quality management: a new perspective on solving the problems of organizations and enterprises*. Hainan Press.
Díaz, J. A., Martínez-Mediano, C., & Chatterji, M. (2018). The impact of ISO quality management systems on primary and secondary schools in Spain. *Quality Assurance in Education*, *1*(26), 2-24.
Dror, S. (2008). The balanced scorecard versus quality award models as strategic frameworks. *Total Quality Management & Business Excellence*, *6*(19), 583-593.
Duan, Y. G. (2018). *Research on enterprise's strategic quality cost management* [Doctoral dissertation], Capital University of Economics and Business.
Engle, P. (2012). The maturity model. *Industrial Engineer*, *12*(44), 22.
GB. (1995). GB/T 19001-1994/IS09000: 1994 Quality systems-model for quality assurance in design, development, production, installation and servicing.
GB. (2008). GB/T19000-2016/IS09000: 2015 Quality management systems— Fundamentals and vocabulary.
GB. (2012). GB/Z 19579-2012 Guidelines for the implementation of excellent performance evaluation criteria (20-22).
GB. (2016). GB/T 19001-2016/IS09001: 2015 Quality management system-Requirements (7-8).
Geoffrey, M., Kituyi, C., & Amulen. (2012). A software capability maturity adoption model for small and medium enterprises in developing countries. *The Electronic Journal of Information Systems in Developing Countries*, *1*(55), 1-19.
GJB. (2006). GJB1405A: 2006 Terms for equipment quality management.
GJB. (2009). GJB9001B-2009 Quality management system requirement (29-30).
Gochermann, J., & Nee, I. (2019). The idea maturity model - a dynamic approach to evaluate idea maturity. *International Journal of Innovation and Technology Management*, *5*(16), 1-13.
Godfrey, A. B., & Juran, J. M. (1999). *Juran's quality handbook*. McGraw-Hill.
Gong, X. M. (2016). *Criteria for quality management maturity based on GB/T 19001*. China Quality Association.
Gryna. (2007). *Juran's quality planning and analysis*. McGraw-Hill.
Guo, J. (2017). *The influence of traditional media staff's turnover on the attraction of traditional media talents* [Master's thesis], Southwest University of Finance and Economics.
Guo, X. S. (2016). *Research on the impact of quality management practices of construction enterprises on project quality performance* [Master's thesis], Chongqing University.
Han, J., Li, H. R., Shen, Q. Y., & Hu, D. L. (2020). 机械加工企业关键过程的识别 [Identification of key processes of machining enterprises]. *China Quality*, *7*(3), 21.
Han, S. W. (2018). *Research on the evaluation and improvement of excellent performance and lean management in company A* [Master's thesis], North University of China.
Hao, G. Y. (2018). *Research on the project quality risk management index system of company X* [Doctoral dissertation], Beijing University of Chemical Technology.
He, B. Y. (2020). *Key technologies of the visual inspection and identification of chassis assembly basic units* [Master's thesis], South China University of Technology.
He, J. J., & Zhang, X. M. (2020). 关于卓越绩效管理促进企业高质量发展的思考 [Thoughts on how excellent performance management promotes enterprise's high-quality development]. *China Market*, (28), 77-78.
He, Z. C., Pan, H. Y., & Xun, G. (2013). 高端装备制造企业发展模式变革趋势研究

[Research on the development of high-end equipment manufacturing enterprises]. *Management World*, *000*(010), 178-179.

He, Z., & Zhao, Y. Z. (2008). 全面质量管理中的关键影响因素分析 [The analysis on the key influence factor of total quality management]. *Statistics and Decisions*, (12), 164-166.

Helmer, D. O. (1963). An experimental application of the delphi method to the use of experts. *Management Science*, *3*(9), 458-467.

Hu, Y. F. (2020). *Research on performance management of middle managers in the headquater of group H* [Master's thesis], Hunan Normal University.

Huang, B. (2018). *Research on quality management evaluation of company H* [Master's thesis], Hebei GEO University.

Huang, W. J., Du, L., & Li, G. J. (2011). *The comparison and analysis of project management maturity models*. The 10th China Project Management Conference, Xi'an.

Huo, X. (2020). 认证认可制度体系与发展模式研究 ——基于"一带一路"沿线国家的分析 [A study on certification and accreditation system and development model——an analysis based on the countries along the Belt and Road]. *Technoeconomics & Management Research*, (2), 94-100.

Hutchins, A. J., & Anderson, C. K. (2020). *Quality management system*. 2020 International Conference on Quality Management, Transport and Information Security, Information Technologies, US.

ISO. (2018). Quality management-quality of an organization-guidance to achieve sustained success.

James, R. E. (2011). *Quality management and quality control*. Machinery Industry Press.

Ji, X. H., Zhang, Z. L., & Zhou, H. M. (2018). 质量管理成熟度模型中创新指标的探索与优化 [Exploration and optimization of innovation indexes in the quality management maturity model]. *China Business & Trade*, (20), 167-170.

Jia, C. F. (2006). 军工项目组织质量管理体系自我评价 [The self-assessment of military project organization's quality management system]. *Project Management Technology*, (1), 276-279.

Jin, Z. L., & Xu, W. J. (2021). GJB 9001C-2017--风险管理实践 [GJB 9001C-2017-risk management practice]. *Electronics Quality*, (03), 43-45.

Jing, P. F. (2021). 浅谈制造企业内部质量管理体系审核 [The audit of internal quality management system in manufacturing enterprises]. *Auto Times*, (2), 59-60.

Joseph, A. D. F., & Frank, M. G. (2017). *Juran's quality management and analysis*. China Machine Press.

Juran, J. M. (1995). The upcoming century of quality. *Electronics Quality*, *2*, 12-14.

Keith, B., Vitasek, K., Manrodt, K., & Kling, J. (2016). *Maturity meets modality*. Palgrave Macmillan US.

Kuckartz, & Udo. (2014). *Qualitative text analysis: a guide to methods, practice and using software*. Sage publications.

Lee, V., & Ooi, K. (2015). Applying the Malcolm Baldrige national quality award criteria: an approach to strengthen organizational memory and process innovation. *Total Quality Management & Business Excellence*, *11*, 1373-1386.

Li, J., Fok, W., Fok, L., & Hartman, S. (2002). The impact of QM maturity upon the extent and effectiveness of customer relationship management systems. *Supply chain management*, *7*(4), 212-224.

Li, L. F. (2013). *Research on the evaluation model of quality management maturity*. The 10th China Standardization Forum, Anhui.

Li, L. (2009). *Establishment and evaluation of quality management maturity model of manufacturing enterprises* [Master's thesis], Hubei University of Technology.

Li, T. C., Hou, J. H., & Hou, J. H. (2014). 航天研究院质量管理体系成熟度评价创新管理 [The evaluation and innovation of the quality management maturity system of the aerospace research institute and its practice]. *China Quality*, (10), 121-122.

Li, Y. B. (2007). 一种新的质量体系评价模式 [A new quality system evaluation model]. *World Standardization and Quality Management*, *3*(3), 35-37.

Li, Y. (2014). *An empirical study on the enterprise quality management maturity in China* [Doctoral dissertation], Xi'an University of Science and Technology.

Liao, B. F. (2018). 卓越绩效模式在核电企业的推进实践 [The practice of excellent performance model in nuclear power enterprises]. *Economic Management Forum*, (12), 267-268.

Liu, H. P., & Liu, W. Z. (2021). 企业全面质量管理思考 [Enterprise's total quality management]. *Co-operative Economy & Science*, (2), 94-95.

Liu, J. T., Chen, Z. Y., & Song, L. Y. (2019). 高职院校质量保证体系构建探讨——基于卓越绩效管理模式 [The construction of quality assurance system in higher vocational colleges — — based on excellent performance management model]. *Contemporary Educational Practice and Teaching Research*, (21), 33.

Liu, S. M., & Li, Z. W. (2017). *Nvivo的应用——质性研究之必备工具 [The application of NVIVO 10——an essential tool for qualitative research]*. Economics Daily Press.

Liu, Y. J., Liu, Y., & Guo, N. (2018). *Application of national standards in excellent performance evaluation criteria*. 15th China Standardization Forum, Zhejiang.

Long, Y., & Li, J. F. (2002). 国外质量管理实证研究及其对我国企业的借鉴意义 [Foreign empirical study on quality management and its reference to Chinese enterprises]. *Industrial Technology Economics*, (6), 69-72.

Lu, L. F. (2020). 深化卓越绩效模式推进高质量发展 [Deepen the excellent performance model and promote high quality development]. *Caixun*, (6), 171-172.

Lu, S. D. (2016). *Research on railway construction system quality performance path model and its application based on BN method* [Doctoral dissertation], Southwest Jiaotong University.

Ma, Y. L. (2017). *Research on the evaluation of quality management maturity of building engineering* [Doctoral dissertation], Chongqing Jiaotong University.

Ma, Z. D., Wang, X. L., & Liang, S. G. (2018). 基于质量文化和品牌的质量管理成熟度模型构建与实证分析——以聊城市企业为例 [Construction and empirical analysis of quality management maturity model based on quality culture and brand: taking Liaocheng city] as an example. *Journal of Liaocheng University (Social Science Edition)*, (3), 114-120.

Mark, B., & Duncan, N. (2011). Did a cowboy rodeo champion create the best theory of quality improvement? Malcolm baldrige and his award. *BMJ Quality & Safety*, *5*(20), 465.

Mohit, I., S., Khan, A., & Grover, S. (2012). Development and comparison of quality award: based on existing quality awards. *International Journal of System Assurance Engineering and Management*, *3*(3), 209-220.

Patti, A. L., Hartman, S. J., & Fok, L. Y. (2001). Investigating organizational quality management maturity: an instrument validation study. *The International Journal of Quality & Reliability Management*, *18*(9), 882-899.

Paulk, M. C. (1994). The capability maturity model for software. *Ieee Software*, *2*(515), 55-56.

Peng, P. (2009). 中小企业质量管理中常见的问题 [Common problems in quality management of SMEs]. *Management and Technology of SMEs*, (13), 2.

Popping, R. (2000). *Computer-assisted text analysis*. Sage Publications.

Qi, M. (2021). 基于层次分析法的员工绩效考核研究 [Research on employee performance appraisal based on analytic hierarchy process]. *Co-operative Economy & Science*, (2), 108-

110.
Qi, W. M. (2012). *卓越绩效评价准则实务 [Practice of performance excellence evaluation criteria]*. China Standard Press.
Qin, Q., & Zhao, Y. B. (2017). 高校教育质量管理成熟度模型研究 [Research on capability maturity model of higher education quality management]. *Higher Education of Sciences*, (2), 10-18.
Raber, D., Winter, R., & Wortmann, F. (2012). *Using quantitative analyses to construct a capability maturity model for business intelligence*. 45th Hawaii International Conference, Hawaii.
Roberts, W. C. (2015). *Text analysis*. Blackwell Publishers.
Saaty, T. L. (1994). How to make a decision: the analytic hierarchy process. *Journal of Operational Research*, *1*(48), 9-26.
Schwarz, G. E. (1978). Estimating the dimension of a model. *The Annals of Statistics*, *6*(2), 461-464.
Shapiro, G. (1997). *Text analysis for the social sciences: methods for drawing statistical inferences from texts and transcripts*. Lawrence Erlbaum Associates.
Shen, Y. J. (2005). 什么是质量 [What is quality?]. *Quality Management*, (8), 16-18.
Shewfelt, R. L. (2014). *Measuring quality and maturity*. Postharvest Handling.
Shi, C. X. (2019). *质量管理导论 [Introduction to quality management]*. Machinery Industry Press.
Shi, J. (2019). 探讨企业全面质量管理体系构建 [Construction of enterprise's total quality management system]. *Low Carbon World*, *9*(11), 288-289.
Shida, Y., & Anada, H. (2011). *Empirical analysis of the influence of informatization on China's equipment manufacturing industry*. International Conference on Product Innovation Management, Wuhan.
Smith, J. (2011). The lasting legacy of the modern quality giants. *Quality*, *10*(50), 40-42.
Song, X. Y. (2012). *Research and practice of quality maturity model——Taking steel group J's product quality formation process as an example* [Master's thesis], Shandong University.
Strauss, A. L., & Corbin, J. M. (2014). Basics of qualitative research: techniques and procedures for developing grounded theory. *Canadian Journal of University Continuing Education*, *2*(36), 129.
Su, C. D. (2004). 专访世界质量大师田口玄一博士 [Interview world quality master Dr. Genichi Taguchi]. *Quality Quaterly*, *14*(3), 30-32.
Su, J. S. (2018). *The optimization plan of A gas company's total quality management system* [Master's thesis], Guangxi Normal University.
Su, Q., Song, Y. T., & Liu, W. Y. (2010). 中国企业质量管理成熟度研究 [Research on the quality management maturity of Chinese enterprises]. *Science of Science and Management of S.&.T.*, *9*(31), 172-177.
Su, W. J. (2006). Research on the development of quality management practice and theory. *Journal of North China Institute of Aerospace Engineering*, *6*, 25-29.
Su, Y. N. (2008). *Research on the quality management model* [Master's thesis], Beijing Industry University.
Suhardi, I., Gunawan, & Dewi, A. Y. (2015). *Total information quality management-capability maturity model: an information quality management maturity model*. 2014 International Conference on Data and Software Engineering, Bandung.
Sun, X. D., Song, W. B., Zong, Y., & Wang, L. (2018). PDCA循环在微电子器件设计实践课程中的应用 [The application of PDCA cycle in the practice of microelectronic device design]. *Electronic World*, *16*(550), 90-92.
Sun, Y. G., & Pang, W. J. (2014). 质量管理 [Quality management]. *Product and Quality*, (8),

315.
Suzuki, K., Tashiro, H., & Fujii, N. U. (2011). *TQM organizational development for a global manufacturer*. IEEE, Singapore.
Thandapani, D., Gopalakrishnan, K., Devadasan, S. R., Sreenivasa, C. G., & Murugesh, R. (2012). Quality models in industrial and engineering educational scenarios: a view from literature. *TQM Journal*, *24*(2), 155-166.
Tiku, S., Azarian, M., & Pecht, M. (2013). Using a reliability capability maturity model to benchmark electronics companies. *International Journal of Quality & Reliability Management*, *5*(24), 547-563.
Wang, A. H. (2011). 六西格玛管理与质量管理体系整合探讨 [Discussion on the integration of Six Sigma management and quality management system]. *Shanghai Quality*, (11), 62-65.
Wang, H. Q., & Wang, Y. W. (2009). 基于成熟度模型的建筑供应链绩效评价 [Performance evaluation of construction supply chain based on maturity model]. *Journal of Shenyang Jianzhu University (Natural Science)*, *25*(2), 5.
Wang, P. L. (2014). *Research on quality control strategy of engine assembly process* [Master's thesis], Heifei University of Technology.
Wang, R., Dong, M., & Hou, W. H. (2019). 制造型企业数字化成熟度评价模型及方法研究 [Research on evaluation model and method of digital maturity of manufacturing enterprises]. *Science and Technology Management Research*, *39*(19), 57-64.
Wang, W. C. (2017). *The relationship between quality management practice and performance in manufacturing industry in China* [Doctoral dissertation], Tianjin University.
Wang, W. R. (2020). 六家组织荣获波多里奇卓越绩效质量奖 [Six organizations won the Malcom Baldrige excellence performance award]. *Chinese Health Quality Management*, *27*(2), 135-136.
Wang, W. S. (2020). *The construction of GJB9001C quality management system in ASD company* [Master's thesis], University of Electronic Science and Technology of China.
Wang, X. D. (2020). *Research on the training mode of reserve managerial talents in WG company* [Master's thesis], Jilin University.
Wang, Y. (2019). 改革开放40周年:中国民营装备制造业的发展 [Reform and opening-up: development of China's private equipment manufacturing industry]. *Modern Science Instruments*, (1), 195-197.
Wang, Z. Y., & Sun, J. (2005). 质量管理三巨头——戴明、克劳士比、朱兰——写在朱兰大师诞辰百岁之际 [The three quality management giants-Deming, Crosby, and Juran-written on the 100th birthday of Juran]. *China Quality*, (03), 38-40.
Wattanasap, S., & Shawyun, T. (2019). Accreditation: through the lens of assessors. *Journal of Institutional Research South East Asia*, *17*(1), 159-189.
Weng, S. Z. (2019). 民营企业质量管理问题、原因及高质量发展对策 [The causes and countermeasures of private enterprise quality management problems]. *Journal of Anhui Administration Institution*, (4), 59-64.
Werner, W. (1992). From quality inspection to quality assurance. *Fresenius Journal of Analytical Chemistry*, *10*(342), 783-786.
Wu, A. L. (2018). *The research on the quality management system of MJ automobile repair chains* [Master's thesis], Jilin University.
Wu, J. H. (2017). *Evaluation and control of enterprise land in Beijing and Tianjin* [Master's thesis], China University of Geosciences.
Wu, J. L. (2018). *The application of excellent performance model in GR company* [Master's thesis], Huazhong University of Science and Technology.
Wu, Y. (2010). *The evaluation and application of enterprise QHSE management performance*

maturity [Doctoral dissertation], Tianjin University.
Wuxi Quality and Technical Supervision Bureau. (2018). *DB3202/T 1002-2018 evaluation criteria for quality management maturity*. China Quality Association.
Xiao, B. (2019). 企业全面质量管理体系构建 [Construction of enterprise's total management system], (5), 76-77.
Yang, H. B. (2019). *The application of six sigma management method in quality management of HC company* [Master's thesis], Zhejiang University of Technology.
Yang, L. (2018). *Research on the maturity of petroleum engineering project management* [Doctoral dissertation], Southwest Petroleum University.
Yang, M. F. (2012). *航天企业质量管理成熟度模型 [Quality management maturity model of aerospace enterprise]*. China Astronautic Publishing House.
Yang, Q. Y. (2010). *Research on the maturity of aerospace quality management* [Master's thesis], Institute of Aerospace Science and Industry Group.
Yang, Q. Y., & Fu, Z. M. (2011). 质量管理成熟度模型评价 [Evaluation of quality management maturity model]. *Project Managemetn Technology*, *9*(3), 34-38.
Yang, W. S. (1996). *质量管理学 [Quality management]*. Wuhuan University Press.
Yang, Y. H., & Song, M. S. (2019). Total innovation quality management: an integrated conceptual framework. *Science and Technology Management Research*, *39*(10), 243-247.
Yin, R. K. (2010). *Case study research: Design and methods*. John Wiley & Sons, Ltd.
Yin, W. W. (2021). *The evaluation of Y chemical company's technological innovation ability* [Doctoral dissertation], Hebei GEO University.
Yoshinori, L. (2005). New model of quality management system-sustainable development. *China Quality*, *1*, 35-37.
Yoshinori, L. (2016). *Successful quality management: quality management practice of Yoshinori Iizuka*. China Standard Press.
Yu, J. N., Kong, X. Q., Deng, F., & Fan, Z. (2016). 基于CMM的企业数据分析能力评估模型构建 [Evaluation model construction of enterprise data analysis based on CMM]. *Fujian Computer*, *32*(8), 3-4.
Zadeh, L. A. (1965). Fuzzy sets. *Information & Control*, *3*(8), 338-353.
Zamawe, F. C. (2015). The implication of using NVivo software in qualitative data analysis: evidence-based reflections. *Malawi Medical Journal the Journal of Medical Association of Malawi*, *27*(1), 13-15.
Zhang, A. L. (2020). *Research on optimization for quality management service system of VC company* [Doctoral dissertation], Shenyang University.
Zhang, C. F. (2014). *Research on R&D quality management of car chassis system of GA company* [Master's thesis], South China University of Technology.
Zhang, G. X., & Sun, J. (2002). 加入WTO后企业的质量管理怎么办? [Where should China quality management go after joining WTO?]. *China Quality*, (1), 7-9.
Zhang, Q. R. (2009). *Research on the application of excellent performance model in State-owned military enterprises* [Master's thesis], University of International Business and Economics.
Zhang, T. (2020). *Study on school-enterprise talent collaborative training platform project maturity evaluation and improvement research on C association* [Master's thesis], University of Electronic Science and Technology of China.
Zhang, Y. (2020). 高端装备制造业研究报告 [Research report on high-end equipment manufacturing industry]. *Shanxi Finance*, *1*(265), 37.
Zhang, Y., & Liao, O. (2015). 质量成熟度模型在化工生产行业的实证研究 [An empirical study of quality maturity model in chemical production industry]. *Sichuan Chemical Industry*, *18*(02), 54-57.

Zhang, Z. L. (2013). *The application of quality management maturity evaluation SMEs* [Master's thesis], Sanxia University.

Zhao, C. X. (2021). 全面质量管理在中小企业中的应用 [Application of TQM in SMEs]. *China Circulation Economy*, (1), 45-47.

Zhao, H. H. (2012). *The Influence of total quality management on enterprise performance* [Master's thesis], Xi'an University of Science and Technology.

Zhi, L. J. (2019). 一文读懂我国认证认可检验检测发展历程 [The development of China's certification, accreditation, inspection and testing]. *China Fiber Inspection*, (05), 43-45.

Zhi, Y. (2017). *Research on quality risk management of equipment development based on QMM* [Doctoral dissertation], Jiangsu University.

Zhong, S. (2011). *Research on the symbiosis development of producer service industry and equipment manufacturing industry in Chongqing* [Master's thesis], Chongqing University of Technology.

Zhou, Y. (2021). 基于层次分析法的特色小镇文化产业链综合评价研究 [Research on quality assurance methods based on business architecture]. *China Finance*, *5*(3), 49-52.

Zhu, G. J. (2008). *Thoughts on improving the operation quality of quality management system*. The 2nd China Aerospace Quality Forum, Beijing.

Zhu, J. P. (2011). *Maturity diagnosis of PN company's quality management* [Master's thesis], South China Universtiy of Technology.

Zhu, S. X. (2016). *The study on maturity evaluation of teaching quality management in higher education institution* [Doctoral dissertation], Shanghai Jiaotong University.

Zhu, Y. T. (2015). 日本崛起叫响质量管理 [The rising of Japan: quality management counts]. *Chemical Enterprise Management*, (31), 88-100.

Annex A

Appended Tables and Figures

Appended Tables

Appended Table 1 Guidance for the scoring of process

Maturity level	Process
1	There is no systematic method; the information is fragmented and isolated; there begins to have a systematic method to deal with the six aspects of the process. (A) The method is not deployed or slightly deployed; the approach is in the early stage of deployment in most aspects or departments, which hinders the effective realization of the process. (D) There is no improvement orientation; the existing improvement is only a "passive response to the problem"; it is in the early stage of transiting from the "passive response to the problem" to the "improvement orientation". (L) There lacks coordination and unity; various aspects or departments do their own staff and mainly rely on joint problem-solving to achieve coordination and agreement with other parties or departments. (I)
2	There are systematic and effective approach to deal with the basic requirements of the scoring clause. (A) The approach has been deployed, although it is still in the early stages of deployment in some aspects or departments. (D) Systematic evaluation and improvement are conducted towards the core process-operation. (L) The six aspects of approach and process are initially coordinated. (I)
3	There are systematic and effective approach in dealing with the six aspects of process requirements. (A) The approach has been well deployed, although the deployment is different in some aspects or departments. (D) Fact-based and systematic evaluation improvements as well as some innovations are carried out to improve the effectiveness and efficiency of the core process, that is operation. (L) The approach is consistent with the six aspects of the process category. (I)
4	There are systematic and effective approach to deal with the six aspects of the process. (A) The approach has been well deployed without obvious gaps. (D) Fact-based and systematic evaluation, improvement and innovation have become key management tools; there is clear evidence proving that the approach have been continuously improved through organization-level analysis and sharing. (L) The approach is integrated with the six aspects of the process category. (I)
5	There are systematic and effective approach to comprehensively respond to the six aspects of the process requirements. (A) The approach has been fully deployed, and there are no obvious weaknesses or gaps in any aspect or department. (D) Fact-based and systematic evaluation, improvement and innovation have become the key management tools of the organization; there is evidence that the approach have been continuously improved and innovated throughout the organization through analysis and

	sharing. (L) The approach and the six aspects of the process are well integrated. (I)

Source: Lu (2016)

Note: "A"= Approach, "D"= Deployment, "L"= Learning, "I"= Integration.

Appended Table 2 Guidance of scoring result

Maturity level	Result
1	The results are not described, or the results are poor; the results are few; there are some good performance levels in several areas at the early stage. (Le) There are no data showing trends, or mostly showing bad trends; there are some data showing trends, some of which showing bad trends. (T) There is no comparative information; there is no or little comparative information. (C) There is no report or few reports in several aspects in terms of the customer satisfaction result, quality management system result, product and service result. (I)
2	In most important aspects of the scoring clause, the performance level is good. (Le) There are some data showing trends, most of which show favorable trends. (T) It is in the early stages of obtaining comparative information. (C) The results are reported on most aspects of the customer satisfaction result, quality management system result, product and service result. (I)
3	A good performance level is required in most important aspects of this scoring clause. (Le) There is a favorable trend in terms of customer satisfaction result, quality management system result, product and service result. (T) Some indicators have good relative performance levels comparing and evaluating with related competitors and/or benchmarks. (C) The results are reported in most aspects of customer satisfaction result, quality management system result, product and service result, and the performance level is relatively good. (I)
4	In most aspects that are important to the requirements of the scoring clause, the performance is of good to excellent level. (Le) In most aspects of customer satisfaction result, quality management system result, product and service result, there is a sustainable favorable trend. (T) Most indicators have very good relative performance levels comparing and evaluating with relevant competitors and (or) benchmarks. (C) The results correspond to most implementation plan on customer satisfaction result, quality management system result, product and service result. (I)
5	The scoring clauses are excellent in most aspects that are important to the scoring clause (Le) The trends are sustainable favorable in all aspects that are important for achieving the mission, vision, and strategic goals of the organization. (T) In most respects, the organization is at the industry's leading position and benchmark level. (C) The result fully corresponds to the requirements of key customers, markets, processes, and strategic implementation plans. (I)

Source: Lu (2016)

Note: "Le"= Levels, "T"= Trends, "C"= Comparisons, "I"= Integration.

Appended Table 3 Principal component factor analysis of the management process

Item	1. Measurement, analysis and improvement	2. Leadership	3. Strategic management	4. Risk management

LD1 Leadership and commitment	0.666	0.514		
LD2 Policy and goal management	0.557	0.537		
LD3 Position responsibility and authority		0.713		
LD4 Communication		0.746		
LD5 Quality culture		0.743		
ZL1 Strategy formulation			0.976	
ZL2 Strategy deployment			0.967	
FX1 Risk planning				-
FX2 Risk evaluation				0.718
FX3 Risk treatment				0.678
FX4 Risk monitoring				0.673
CL1 Measurement, analysis and judgement	0.937			
CL2 Statistical technology	0.917			
CL3 Quality information	0.837			
CL4 Internal audit	0.906			
CL5 Management review	0.908			
CL6 Corrective action and make the five aspects to zero	0.804			
CL7 Innovation management	0.937			

Note: “LD”= leadership, “ZL”= strategic management, “FX”= risk management, “CL”= measurement, analysis and improvement.

Appended Table 4 Principal component factor analysis of the support process

Item	Resource management	Documented information control process
ZY1 Human resources	0.935	
ZY2 Basic infrastructure	0.935	
ZY3 Monitoring and measuring equipment	0.816	
ZY4 Process operating environment	0.817	
ZY5 Information and knowledge resources	0.663	
ZY6 Relationship of related parties	0.935	
XX1 Document control		0.941
XX2 Record control		0.928

Note: “ZY”= resource management, “XX”=documented information control process.

Appended Table 5 Principal component factor analysis of customer-oriented process

Item	1. Design and development of product and service	2. Provision of product and service
KF1 Product and service requirement	0.946	
KF2 Design and development process of product and service	0.660	
KF3 Technology management	0.864	
KF4 General quality characteristic management	0.946	
KF5 New product trial production	0.553	0.570
KF6 Trial control	0.731	
TG1 External provision process		0.809
TG2 Control of products and services provision		0.700
TG3 Identification, protection and traceability		0.850
TG4 Key process control		0.616
TG5 Release of products and services	0.617	0.590
TG6 Non-conforming product management		0.768
TG7 After-sales service		0.889

Note: “KF”= design and development of product and service, “TG”= provision of product and service.

Appended Table 6 Principal component factor analysis of result

Item	1. Quality management result
JG1 Customer satisfaction results	0.820
JG2 Quality management system results	0.914
JG3 Products and services results	0.915

Note: "JG" = quality management result.

Appended Table 7 Statistical description of the sample

Category	Content	Sample number	Percentage (100%)
Name	Male	108	45%
	Female	132	55%
Age	＜25 years old	20	8.3%
	26.30 years old	41	17.1%
	31-35 years old	44	18.3%
	36.40 years old	39	16.3%
	＞40 years old	96	40%
Education	High school	69	28.7%
	College	69	28.7%
	Bachelor	94	39.2%
	Master	8	3.3%
Position	Senior manager	16	6.7%
	Middle-level manager	28	11.7%
	R&D/technology staff	88	36.7%
	Quality management staff	88	36.7%
	User representative	20	8.3%
Working years	0-3 years	77	32.1%
	4.8 years	56	23.3%
	＞9 years	107	44.6%

Appended Table 8 Model fit of the management process

MP by	Estimate	S.E.	Est./S.E.	P-value
LD1 Leadership and commitment	0.811	0.025	32.644	***
LD2 Policy and goal management	0.798	0.026	31.216	***
LD3 Position responsibility and authority	0.830	0.022	37.420	***
LD4 Communication	0.849	0.021	41.398	***
LD5 Quality culture	0.834	0.022	38.216	***
ZL1 Strategy formulation	0.431	0.116	3.715	***
ZL2 Strategy deployment	0.590	0.027	21.852	**
FX1 Risk evaluation	0.833	0.024	35.374	***
FX2 Risk treatment	0.919	0.013	71.350	***
FX3 Risk monitoring	0.909	0.014	62.807	***
CL1 Measurement, analysis and judgement	0.556	0.168	3.310	**
CL2 Statistical technology	0.983	0.067	14.672	**
CL3 Quality information	0.796	0.026	30.613	***
CL4 Internal audit	0.596	0.145	4.110	**
CL5 Management review	0.702	0.101	6.950	**
CL6 Corrective action and make the five aspects to zero	0.508	0.074	6.864	*
CL7 Innovation management	0.772	0.144	5.360	*

Model fit index	X^2/df=2.968	CFI=0.957	TLI=0.935	
	RMSEA=0.091	SRMR=0.036		

Note: ***p<0.001, ***p<0.01, *p<0.05; "MP"=management process, "LD"= leadership, "ZL"= strategic management, "FX"= risk management, "CL"= measurement, analysis and improvement.

Appended Table 9 Model fit of the support process

	Estimate	S.E.	Est./S.E.	P-value
SP by				
ZY1 Human resources	0.843	0.021	40.442	***
ZY2 Basic infrastructure	0.833	0.022	37.405	***
ZY3 Monitoring and measuring equipment	0.881	0.017	51.923	***
ZY4 Process operating environment	0.861	0.019	44.267	***
ZY5 Information and knowledge resources	0.834	0.022	37.560	***
ZY6 Relationship of related parties	0.787	0.027	29.259	***
XX1 Document control	0.921	0.016	55.863	***
XX2 Record control	0.872	0.020	43.908	***
Model fit index	X^2/df=2.459	CFI=0.942	TLI=0.915	
	RMSEA=0.049	SRMR=0.037		

Note: ***p<0.001, ***p<0.01, *p<0.05; "SP"=support process, "ZY"= resource management, "XX"=documented information control process.

Appended Table 10 Model fit of customer-oriented process model

	Estimate	S.E.	Est./S.E.	P-value
COP by				
KF1 Product and service requirement	0.845	0.031	27.259	**
KF2 Design and development process of product and service	0.801	0.038	21.219	***
KF3 Technology management	0.843	0.037	22.877	***
KF4 General quality characteristic management	0.826	0.034	24.346	***
KF5 New product trial production	0.716	0.061	11.761	***
KF6 Trial control	0.771	0.041	18.858	***
TG1 External provision process	0.621	0.035	17.743	**
TG2 Control of products and services provision	0.537	0.030	17.900	***
TG3 Identification, protection and traceability	0.824	0.034	24.327	***
TG4 Key process control	0.796	0.038	20.726	***
TG5 Release of products and services	0.901	0.023	38.407	***
TG6 Non-conforming product management	0.826	0.034	24.220	***
TG7 After-sales service	0.878	0.027	33.044	***
Model fit index	X^2/df=3.132	CFI=0.910	TLI=0.878	
	RMSEA=0.033	SRMR=0.063		

Note: ***p<0.001, ***p<0.01, *p<0.05; "COP"=customer-oriented process; "KF"= design and development of product and service, "TG"= provision of product and service.

Appended Table 11 Model fit of the result

	Estimate	S.E.	Est./S.E.	P-value
RE by				
JG1 Customer satisfaction results	0.931	0.017	54.371	***

JG2 Quality management system results	0.825	0.024	33.817	***
JG3 Products and services results	0.885	0.020	44.462	***
Model fit index	X^2/df=0.000	CFI=1	TLI=1	
	RMSEA=0.000	SRMR=0.000		

Note: ***p<0.001, ***p<0.01, *p<0.05; "RE"=result, "JG" = quality management result.

Appended Table 12 The impact of management process on support process

		Estimate	S.E.	Est./S.E.	P-value
ZY	on				
	LD	0.349	0.178	1.963	*
	ZL	-0.240	0.087	-2.753	-
	FX	-0.019	0.134	-0.145	-
	CL	0.904	0.276	3.279	***
XX	on				
	LD	-0.656	0.353	-1.858	-
	ZL	-0.061	0.146	-0.420	-
	FX	-0.307	0.259	-1.186	-
	CL	1.990	0.550	3.619	***

Note: ***p<0.001, ***p<0.01, *p<0.05; ZY=resource management, XX=documented information control process, LD=leadership, ZL=strategic management, FX=risk management, CL=measurement, analysis and improvement.

Appended Table 13 The impact of management process on customer-oriented process

		Estimate	S.E.	Est./S.E.	P-value
KF	on				
	LD	-0.325	0.234	-1.385	-
	ZL	0.061	0.108	0.566	-
	FX	-0.308	0.198	-1.558	-
	CL	1.535	0.362	4.246	***
TG	on				
	LD	0.212	0.219	0.971	-
	ZL	-0.098	0.111	-0.883	-
	FX	-0.560	0.196	-2.859	***
	CL	1.346	0.348	3.871	***

Note: ***p<0.001, ***p<0.01, *p<0.05; KF=design and development of product and service, TG=provision of product and service, LD=leadership, ZL=strategic management, FX=risk management, CL=measurement, analysis and improvement.

Appended Table 14 The impact of management process on result

		Estimate	S.E.	Est./S.E.	P-value
JG	on				
	LD	0.839	0.202	4.158	***
	ZL	-0.150	0.098	-1.530	0.126
	FX	-0.162	0.140	-1.153	0.249
	CL	0.434	0.284	1.524	0.127

Note: ***p<0.001, ***p<0.01, *p<0.05; JG=result, LD=leadership, ZL=strategic management, FX=risk management, CL=measurement, analysis and improvement.

Appended Table 15 The impact of support process on customer-oriented process

		Estimate	S.E.	Est./S.E.	P-value
KF	on				
	ZY	0.688	0.084	8.148	***

	XX	0.340	0.087	3.902	***
TG	on				
	ZY	0.818	0.094	8.655	***
	XX	0.160	0.099	1.610	-

Note: ***p<0.001, ***p<0.01, *p<0.05; KF=design and development of product and service, TG=provision of product and service, ZY=resource management, XX=documented information control process.

Appended Table 16 The impact of support process on result

		Estimate	S.E.	Est./S.E.	P-value
JG	on				
	ZY	0.980	0.127	7.739	***
	XX	-0.054	0.103	-0.526	0.599

Note: ***p<0.001, ***p<0.01, *p<0.05; JG=result, ZY=resource management, XX=documented information control process.

Appended Table 17 The impact of customer-oriented processes on result

		Estimate	S.E.	Est./S.E.	P-value
JG	on				
	KF	-0.013	0.488	-0.026	-
	TG	0.984	0.485	2.028	*

Note: ***p<0.001, ***p<0.01, *p<0.05; JG=result, KF=design and development of product and service, TG=provision of product and service.

Appended Table 18 The mediating role of customer-oriented process in the impact of management process on quality result

	Lower 2.5%	Lower 5%	Estimate	Upper 5%	Upper 2.5%
FX--TG--JG	-0.151	-0.135	-0.076	-0.031	-0.023
CL--TG--JG	0.165	0.178	0.265	0.377	0.396

Note: FX=risk management, CL=measurement, analysis and improvement, TG=provision of product and service, JG=result.

Appended Table 19 The mediating role of customer-oriented processes in the impact of support process on quality result

	Lower 2.5%	Lower 5%	Estimate	Upper 5%	Upper 2.5%
ZY--TG--JG	0.297	0.312	0.403	0.514	0.537
XX--TG--JG	0.011	0.019	0.063	0.117	0.129

Note: ZY=resource management, XX=documented information control process, TG=provision of product and service, JG=result.

Appended Table 20 The meaning of the judgment matrix elements

Value	Meaning
1	Element i is as important as element j
3	Element i is slightly more important than element j
5	Element i is obviously more important than element j
7	Element i is strongly more important than element j
9	Element i is absolutely more important than element j

Source: B. Huang (2018); M. Qi (2021)

Appended Table 21 Average random consistency index value

n	1	2	3	4	5	6	7	8
R.I.	-	-	0.58	0.89	1.12	1.26	1.36	1.41
n	9	10	11	12	13	14	15	16
R.I.	1.46	1.49	1.52	1.54	1.56	1.58	1.59	1.60

Appended Table 22 Paired judgment matrix of the importance of indicators to leadership

Leadership B1	Leadership and commitment C1	Policy and goal management C2	Position responsibility and authority C3	Communication C4	Quality culture C5
Leadership and commitment C1	1	2	2	3	3
Policy and goal management C2	1/2	1	1	2	2
Position responsibility and authority C3	1/2	1	1	2	2
Communication C4	1/3	1/2	1/2	1	1
Quality culture C5	1/3	1/2	1/2	1	1

Appended Table 23 Paired judgment matrix and relative weight of the importance of indicators to leadership

Leadership B1	C1	C2	C3	C4	C5	W_i
C1	1	2	2	3	3	0.3682
C2	1/2	1	1	2	2	0.2065
C3	1/2	1	1	2	2	0.2065
C4	1/3	1/2	1/2	1	1	0.1094
C5	1/3	1/2	1/2	1	1	0.1094

Appended Table 24 Paired judgment matrix and relative weight of the importance of indicators to strategic management

Strategy management B2	C6	C7	W_i
C6	1	1/3	0.2500
C7	3	1	0.7500

Appended Table 25 Paired judgment matrix and relative weight of the importance of indicators to risk management

Risk management B3	C8	C9	C10	W_i
C8	1	1/3	1/2	0.1634
C9	3	1	2	0.5396
C10	2	1/2	1	0.2970

Appended Table 26 Paired judgment matrix and relative weight of the importance of indicators to measurement, analysis and improvement

Measurement, analysis, and improvementB4	C11	C12	C13	C14	C15	C16	C17	W_i
C11	1	2	2	1	1	2	1	0.1818
C12	1/2	1	1	1/2	1/2	1	1/2	0.0909
C13	1/2	1	1	1/2	1/2	1	1/2	0.0909
C14	1	2	2	1	1	2	1	0.1818
C15	1	2	2	1	1	2	1	0.1818
C16	1/2	1	1	1/2	1/2	1	1/2	0.0909
C17	1	2	2	1	1	2	1	0.1818

Appended Table 27 The key process areas and process indicator weights of quality management activities of private enterprises

Key process area	Indicator weight	Key process	Indicator weight	Total weight
Leadership	0.0561	Leadership and commitment	0.3463	0.0194
		Policy and goal management	0.2105	0.0118
		Position responsibility and authority	0.1210	0.0068
		Communication	0.0755	0.0042
		Quality culture	0.2466	0.0138
Strategic management	0.0527	Strategy formulation	0.3929	0.0207
		Strategy deployment	0.6071	0.0320
Risk management	0.0564	Risk evaluation	0.2419	0.0136
		Risk treatment	0.4494	0.0253
		Risk monitoring	0.3087	0.0174
Measurement, analysis, and improvement	0.0749	Measurement, analysis and judgement	0.1455	0.0109
		Statistical technology	0.1161	0.0087
		Quality information	0.1048	0.0078
		Internal audit	0.2070	0.0155
		Management review	0.2012	0.0151
		Corrective action and make the five aspects to zero	0.0820	0.0061
		Innovation management	0.1433	0.0107

Resources	0.0854	Human resources	0.2926	0.0250
		Basic infrastructure	0.1825	0.0156
		Monitoring and measuring equipment	0.0826	0.0071
		Process operating environment	0.0821	0.0070
		Information and knowledge resources	0.1933	0.0165
		Relationship of related parties	0.1670	0.0143
Documented information control	0.0344	Document control	0.5714	0.0197
		Record control	0.4286	0.0147
Design and development of the product and service	0.1707	Product and service requirement	0.2437	0.0416
		Design and development process of product and service	0.2806	0.0479
		Technology management	0.0856	0.0146
		General quality characteristic management	0.0723	0.0123
		New product trial production	0.1265	0.0216
		Trial control	0.1914	0.0327
Product production and service provision	0.2287	External provision process	0.1318	0.0301
		Control of products and services provision	0.1555	0.0356
		Identification, protection and traceability	0.0642	0.0147
		Key process control	0.2257	0.0516
		Release of products and services	0.1186	0.0271
		Non-conforming product management	0.0809	0.0185
		After-sales service	0.2233	0.0511
Quality management result	0.2407	Customer satisfaction results	0.2338	0.0563

	Quality management system results	0.3032	0.0730
	Products and services results	0.4630	0.1114

Appended Table 28 Standards for dividing the comprehensive score of maturity

The interval of P value	Maturity level
1≤P＜1.5	Initial level
1.5≤P＜2.5	Repeatable level
2.5≤P＜3.5	Defined level
3.5≤P＜4.5	Managed level
4.5≤P＜5	Optimized level

Source: Yin (2021)

Appended Table 29 The subordinating degree of the indicators in the “leadership” factor set in GXTF company

Leadership	Initial level	Repeatable level	Defined level	Managed level	Optimized level
Leadership and commitment	0	0	0.4	0.5	0.1
Policy and goal management	0	0.2	0.7	0.1	0
Position responsibility and authority	0	0	0.6	0.3	0.1
Communication	0	0.1	0.6	0.3	0.1
Quality culture	0	0.1	0.8	0.1	0

Appended Table 30 The subordinating degree of the quality management maturity levels of the key process areas in GXTF company

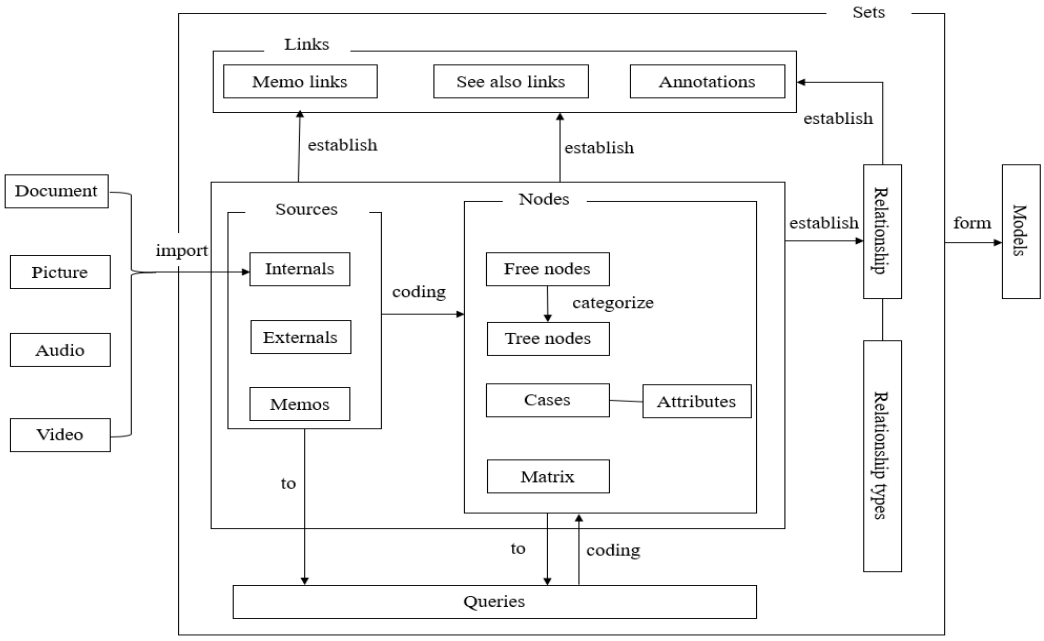
Key process area	Initial	Repeatable	Defined	Managed	Optimized
Leadership	0	0.0743	0.6011	0.2778	0.0543
Strategic management	0.1	0.7607	0.1393	0	0
Risk management	0.2892	0.4141	0.2726	0.0242	0
Measurement, analysis and improvement	0.0259	0.1353	0.5218	0.2425	0.0741
Resources	0	0.0486	0.5617	0.2997	0.0902
Documented information control	0	0.1429	0.5	0.3571	0
Design and development of product and service	0	0.0805	0.7134	0.1818	0.0244
Product production and service	0	0.1283	0.6286	0.1761	0.067

provision					
Quality management result	0	0.1532	0.5303	0.2468	0.0697

Appended Table 31 The main inputs and outputs of risk treatment

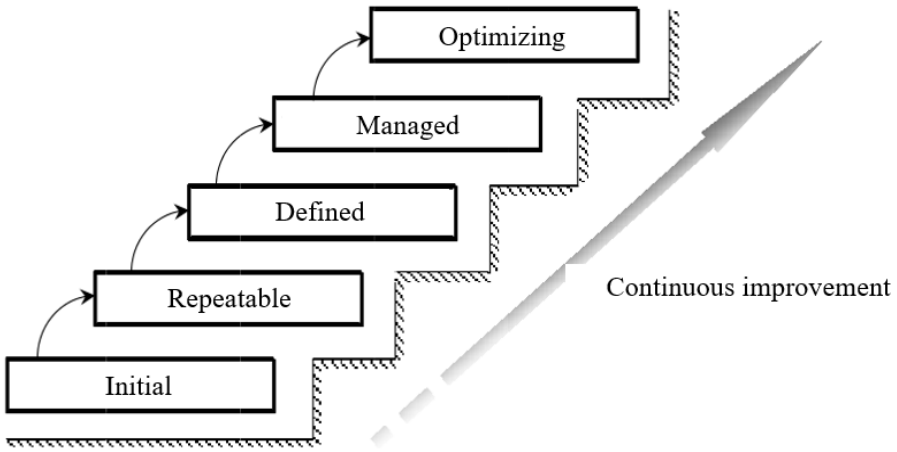
The main inputs of risk processing	The main outputs of risk treatment
Risk management plan Goals and priorities of the development project The organization management system, responsibility, decision-making process and existing resources of the develop project List of risk sources Risk ranking result or list Resource analysis data Review and expert opinions at the development stage Accumulated experience and relevant data of similar foreign and domestic projects Risk tolerance and risk information of the business-related parties Expert opinions, standards, templates and other available information.	-- Information such as responsible person, time limit, resources. -- Necessary risk treatment plan -- Risk management plan and change records

Appended Figures



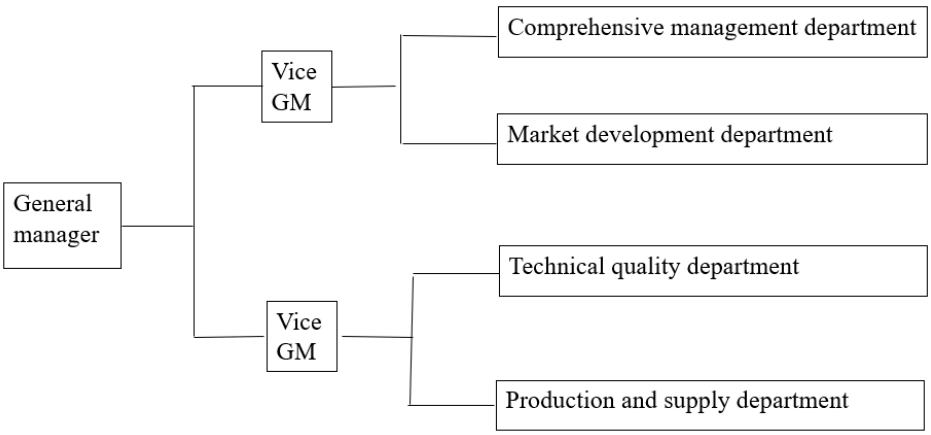
Source: Liu and Li (2017)

Appended Figure 1 The operation procedure of Nvivo



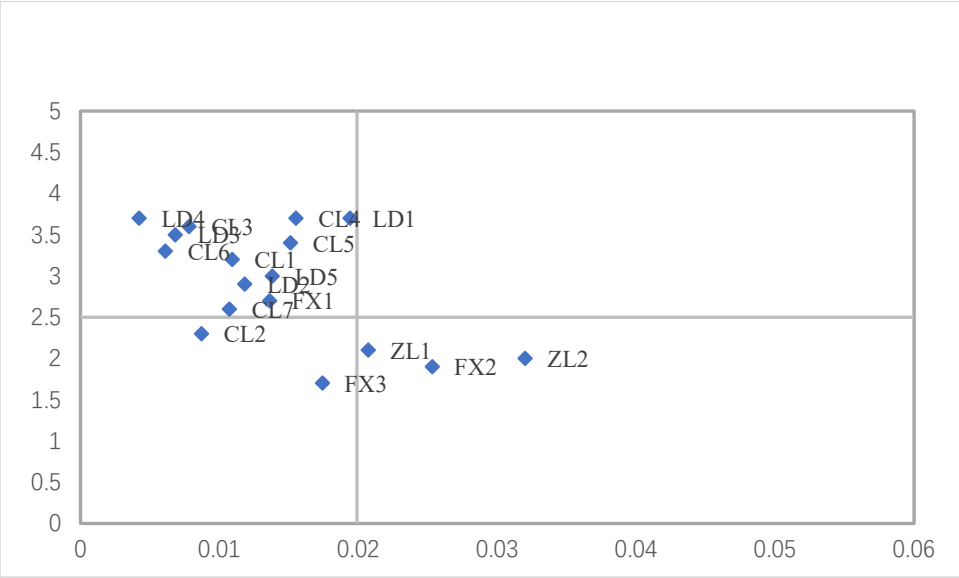
Source: Wang and Zhang (2020)

Appended Figure 2 QMM levels of private equipment manufacturing enterprises



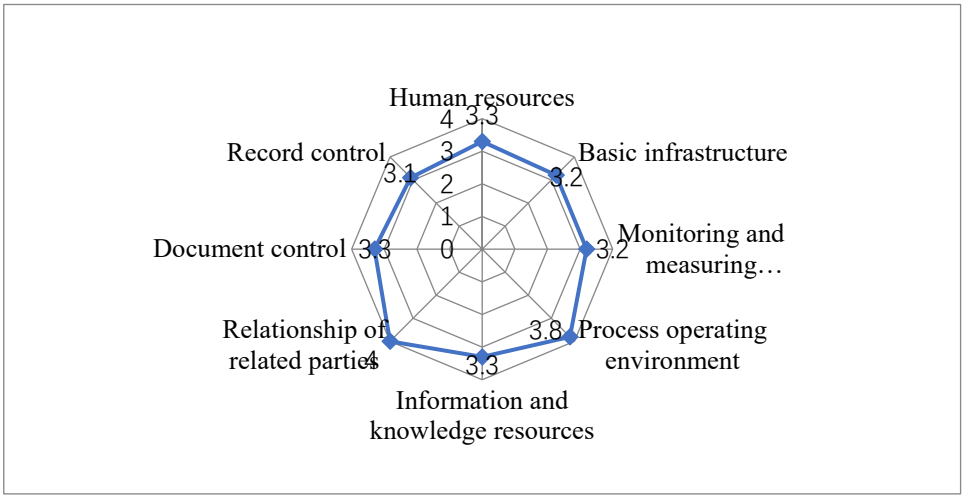
Appended Figure 3 Organizational structure of the company

Appended Figure 4 The maturity of key processes in GXTF company's management process

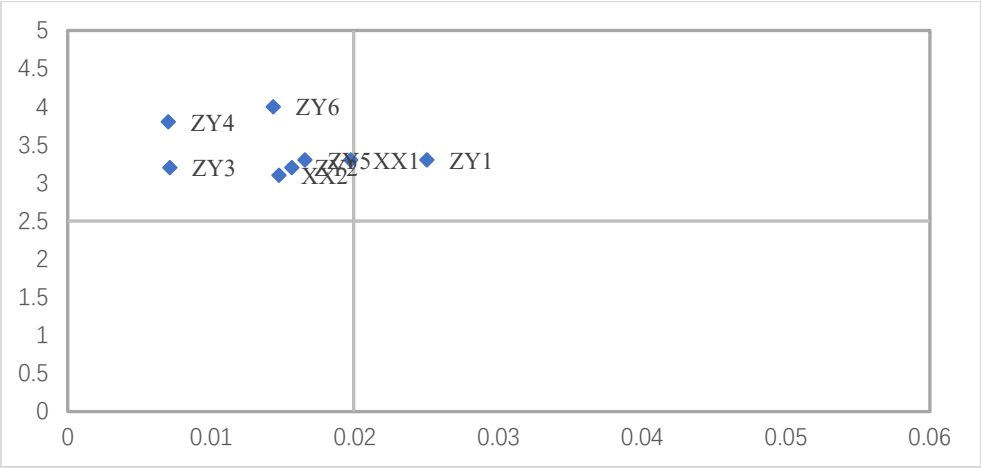


Note: “LD”= leadership, “ZL”= strategic management, “FX”= risk management, “CL”= measurement, analysis and improvement.

Appended Figure 5 Priority matrix of the process indicators in the management process of GXTF company

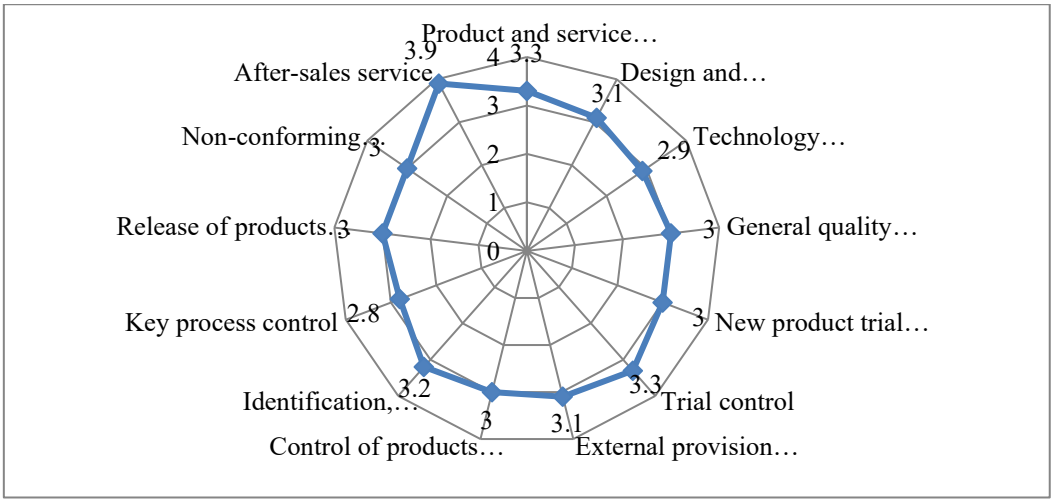


Appended Figure 6 The maturity of the key processes in GXTF company’s support process

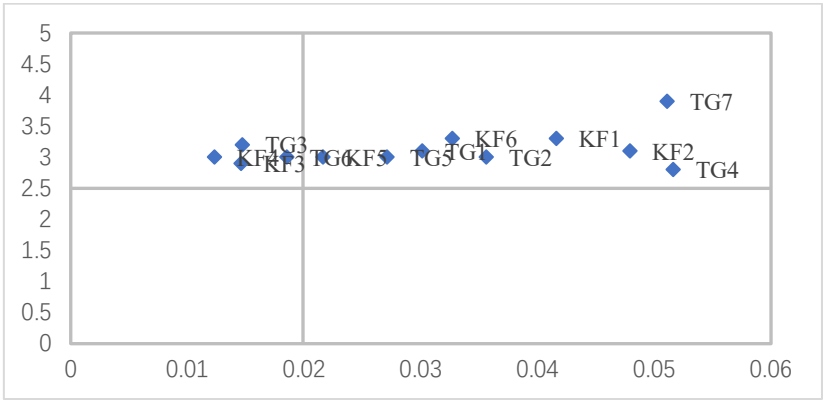


Note: “ZY”= resource management, “XX”=documented information control process.

Appended Figure 7 Priority matrix of the process indicators in the GXTF company’s support process

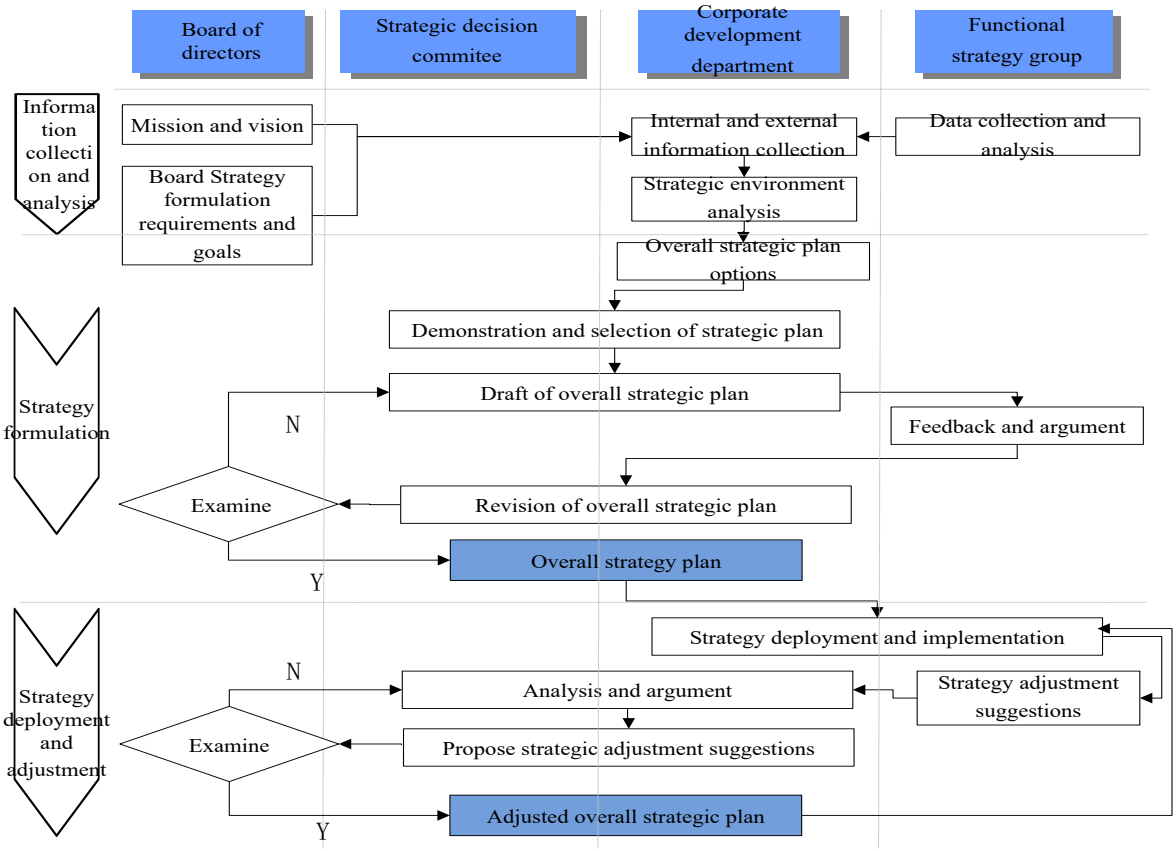


Appended Figure 8 The maturity of the key process of GXTF company’s customer-oriented process



Note: “KF”= design and development of product and service, “TG”= provision of product and service.

Appended Figure 9 Priority matrix of the process indicators in GXTF company’s customer-oriented process



Appended Figure 10 The strategic management process of GXTF company

[This page is deliberately left blank.]

Annex B

Questionnaire on quality maturity evaluation

Dear Sir/Madame,

Greetings! Thank you very much for filling out the questionnaire. The questionnaire is for the research on the quality management maturity of private equipment manufacturing enterprises. Your support is the key to the success of the research. Thank you again for your cooperation and support!

Basic information

1. Gender:

☐Male☐ ☐Female

2. Age:

☐<25 years old ☐26-30 years old ☐☐31-35 years old ☐☐36-40 years old ☐>40 years old

3. Education:

☐High school's degree ☐College degree☐☐Bachelor's degree☐▫Master's degree and above

4. Location of the enterprise:

☐Guizhou ☐Chengdu ☐Xi'an ☐Zhejiang

5. Nature of your job:

☐Management ☐Technology ☐Production ☐Marketing ☐Administration

6. Your position in the enterprise:

☐Top-level manager☐☐Middle-level manager☐☐Developing/technology staff ☐Quality management staff ☐Customer representative

7. Working years:

☐0—3 years☐☐4—8 years☐☐>9 years

8. Basic information of the enterprise

1) Is your enterprise in the private equipment manufacturing industry?

☐Yes ☐No

Enterprise name:

2) Enterprise scale:

☐<100☐employees ☐100-500 employees ☐>500 employees

3) Check the management system accreditation your enterprise has passed: (Multiple choice)
☐ISO9000 standard ☐GJB9001C ☐ISO14000 standard ☐ISO45001 standard
☐Compulsory accreditation in China（such as CCC accreditation） ☐Others (please specify)
4) The management method your enterprise adopted in quality improvement: (Multiple choice)
☐5S/6S ☐QC Group ☐6 Sigma management ☐Lean management
☐Process recreation ☐Excellent performance model ☐No defect management
5) Your company's R&D level in the past three years:
☐very low ☐low ☐moderate ☐high ☐very high

Scoring guideline

Please read the descriptions of the characteristics of different maturity levels below carefully and evaluate the QM maturity of your company.
Refer to the scoring guidelines of process in GB/T19580 in Appended Table 1 and determine the evaluation level of key process area 1 to key process area 8.

The company's quality management

Please fill in the questionnaires according to the description of the activities and behaviors of the key process, and circle the corresponding maturity.
Key process area 1: Leadership

Key process	The activities of the key process	Maturity level				
A1 Leadership and commitment	In accordance with Clause 5.1 of the GJB9001C system, promote customer focus; set up the quality department and clarify the quality management responsibilities to ensure not disturbed by other administrations and be responsible for the enterprise quality; according to the national military standard, form a documented integrity system, ensure all departments carry out integrity-related work in accordance with the requirements of the quality integrity system; establish an integrity management system to ensure the quality and integrity of the enterprise; establish and implement a mechanism for	1	2	3	4	5

	soliciting customers' improvement opinions on the quality of products and services; be responsible for the quality of final products and services; provide necessary resources, training and authority to continuously promote the effectiveness of the quality management system.					
A2 Policy and goal management	In accordance with Clauses 5.2 and 6.2 of GJB9001C system, the policy adapts to the organization's purpose and environment and supports its strategic direction, and is communicated, understood and applied within the organization; establish, implement and maintain the effective operation of quality objectives according to the process required by the quality management system, formulates quality objective evaluation criteria, and implements qualitative and quantitative analysis, dynamically determine the process and the relationship between policy and strategic direction, and consider all applicable aspects and factors to support the establishment, maintenance and management of the process.	1	2	3	4	5
A3 Position responsibility and authority	In accordance with Clause 5.3 of GJB9001C system, ensure that the organization's related job responsibilities and authorities are assigned, communicated and understood; ensure the quality responsibilities of all levels and positions, and establish and implement a quality accountability and incentive system.	1	2	3	4	5
A4 Communication	In accordance with Clause 7.4 of GJB9001C system, determine the internal and external communication related to the quality management system and establish a long-term mechanism to ensure that communication is barrier-free.	1	2	3	4	5
A5 Quality culture	In accordance with Clause 7.3 of GJB9001C system, attach importance to communication between leaders	1	2	3	4	5

	and employees, effectively convey the organization's vision, mission, and values; carry out various activities to strengthen employees' quality awareness; the organization is people-oriented, and employees actively participate in quality activities; employees are motivated to participate in improvement activities and propose opportunities for improvement in the responsible process.					

Key process area 2: Strategy management

Key process	The activities of the key process	Maturity level				
B1 Strategy formulation	The organization use tools such as PEST analysis, SWOT analysis, and the five forces model to find a suitable strategy implementation path when formulating strategies, make strategic choices, and decompose and implement strategic goals; ensure that changes in domestic and foreign situations, advantages and disadvantages of resource, strategic execution capabilities are taken into account when formulating strategies; clarify strategies and strategic goals, as well as the timetable and key quantitative indicators corresponding to the strategic goals, reflect innovation opportunities in products and services, and consider long-term and short-term challenges and opportunities and the needs of interested parties.	1	2	3	4	5
B2 Strategic deployment	The organization transforms strategies and strategic objectives into implementation plans, check during implementation, change the goals and plans according to the current situation of the organization's implementation to ensure the applicability of the goals and plans, so that the strategy can be effectively implemented in the organization, reflect the innovation of products and services and meet the long-term and short-term challenges and opportunities of the	1	2	3	4	5

	organization and the stakeholders.					

Key process area 3: Risk management

Key process	The activities of the key process	Maturity level				
C1 Risk planning	The organization has compiled a *Risk Management Plan* in accordance with the requirements of Clause 8.1 of the GJB9001C system, tracked each risk during the design and development process, and used the *Risk Management Plan* to understand the current status of various risks and update them in time.	1	2	3	4	5
C2 Risk evaluation	The organization carried out risk identification, risk analysis, and risk evaluation activities as required. Risk analysis includes consequence analysis, possibility analysis, uncertainty and sensitivity analysis, record risk analysis process and results. Risk evaluation: risk consequence level and judgment criteria, risk possibility level and judgment criteria, determine the risk level; based on the existing risk sources and determine the existing risk control measures according to the assessed risk value, and evaluate according to the acceptable risks.	1	2	3	4	5
C3 Risk treatment	Select risk response measures; formulate risk response plans; implement approved risk response measures or plans and record the risk response process and results.	1	2	3	4	5
C4 Risk monitoring	According to established risk management objectives or risk criteria, regularly review the adaptability and effectiveness of risk assessment, response or other risk management activities. The risk review can be carried out alone or in combination with other professional reviews, quality reviews or technical reviews; ensure the continued effectiveness of the risk management process.	1	2	3	4	5

Key process area 4: Measurement, analysis and improvement

Key process	The activities of the key process	Maturity level				
D1 Measurement, analysis and judgement	In accordance with Clause 9.1 in GJB9001C, set monitoring points, determine monitoring items, select monitoring methods, and specify monitoring frequency according to the characteristics of the process; check the design and development process (such as the completion rate of the new product design plan, the number of new products developed each year, the number of patent achievements, the design error rate), the production process (such as the completion rate of the production plan, the qualified rate of one-time product inspection, tooling preparation timeliness rate, equipment integrity rate), quality management process (such as product error, missed inspection rate, measuring instrument inspection rate, measuring instrument verification plan completion rate, cycle verification rate); analyze the problems found in the inspections in a timely manner and take effective measures to solve them.	1	2	3	4	5
D2 Statistical technology	The organization conducts effective measurement and analysis of the required process based on statistical technology; the organization attaches importance to the training and application of statistical technology, which plays an active role in the quality of products and services.	1	2	3	4	5
D3 Quality information	According to Clause 7.6 of GJB9001C system, the organization defines the requirements related to the enterprise quality information, incorporates the quality information into the relevant procedures and operation documents, and establishes an information database when applicable. Establish reliable channels for communicating quality information with customers, deliver the information they need to customers in a timely manner, and collect and properly handle customer feedback	1	2	3	4	5

	information. Meet the needs of laws, regulations and customers, and proposed improvement measures.					
D4 Internal audit	An internal audit plan is prepared, implemented as planned, and corrective measures are taken for the non-conformities issued, and a continuous improvement mechanism was formed.	1	2	3	4	5
D5 Management review	Management reviews should be conducted at planned and regular intervals to assess the organization's progress in achieving its policies, strategies and goals, and review the organization's improvement, learning and innovation activities, including adaptability and flexibility related to the organization's mission, vision, values and culture; the review should enable evidence-based decision-making and establish actions to achieve the desired results.	1	2	3	4	5
D6 Corrective action and make the five aspects to zero	Establish a fault management organization according to GJB841, report and analyze product faults, and get closed-loop processing, and report the operation status of FRACAS to customers; organize and implement technical zeroing and management zeroing according to the double five standards; summarize, standardize and institutionalize relevant experiences to avoid recurring similar problems.	1	2	3	4	5
D7 Innovation management	The organization can use a process consistent with the strategic direction to plan and optimize innovation plans; carry out innovation activities based on the needs and expectations of stakeholders; the innovation process of new products and services can identify changes in external and internal issues in order to plan innovation; innovation is a priority considering the urgency, the resources availability and the organization's strategy; external suppliers and partners participate in the innovation process to regularly evaluate the effectiveness and efficiency of the innovation process.	1	2	3	4	5

Key process area 5: Resource management

Key process	The activities of the key process	Maturity level				
E1 Human resources	The organization implements 7.1.2 and 7.2 of the GJB9001C system, and combines the job descriptions of personnel in various departments (specifying the requirements for job competency requirements for staff who are engaged in affecting product quality) to ensure that the job descriptions conform to the actual situation of the organization; the human resources department recruits according to the requirements of the job description, train personnel, and implement the optimal allocation of post personnel. Carry out quality awareness education to standardize employee behavior. Pay attention to the physical and mental health of employees, mobilize the enthusiasm of employees, encourage employees to make small reforms and rational suggestions, and improve employees' satisfaction with the company.	1	2	3	4	5
E2 Basic infrastructure	Organize the implementation according to the requirements of GJB9001C system 7.1.3, configure the infrastructure according to the requirements of products and services, establish equipment accounts, prepare maintenance plans, implement maintenance according to the plan, pay attention to the management of process equipment (such as tooling, fixtures), and continuously improve the foundation the technical level of the facility; pay attention to factors such as environment, safety and resource consumption during equipment construction, use and elimination.	1	2	3	4	5
E3 Monitoring and measuring equipment	In accordance with 7.1.5, the organization provides monitoring and measurement equipment according to the development requirements of the organization's products and services; formulate and implement a monitoring and measurement equipment verification plan and implement verification on a periodic basis; continuously improve the	1	2	3	4	5

	technical level of monitoring and measurement equipment.					
E4 Process operating environment	In accordance with 7.1.4, the organization shall determine, provide and maintain the required environment; effectively manage the working environment such as temperature and humidity, static electricity, noise, such as CNC machining of precision aluminum parts, copper parts, and control of the ambient temperature for parts detection, equipped with temperature and humidity meters and temperature and humidity records; DENSO shall specify anti-static requirements, install static-discharging facilities, test the workbench insulation and keep records; consider the psychological factors of employees, detect occupational hazards in the workplace, and provide employees with labor protection equipment, provide appropriate protection and monitor them.	1	2	3	4	5
E5 Information and knowledge resources	The organization identify and develop information sources, ensure the acquisition and provision of required data and information, and make it easy for employees, suppliers, partners and customers to obtain relevant data and information; strengthen the declaration and management of organizational patents and achievements, clarify the competent departments, constantly sort out core technologies and key technologies, and implement relevant systems; collect, publicize and share knowledge of partners within the organization; be able to respond to changing needs and development trends, determine and acquire necessary knowledge and keep knowledge updated.	1	2	3	4	5
E6 Relationship of related parties	Related parties: customers (such as orderers, military representatives, users, general units); owners of the organization; external suppliers (such as components, raw materials, process partners); partners (such as new product development cooperation units); employees of the organization.	1	2	3	4	5

	The organization identifies and manages the relationship between related parties, strengthens the collection and publicity of laws and regulations, establishes communication channels with related parties, and promotes win-win cooperation for the organization.					

Key process area 6: Documented information control

Key process	The activities of the key process	Maturity level				
F1 Document control	In accordance with 7.5 in GJB9001C, the documents required by the quality management system shall be controlled; stipulate according to relevant standards, specifications, product requirements and the organization's own requirements, clarify how to proofread, audit, process and quality countersign, standardized inspection, approval and documents that customers need to countersign, and the qualification requirements of relevant signatories; technical documents and drawings shall be coordinated and current effective; the organization shall properly identify and control the documented information from external sources necessary for the planning and operation of the quality management system determined by the organization.	1	2	3	4	5
F2 Record control	The organization implements the requirements of GJB9001C system 7.5 and pays attention to the identification of records (with a unique name and number/version); storage of records (anti-insect, moisture-proof, damage-proof, and loss-proof); record retrieval (easy to find, catalog, requirements for archiving and reviewing); the retention period of records (according to product characteristics, the retention period is determined by regulatory requirements); the destruction of expired records requires registration and approval.	1	2	3	4	5

Key process area 7: Design and development of product and service

Key process	The activities of the key process	Maturity level				
G1 Product and service requirement	The organization implements according to the requirements of GJB9001C system 8.2; in documents such as contracts, orders, agreements, tenders, include requirements for product functions and general quality characteristics, product delivery requirements, and after-sales services (such as delivery methods, settlement methods, Three Guarantees in after-sales service, repair and maintenance services); The customer has not put forward specific requirements, but it is necessary to consider the expected use of the product; the *Regulations on the Quality Management of Weapons and Equipment*, the prevention of excess products and other laws and regulations. Additional requirements: error-proof designs of products such as aircraft. Obtain the approval of the customer when products and requirements' delivery date change.	1	2	3	4	5
G2 Design and development process of product and service	The organization implements according to the requirements of GJB9001C system 8.3; starting from the design and development plan, pay attention to the analysis of product characteristics, and identify key characteristics and important characteristics; strictly design and development review, pay attention to the follow-up and implementation of review issues; pay attention to new product development (pre-production readiness inspection, first article appraisal, process review, quality delivery review); strictly follow the test outline to carry out the pre-test preparation status inspection, strengthen the handling of test problems, and notify users of the handling in time; standardize design and development activities from design and development planning, design and development input, design and development control, design and development output,	1	2	3	4	5

	design and development changes to ensure that the process is controlled, and form a long-term mechanism.					
G3 Technology management	In accordance with GJB3206A, formulate the technical status management procedure and plan of the document; specify the requirements related to stage, identification, control, documentation, functional audit and physical audit; strengthen the management of functional baseline, allocation baseline, and product baseline; strengthen the category of design and change, and the management and approval of design changes to ensure controlled management.	1	2	3	4	5
G4 General quality characteristic management	According to standards such as GJB450, GJB368, GJB3872, GJB2547, GJB900, GJB4239, GJB1909, manage the six properties including reliability, formulate six-property-related outlines and analysis reports, conduct reliability verification, strictly organize a special review of the environmental appraisal outline, and carry out environmental appraisal tests in accordance with procedures, and implement double “five to zero” work.	1	2	3	4	5
G5 New product trial production	The organization shall implement according to the requirements of 8.3.7 of the GJB9001C system. The organization should formulate control procedures related to the trial production process of new products, strictly control the change of technical status, and formulate process reviews in stages. The quality department or technical department organizes and conducts product quality preparation check, the process department organizes the first article identification, and the quality department organizes the product quality review.	1	2	3	4	5
G6 Trial control	In accordance with 8.3.8 in GJB9001C, the organization prepare a “test program” according to the specified requirements, and clarify the requirements of purpose, project, content, condition, procedure, mean and record of	1	2	3	4	5

	the test; for the test concerned by the customer, the test program should be approved by the customer. Check the preparation status before the test, such as the training and labor division of the test personnel, whether the status of the products to be tested meets the requirements, whether the calibration status of the test equipment and testing instruments meets the requirements. Carry out the test according to the test outline, record the test data and test process according to the specified requirements, and ensure the completeness and accuracy of the test data.					

Key process area 8: Provision of product and service

Key process	The activities of the key process	Maturity level				
H1 External provision process	According to the requirements of 8.3.8 of GJB9001C system, the organization shall compile a list of qualified suppliers, dynamically evaluate suppliers and effectively identify risks; the determination of procurement projects and suppliers should be fully demonstrated and approved according to regulations; the technical requirements and quality assurance requirements for the supplier are specified in the technical agreement/contract; the product can be used after verification and confirmation that it meets the requirements.	1	2	3	4	5
H2 Control of products and services provision	In accordance with 8.5.1 in GJB 9001C, the organization implements process evaluation of special processes (heat treatment, surface treatment); the ability of the output and service process to achieve the planned result should be confirmed, and reconfirmed regularly; conduct self-inspection and special inspection of the first product, and implement control over redundants; ensure that the organization conducts	1	2	3	4	5

	production and service provision under controlled conditions.					
H3 Identification, protection and traceability	The organization implements in accordance with 8.5.2 in GJB9001C. The organization shall implement batch management of products according to regulations, and establish a batch management system. It is necessary to achieve “five clears”, that is, clear product batch, clear quality status, clear original records, clear quantities, and clear furnace batch numbers; and “six batches”, that is, batch material feeding in batches, processing in batches, transferring in batches, storage in batches, assemble in batches, leave the factory in batches, and keep the batch marks of the products from material feeding to assembly and delivery. Records are established by batches, such as on-process flow cards to record the material feeding, processing, assembly, commissioning, inspection, quantity and quality of delivery, operator and inspector, and keep them as required. The batch identification of the product should be consistent with the original production records, such as product number, batch number, model, date. The records should be able to trace the situation of the product before delivery as well as the distribution and location after delivery.	1	2	3	4	5
H4 Key process control	The organization implements in accordance with 8.5.7 in GJB9001C. The organization shall identify key processes, prepare a list of key processes, and implement key process control; implement management of key processes in accordance with GJB909A *Quality Control of Key Parts and Important Parts* and GJB467 *Process Quality Control Requirements*, and ensure that the key process and process capabilities are in compliance with the	1	2	3	4	5

	requirements					
H5 Release of products and services	The organization implements in accordance with 8.6 in GJB9001C. The inspection and test records that the product complies with the acceptance criteria; the authorized release personnel (such as the signature of the inspection, the inspection stamp); the relevant product certification and inspection, test records and records of quality problems or failures; emergency exception release shall be subject to the consent of the customer.	1	2	3	4	5
H6 Non-conforming product management	The organization implements in accordance with 8.7 in GJB9001C. The organization shall form a document in accordance with the requirements of GJB 571, stipulate the relevant responsibilities and authorities for the control and disposal of nonconforming products, and clarify the requirements for the isolation, identification, recording, review and disposal of nonconforming products; concessionary use of key characteristics is not allowed.	1	2	3	4	5
H7 After-sales service	The organization implements in accordance with 8.5.5 in GJB9001C. Complete technical training on product use and maintenance according to regulations; ensure that technical documents related to product use and maintenance are controlled and updated; ensure that technical support and resources are provided, and technical service personnel are appointed to provide on-site services; appropriate measures such as investigation, processing and reporting should be taken and verified when problems are found after delivery.	1	2	3	4	5

Key process area 9: Quality management result

Key process	The activities of the key process	Maturity level				
M1 Customer satisfaction results	The organization implements in accordance with 4.7.3.2 in GB/T19580-2012. KPIs include customer satisfaction, customer complaint rate and timely after-sales service rate; benchmarking results include comparison of segmented data; customer loyalty KPIs include recognition from customers and evaluation agencies.	1	2	3	4	5
M2 Quality management system results	The organization implements in accordance with 4.7.6 in GB/T19580-2012. KPIs include overall labor productivity, quality, cost, cycle time, supplier and partner performance, and other effectiveness measurements.	1	2	3	4	5
M3 Products and services results	The organization implements in accordance with 4.7.2 in GB/T19580-2012. KPI include six indicators such as the function and reliability of products and services, delivery cycle, after-sales service or technical support and other indicators; results of comparison with competitors, comparison with international and domestic similar products; achievements, patents, brands, trademarks related to main products and services, advantages in energy conservation and environmental protection.	1	2	3	4	5

Annex C

Evaluation Scale for Private Equipment Manufacturing Enterprise's Quality Management Maturity

This maturity evaluation scale aims to help private equipment manufacturing enterprises to further promote the quality management system and continuously improve the enterprise's quality management level through self-evaluation.

I. Management process

1. Leadership

(1) Leadership and commitment

Evaluation content	Maturity level
The top management never or seldom participate in the planning, construction and operation of the quality management system (QMS).	1
The top management establishes a preliminary systematic standard for QMS planning, construction and operation, regulation compliance, and customer satisfaction enhancement.	2
The top management promotes the customer-focused goal, sets up the quality department and clarify the quality management responsibilities to ensure not disturbed by other administrations and be responsible for the enterprise quality; according to the national military standard, form a documented integrity system, ensure all departments carry out integrity-related work in accordance with the requirements of the quality integrity system; establishes and implements a mechanism for soliciting customers' opinions on the quality and improvement of products and services; be responsible for the final products and services; provide necessary resources, training and authority, and promote the effectiveness of the quality management system, which is well implemented.	3
The top management emphasizes the scientific evaluation and continuous improvement of QMS, standardizes effective measures, and takes innovative measures to improve performance.	4
The top management fully, systematically and effectively participate in QMS activities, reflecting the best practices of the industry.	5
Result/comments:	

(2) Policy and goal management

Evaluation content	Maturity level
The top management never or seldom participate in the formulation, implementation and maintenance of the quality policy and objectives. The description of the quality policy is scattered and unrealistic, and the quality objectives are unspecific, untargeted, and unmeasurable.	1
The top management participates in the formulation, implementation and maintenance of the quality policy and quality objectives, and establishes a preliminary and standardized method. The quality policy and quality objectives basically correspond with the reality and coordinate with the purpose and strategy of the organization.	2
The policy is adapted to the purpose and environment of the organization and supports	3

its strategic direction, and is communicated, understood and applied within the organization; top management establishes, implements and maintains the effective operation of quality objectives according to the process required by the quality management system, formulates quality objective evaluation criteria, implements qualitative and quantitative analysis, dynamically determines the process and the relationship between policies and strategic directions, and considers all applicable aspects and factors to support the establishment, maintenance and management of the process; the quality policy and quality objectives are realistic and systematic, and are in harmony with the organization's purpose and strategy.	
The quality policy and quality objectives are realistic, systematic and advanced, which are fully coordinated with the purpose and strategy of the organization.	4
The top management presides over the establishment, implementation and maintenance of a comprehensive, systematic and effective quality policy and quality target, reflecting the best practice of the industry.	5
Result/comments:	

(3) Position responsibility and authority

Evaluation content	Maturity level
The top management fails to ensure the effective assignment, communication and understanding of the responsibilities and authorities of the relevant positions. The identification of the job responsibilities and authority is fragmented and unsystematic.	1
The top management ensures that the positions, responsibilities and authorities within the organization are initially and standardizedly identified.	2
The top management basically ensures that the responsibilities and authorities of the relevant positions are well assigned; initially establishes a quality responsibility reward and punishment system, and strictly implement rewards and punishments. Basically effectively implemented.	3
The top management ensures that the responsibilities and authorities of relevant positions in the organization are systematically and effectively assigned, communicated and understood; ensures the establishment of a quality responsibility reward and punishment system, and strictly implement rewards and punishments. Effectively implemented.	4
The top management ensures that the responsibilities and authorities of each department of the organization are effectively allocated, and the quality responsibility reward and punishment system is sound and effectively implemented, reaching the benchmark level.	5
Result/comments:	

(4) Communication

Evaluation content	Maturity level
There lacks systematic communication, and internal and external communication has not been carried out or only been carried out accidentally and partially.	1
The communication is suitable for the actual situation of the enterprise, and a systematic method has been formed. Internal and external communication has been initially carried out.	2
The communication is realistic, systematic and effective. Internal and external communication has been carried out systematically, and the monitoring communication has been established.	3
The communication is realistic, systematic and effective, and it is strictly implemented without obvious deviation. The communication is monitored, analyzed, evaluated and continuously improved.	4
The communication is comprehensive, systematic, and effective, and it is carried out continuously and covers all relevant parties. The monitoring mechanism for communication is comprehensive and accurate, and is continuously improved and	5

innovated based on the analysis and evaluation, which has reached the benchmark level.	
Result/comments:	

(5) Quality culture

Evaluation content	Maturity level
The establishment of the quality culture lacks systemicity, and relevant personnel do not know much about the organization's vision, mission, and values.	1
The quality culture is suitable for the actual situation of the enterprise, and the preliminary method is formed. The relevant personnel understand the vision, mission and values of the organization. Some activities are carried out to strengthen the quality awareness of employees, but there is still a gap in the continuity and coverage.	2
The quality culture corresponds with the actual situation of the company. A systematic and effective method is formed to allow relevant personnel to understand the organization's vision, mission, and values. The organization is people-centered, and employees actively participate in quality activities. Employees are motivated to participate in improvement activities and propose the improvement opportunities in the processes that they are responsible for.	3
The quality culture corresponds with the actual situation of the company, and is effective and has obvious improvements. The quality culture allows relevant personnel to understand the organization's vision, mission, and values, and actively make contributions. A quality culture improvement mechanism is established, which effectively promotes the improvement of the quality culture.	4
The development of the quality culture is comprehensive, systematic, effective and comprehensive, which is recognized in the industry.	5
Result/comments:	

2. Strategic management

(1) Strategy formulation

Evaluation content	Maturity level
The strategy formulation is basically not implemented.	1
The strategy formulation is initially implemented.	2
Use tools such as PEST analysis, SWOT analysis, and five forces model to find a suitable strategy implementation path when formulating strategies, make strategic choices, and decompose and implement strategic goals; consider factors such as changes in domestic and foreign situations, advantages and weaknesses in resource, strategic execution capabilities; clarify the strategy and strategic objectives, as well as the timetable and key quantitative indicators corresponding to the strategic objectives, and reflect innovation opportunities in products and services, considering long-term and short-term challenges and opportunities and needs of related parties. The implementation is basically effective.	3
The strategy formulation is realistic, systematic, effective, and advanced.	4
The strategy formulation is comprehensive, systematic and effective, with comprehensive coverage, and continuous improvement and innovation. The strategy formulation has reached the benchmark level.	5
Result/comments	

(2) Strategy deployment

Evaluation content	Maturity level
The strategic deployment is basically not implemented.	1
The strategic deployment is basically implemented.	2

The strategic deployment corresponds with the actual situation of the enterprise and is effectively implemented. The organization transforms the strategy and strategic goals into an implementation plan, checks during the implementation process, and makes corresponding changes to the goals and plans according to the current situation of the organization's implementation to ensure the applicability of the goals and plans, so that the strategy can be effectively implemented in the organization, which reflects opportunities for innovation in products and services that meet the long-term and short-term challenges and opportunities of the organization and the needs of stakeholders.	3
The strategic deployment is realistic, systematic, effective, and advanced.	4
The strategic deployment is comprehensive, systematic and effective, with comprehensive coverage and continuous improvement and innovation.	5
Result/comments	

3. Risk management

(1) Risk evaluation

Evaluation content	Maturity level
The risk assessment is basically not carried out.	1
The risk assessment is initially implemented, and the organization has initially carried out risk identification, risk analysis and risk evaluation according to the development stage and product level analysis.	2
The organization has carried out risk identification, risk analysis and risk evaluation according to the development stage and product level analysis. The risk assessment has been well implemented.	3
The risk assessment is realistic, systematic, effective and advanced.	4
The risk assessment is comprehensive, systematic and effective, with comprehensive coverage and continuous improvement and innovation.	5
Result/comments:	

(2) Risk treatment

Evaluation content	Maturity level
The organization has no risk treatment measures nor risk treatment plan.	1
The organization basically selects risk response measures; basically formulates risk response plans; basically implements the approved risk response measures or plans and records the risk response process and results.	2
The organization selects risk treatment measures, formulates risk treatment plans, implements approved risk treatment measures or plans, and records the risk treatment process and results.	3
The risk management is realistic, systematic, effective, and advanced.	4
The risk treatment is comprehensive, systematic and effective, with comprehensive coverage and continuous improvement.	5
Result/comments:	

(3) Risk monitoring

Evaluation content	Maturity level
The organization does not regularly review the adaptability and effectiveness of risk assessment, risk treatment, or other risk management activities.	1
The organization regularly review the adaptability and effectiveness of risk assessment, risk treatment, or other risk management activities, and has some gains.	2
The organization regularly reviews the adaptability and effectiveness of risk assessment,	3

risk treatment, or other risk management activities according to certain risk management goals and risk principles, and has obvious improvement.	
The risk monitoring is realistic, systematic, effective, and advanced.	4
The risk monitoring is comprehensive, systematic, effective, and advanced, which can guarantee the continuous effect of the risk management process.	5
Result/comments:	

4. Measurement, analysis and improvement

(1) Measurement, analysis and judgement

Evaluation content	Maturity level
The organization occasionally carry out measurement, analysis and evaluation. The content and time requirements of the measurement, analysis, and evaluation are unclear.	1
The measurement, analysis and evaluation are initially implemented.	2
The organization sets monitoring points, determines monitoring items, selects monitoring methods, and specifies monitoring frequency according to the characteristics of the process; check the design and development process (such as the completion rate of the new product design plan, the number of new products developed each year, the number of patent achievements, the design error rate), the production process (such as the completion rate of the production plan, the qualified rate of one-time product inspection, tooling preparation timeliness rate, equipment integrity rate), quality management process (such as product error, missed inspection rate, measuring instrument inspection rate, measuring instrument verification plan completion rate, cycle verification rate); analyze the problems found in the inspections in a timely manner and take effective measures to solve them.	3
The measurement, analysis, and evaluation processes are systematically executed as planned, and can be continuously improved.	4
The measurement, analysis and evaluation process are comprehensive, systematic and effective, forming a continuous improvement mechanism.	5
Result/comments:	

□ (2) Statistical technology

Evaluation content	Maturity level
The statistical techniques have limited application and is seldom used within the organization.	1
The organization collects relevant external and internal information regularly, and uses some basic statistical tools.	2
The organization has a systematic analysis process and extensive use of statistical tools, identifies the needs and expectations of related parties through analysis, and relies on information analysis to make effective decisions and actions.	3
The application of statistical techniques is practical, systematic, effective, and advanced.	4
The application of statistical technology is comprehensive, systematic and effective, and has formed a continuous and effective mechanism.	5
Result/comments:	

(3) Quality information

Evaluation content	Maturity level
The organization establishes a basic quality information-related ledger, but the quality information management system is not clearly defined.	1
The requirements for quality information are basically determined, a quality information	2

management system is initially established, and a quality information system is basically formulated.	
The requirements related to the quality information of the enterprise are clarified, and the quality information is incorporated into the relevant procedures and operation documents, and an information base is established when applicable. Establish reliable channels for communicating quality information with customers, deliver the information they need to customers in a timely manner, and collect and properly handle customer feedback information. Satisfy the needs of the laws, regulations and customers and propose improvement measures.	3
Quality information management is practical, systematic, effective and advancing with the time.	4
The effect of quality information management is better than that of other organizations.	5
Result/comments:	

(4) Internal audit

Evaluation content	Maturity level
The organization conducts internal audits for problems, customer complaints. The collected data is mainly used to solve problems in product and service problems.	1
The internal audits are carried out regularly, and the collected data is mainly used to systematically review the process.	2
Audits can ensure the accuracy of data and the effectiveness of the management system. Internal audits can identify, monitor, and close the problems, non-conformities and risks.	3
The organization comprehensively analyze the problems, non-conformaties and risks to identify weaknesses in the management system, and continuously evaluates the data collection process to improve its effectiveness and efficiency.	4
To help identify more opportunities for improvement, the organization invites other relevant parties to participate in the review. The organization establishes a process for reviewing all established internal audit reports to determine the corrective actions or improvement opportunities required in the organization.	5
Result/comments:	

(5) Management review

Evaluation content	Maturity level
The management review is in the preliminary state, which is poor in standardization and effectiveness.	1
The management review is conducted in a standardized and systematic manner, but the role of the review output for management decision-making is not obvious.	2
Management reviews are conducted at planned and regular intervals to assess the organization’s progress towards achieving its policies, strategies and objectives; review the organization’s improvement, learning and innovation activities, including adaptability, flexibility and responsiveness in relation to the organization’s mission, vision, values and culture; reviews should enable evidence-based decision-making and establish actions to achieve desired outcomes. The implementation is basically effective.	3
The management review is systematic and standardized, and can effectively promote the improvement of the quality management system, and continuously evaluate and improve the management review methods and processes.	4
The planning of management review considers the needs and resources of all aspects, is highly compatible with the overall management of the organization, and comprehensively and effectively promotes the continuous improvement of the suitability, adequacy and effectiveness of the quality management system.	5
Result/comments:	

(6) Corrective action and five principles of quality problem close loop

Evaluation content	Maturity level
There lacks a systematic method to deal with corrective measures and five principles of quality problem close loop.	1
Be able to cope with corrective measures and five principles of quality problem close loop, but there is still a gap in the comprehensiveness and coverage.	2
The methods, procedures, and responsibilities of the corrective measures and five principles of quality problem close loop are clarified to form a document and standardization, which are implemented systematically and effectively, but deviations exist occasionally.	3
The corrective measures and five principles of quality problem close loop are scientifically, systematically and effectively responded to. Meanwhile, the methods are improved through monitoring, analysis and evaluation to avoid the recurrence of similar problems.	4
The organization comprehensively, systematically, and perfectly responds to corrective measures and five principles of quality problem close loop, and forms a continuous improvement mechanism through scientific monitoring, analysis and evaluation as well as continuous improvement and innovation.	5
Result/comments	

(7) Innovation management

Evaluation content	Maturity level
The innovations are limited. The introduction of new products is arbitrary and there is no planning for innovation.	1
The organization carries out innovation activities based on customer requirements and expectations.	2
The innovation process of new products and processes can identify changes in the organizational environment in order to make plans for innovation.	3
The organization prioritizes innovation based on urgency, the balance between resource availability and the organization's strategy. Suppliers and partners are also involved in the innovation process. The effectiveness and efficiency of the innovation process as part of the learning process is regularly evaluated. Innovation is used to improve the way an organization operates.	4
Innovative activities can predict possible changes in the organization's environment. A prevention plan is developed to avoid or mitigate the identified risks associated with innovative activities. Organizations have innovations in products, processes, organizational structures, operating models, and organizational management systems.	5
Result/comments	

□

II. Support process

1. Resources

(1) Human resources

Evaluation content	Maturity level
The people-oriented human resource system is basically not established.	1
The people-oriented human resource system is initially established.	2
Combine with the job descriptions of personnel in various departments (specifying the requirements for job competency requirements for staff who are engaged in affecting product quality) to ensure that the job descriptions conform to the actual situation of the organization; the HR department recruits according to the requirements of the job	3

description, train personnel, and implement the optimal allocation of post personnel. The HR department carries out quality awareness education to standardize employee behavior, pays attention to the physical and mental health of employees, mobilizes the enthusiasm of employees, encourage employees to make small reforms and rational suggestions, and improve employees' satisfaction with the company. The implementation is basically effective.	
The HR system has basically formed a mechanism for continuous improvement. The implementation is effective.	4
The human resource system forms a continuous improvement mechanism and is a benchmark for the industry.	5
Result/comments:	

(2) Basic infrastructure

Evaluation content	Maturity level
The basic infrastructure is prepared.	1
The organization's infrastructure is planned and managed. The requirements of laws and regulations are into consideration.	2
Configure the infrastructure according to the requirements of products and services, establish equipment accounts, prepare maintenance plans, implement maintenance according to the plan, pay attention to the management of process equipment (such as tooling, fixtures), and continuously improve the foundation the technical level of the facility; In the process of elimination, pay attention to factors such as environment, safety and resource consumption. The implementation is basically effective.	3
Configure the infrastructure according to the requirements of products and services, establish equipment accounts, prepare maintenance plans, implement maintenance according to the plan, pay attention to the management of process equipment (such as tooling, fixtures), and continuously improve the foundation the technical level of the facility; In the process of elimination, pay attention to factors such as environment, safety and resource consumption. The implementation is effective.	4
The performance and cost of the organization's infrastructure are better than similar organizations. Contingency plans are used to mitigate potential threats and explore new opportunities.	5
Result/comments:	

(3) Monitoring and measuring equipment □ □

Evaluation content	Maturity level
Basic monitoring and measuring equipment are prepared.	1
The organization's monitoring and measurement equipment is planned and managed. The requirements of laws and regulations are taken into consideration.	2
The organization provides monitoring and measurement equipment according to the development requirements of the organization's products and services; formulates and implement a monitoring and measurement equipment verification plan and implement verification on a periodic basis; continuously improves the technical level of monitoring and measurement equipment.	3
The risks of monitoring and measuring equipment are identified, and preventive measures are implemented.	4
The performance and cost of the organization's monitoring and measurement equipment are better than similar organizations. Contingency plans are used to mitigate potential threats and explore new opportunities.	5
Result/comments:	

(4) Process operating environment

Evaluation content	Maturity level
A basic process operating environment is prepared.	1
The process operating environment requirements are clarified to ensure that the process operating environment meets the requirements of corresponding laws and regulations.	2
The organization determines, provides and maintains the required environment; effectively manages the working environment such as temperature and humidity, static electricity, noise, such as CNC machining of precision aluminum parts, copper parts, and control of the ambient temperature for parts detection, equipped with temperature and humidity meters and temperature and humidity records; DENSO shall specify anti-static requirements, install static-discharging facilities, test the workbench insulation and keep records; considers the psychological factors of employees, detect occupational hazards in the workplace, and provide employees with labor protection equipment, provide appropriate protection and monitor them.	3
The risks of the process operating environment are identified, and preventive measures are implemented.	4
The performance of the organization's process operating environment is better than that of similar organizations. Contingency plans are used to mitigate potential threats and explore new opportunities.	5
Result/comments:	

(5) Information and knowledge resources

Evaluation content	Maturity level
A basic information and knowledge resource system are established.	1
The process of identifying, acquiring, protecting, using and evaluating information and knowledge resources as well as a basic communication system for sharing information and knowledge resources are implemented.	2
The organization organizes to identify and develop information sources, ensures that the required data and information are obtained and provided, and makes it easy for employees, suppliers, partners and customers to obtain relevant data and information. strengthens the declaration and management of organizational patents and achievements, clarify the competent departments, constantly sort out core technologies and key technologies, and implement relevant systems; collect, publicize and share knowledge of partners within the organization; The organization is able to cope with continuous changes in demands and development trends, and determines, acquires, and updates the necessary knowledge. The implementation is basically effective.	3
The organization shares information and knowledge resources with partners and other related parties.	4
The performance of information and knowledge resource management is better than other organizations.	5
Result/comments:	

(6) Relationship of related parties

Evaluation content	Maturity level
There is no systematic identification of the related parties and their requirements related to the quality management system.	1
The related parties (such as customers, employees, suppliers) and their requirements related to the quality management system are initially identified.	2
Related parties: customers (such as orderers, military representatives, users, general units); owners of the organization; external suppliers (such as components, raw materials,	3

process partners); partners (such as new product development cooperation units); employees of the organization. The organization identifies and manages the relationship between related parties, strengthens the collection and publicity of laws and regulations, establishes communication channels with related parties, and promotes win-win cooperation for the organization. The implementation is basically effective.	
The organization thoroughly understands the differentiated needs and expectations of different stakeholders and groups, effectively applies to the relationship management of related parties, and continuously deepens the understanding and application on the basis of monitoring, analysis and evaluation.	4
The organization comprehensively and systematically understands the differentiated needs and expectations of different stakeholders and their different groups, and effectively applies to drive the harmonious and win-win situation of all stakeholders with customer satisfaction and loyalty.	5
Result/comments:	

2. Documented information control

(1) Document control

Evaluation content	Maturity level
The regulation, creation, update, and control of documented information are not systematic, and are only accidental and partial.	1
The organization begins to establish, implement and maintain documented information of the quality management system based on the actual situation of the organization, and initially establishes a monitoring method for documented information.	2
The documents required by the quality management system should be controlled; refer to the relevant standards, specifications, product requirements and the organization's own requirements, and specify how to proofread, audit, process and quality countersign, standardized inspection, approval and the documents that customers need to countersign, and the eligibility requirements of the relevant signatories. The technical documents and drawings are consistent and effective; the organization shall appropriately identify and control documented information from external sources that is determined by the organization to be necessary for the planning and operation of the quality management system.	3
The documented information management corresponds with the reality of the organization and has been systematically and effectively implemented without obvious deviation. The documented information management is continuously monitored and optimized on the basis of analysis and evaluation to achieve better results.	4
The documented information management corresponds with the reality of the organization and is comprehensively, systematically and effectively implemented. The documented information management is continuously monitored, analyzed, and evaluated. Meanwhile, continuous improvement and innovation are performed, reflecting the best practices of the industry.	5
Result/comments:	

(2) Record control

Evaluation content	Maturity level
The regulation, creation, update, and control of documented information are not systematic, but are accidental and partial.	1
The organization begins to establish, implement, and retain documented information of the quality management system based on the actual situation of the organization, and initially establish a monitoring method for documented information.	2

Record identification (with unique name and number/version); record storage (insect-proof, moisture-proof, damage-proof, and loss-proof); record retrieval (requirements for easy search, cataloging, filing, and reference); record preservation period (preservation period is determined according to product characteristics and regulatory requirements); the destruction of expired records requires registration and approval. The implementation is basically effective.	3
The documented information management corresponds with the reality of the organization and is systematically and effectively implemented. The management of documented information is continuously monitored and optimized on the basis of analysis and evaluation to achieve better results.	4
The documented information management corresponds with the reality of the organization and is comprehensively, systematically and effectively implemented. The management of documented information is continuously monitored, analyzed, and evaluated. Meanwhile, continuous improvement and innovation are performed, reflecting the best practices of the industry.	5
Result/comments:	

III. Customer-oriented process

1. Design and development of products and services

(1) Product and service requirement

Evaluation content	Maturity level
The management and planning of product and service requirement is not systematic. Communication with customers, determination review, and changes of product and service requirements are carried out occasionally or partially.	1
The management and planning of product and service requirement is based on the actual situation of the organization. The communication with customers as well as the determination, review, and changes of product and service requirements are carried out initially.	2
The organization determines that the requirements related to the product include: the requirements specified by the customer, the implicit requirements of the customer, the laws and regulations related to the product, and the necessary requirements by the organization; the organization should ensure that it has the ability to provide customers with products and services that meet the requirements; when the change of the products affects the customer's requirements, the change should be approved by the customer. Most of the above content has been implemented well.	3
The relevant content of the product and service requirements are continuously, comprehensively, and strictly implemented, and the completion is relatively good. The monitoring system for product and service requirements are continuously improved.	4
The implementation of product and service requirements is comprehensive, systematic and effective, reflecting the best practices in the industry.	5
Result/comments:	

(2) Design and development process of product and service

Evaluation content	Maturity level
The management and planning for the design and development of products and services is not systematic. The design and development inputs are not reviewed.	1
The management and planning for the design and development of products and services is based on the reality of the organization. The design and development input are reviewed in accordance with regulations, and the work related to the design and development process of products and services is initially carried out.	2
Starting from the design and development plan, pay attention to the analysis of product	3

characteristics, and identify key characteristics and important characteristics; strictly design and development review, pay attention to the follow-up and implementation of review issues; pay attention to new product development (pre-production readiness inspection, first article appraisal, process review, quality delivery review); strictly follow the test outline to carry out the pre-test preparation status inspection, strengthen the handling of test problems, and notify users in time; standardize the design and development to ensure the process in control and form a long-term mechanism.	
The design and development of the product and service is continuously, comprehensively and strictly enforced, and the completion status is excellent. The monitoring system in terms of design and development are continuously improved and optimized, achieving good results.	4
The design and development of products and services are comprehensive, systematic and effective, reflecting the best practices in the industry.	5
Result/comments:	

(3) Technology management

Evaluation content	Maturity level
There is no documented technical status management procedure, and the technical status management is disorderly.	1
A documented technical state management procedure is formulated and formed, and the technical state management is initially implemented.	2
In accordance with GJB3206A, formulate and form the technical status management procedure and plan, specify the requirements related to stage, identification, control, documentation, functional audit and physical audit; strengthen the management of functional baseline, allocation baseline, and product baseline; strengthen the category of design and change, and the management and approval of design changes to ensure controlled management.	3
Technical status management corresponds with the reality of the organization, the system is effective, and the improvement orientation is obvious.	4
The technical status management is comprehensive, systematic and effective, reflecting the best practices in the industry.	5
Result/comments:	

(4) General quality characteristic management

Evaluation content	Maturity level
There is no documented general quality characteristic management procedure, and the general quality characteristic management is disorderly.	1
A documented general quality characteristic management procedure is formulated and formed, and the general quality characteristic management is initially implemented.	2
The organization determines the qualitative and quantitative requirements of general quality characteristics and work item requirements according to standards such as GJB450, GJB368, GJB3872, GJB2547, GJB900, GJB4239, GJB1909, manage the six properties including reliability, formulate six-property-related outlines and analysis reports, conduct reliability verification, strictly organize a special review of the environmental appraisal outline, and carry out environmental appraisal tests in accordance with procedures, and implement double “five to zero” work.	3
The general quality characteristic management corresponds with the reality of the organization, the system is effective, and the improvement orientation is obvious.	4
The general quality characteristic management is comprehensive, systematic and effective, reflecting the best practices in the industry.	5
Result/comments:	

(5) New product trial production

Evaluation content	Maturity level
The trial production of new products is basically not implemented.	1
The trial production of new products is initially implemented and needs to be further implemented in accordance with the requirements of the corresponding standards.	2
The organization should formulate control procedures related to the trial production process of new products, strictly control the change of technical status, and formulate process reviews in stages. The quality department or technical department organizes and conducts product quality preparation check, the process department organizes the first article identification, and the quality department organizes the product quality review.	3
The trial production of new products corresponds with the reality of the organization, the system is effective, and the improvement orientation is obvious.	4
The trial production of new products is comprehensive, systematic and effective, reflecting the best practices in the industry.	5
Result/comments:	

(6) Trial control

Evaluation content	Maturity level
The test program planning is not in place, and it is not reviewed as required and could not be implemented effectively.	1
The experimental control is implemented initially, and further specifications are needed.	2
Prepare a “test program” according to the specified requirements, and clarify the requirements of purpose, project, content, condition, procedure, mean and record of the test; for the test concerned by the customer, the test program should be approved by the customer. Check the preparation status before the test, such as the training and labor division of the test personnel, whether the status of the products to be tested meets the requirements, whether the calibration status of the test equipment and testing instruments meets the requirements. Carry out the test according to the test outline, record the test data and test process according to the specified requirements, and ensure the completeness and accuracy of the test data.	3
The test control corresponds with the reality of the organization, the system is effective, and excellent results are achieved.	4
The test control is comprehensive, systematic and effective, reflecting the best practices in the industry.	5
Result/comments:	

2. Product production and service provision

(1) External provision process

Evaluation content	Maturity level
The management and planning for the control of externally provided processes, products and services are not systematic and are only carried out accidentally or partially.	1
The management and planning for the control of externally provided processes, products and services is based on the reality of the organization. The selection, evaluation, performance monitoring, re-evaluation, communication of external suppliers, verification of externally provided processes, products and services are initially carried out, and the preliminary monitoring methods for the project are established.	2
Compile a list of qualified suppliers, dynamically evaluate suppliers and effectively identify risks; the determination of procurement projects and suppliers should be fully	3

demonstrated and approved according to regulations; the technical requirements and quality assurance requirements for the supplier are specified in the technical agreement/contract; the product can be used after verification and confirmation that it meets the requirements.	
The monitoring system for the control of externally provided processes, products and services are continuously improved and optimized. Corresponding informatization and intelligent methods are used, and analysis and evaluation are carried out based on monitoring. When necessary, improvements and innovative measures are taken to improve performance and achieve good results.	4
Comprehensive and scientific analysis, evaluation, improvement, and innovation are carried out on the monitoring results of externally provided processes, products and service control, reflecting the best practices in the industry.	5
Result/comments:	

(2) Control of product production and service provision

Evaluation content	Maturity level
The management and planning for production and service provision are not systematic. Production and service provision control, labeling and traceability implementation, customer and supplier property management, effective protection, and post-delivery activity control are only carried out accidentally or partially.	1
The management and planning for production and service provision are based on the actual situation of the organization. Production and service provision control, labeling and traceability implementation, customer and supplier property management, effective protection, and post-delivery activity control are carried out initially, but there are still gaps in coverage. Preliminary monitoring methods for production and service provision are established.	2
For special processes (heat treatment, surface treatment), process evaluation should be implemented, and the ability of output and service processes to achieve planned results should be confirmed, and re-confirmed regularly; conduct self-check and special-check on the first article and implement control on additional items to ensure that the organization conducts production and service provision under controlled conditions. The implementation is basically effective.	3
The management and planning output of production and service provision correspond with the reality of the organization, and the system is effective. The improvement orientation is obvious. Production and service provision control, labeling and traceability implementation, customer and supplier property management, effective protection, post-delivery activity control are continuously and fully implemented strictly, without obvious deviation. The completion is excellent. The monitoring system for production and service provision are continuously improved and optimized, achieving excellent results.	4
The comprehensive and scientific analysis, evaluation, improvement and innovation of the monitoring results of product production and service provision control reflect the best practices in the industry.	5
Result/comments:	

(3) Identification, protection and traceability

Evaluation content	Maturity level
The batch management is initially established, with some product identification, protection and traceability management requirements.	1
The batch management are carried out initially, but it is not comprehensive enough.	2
The organization shall implement batch management of products according to regulations, and establish a batch management system. It is necessary to achieve “five clears”, that is, clear product batch, clear quality status, clear original records, clear	3

quantities, and clear furnace batch numbers; and “six batches”, that is, batch material feeding in batches, processing in batches, transferring in batches, storage in batches, assemble in batches, leave the factory in batches, and keep the batch marks of the products from material feeding to assembly and delivery. Records are established by batches, such as on-process flow cards to record the material feeding, processing, assembly, commissioning, inspection, quantity and quality of delivery, operator and inspector, and keep them as required. The batch identification of the product should be consistent with the original production records, such as product number, batch number, model, date. The records should be able to trace the situation of the product before delivery as well as the distribution and location after delivery.	
The identification, protection and traceability are continuously and fully implemented strictly, without obvious deviation, and the completion status is excellent.	4
The comprehensive and scientific analysis, evaluation and improvement of the monitoring results in terms of identification, protection and traceability reflect the best practices in the industry.	5
Result/comments:	

(4) Key process control

Evaluation content	Maturity level
The key process is initially established, and there are some key process control requirements.	1
The key process is initially carried out, and the process capability analysis are basically not implemented.	2
The organization has identified key processes, compiled a list of key processes, and implemented key process control; implement management of key processes in accordance with GJB909A *Quality Control of Key Parts and Important Parts* and GJB467 *Process Quality Control Requirements*, and ensured most process capability of the key processes meets the requirements.	3
The key process is continuously and fully implemented strictly, without obvious deviation, and the completion is excellent.	4
The comprehensive and scientific analysis, evaluation and improvement of the monitoring results of key processes reflect the best practices in the industry.	5
Result/comments:	

(5) Release of products and services

Evaluation content	Maturity level
The relevant requirements for the release of products and services are not clear, and the acceptance personnel are not authorized.	1
The release of products and services are carried out initially, and the acceptance personnel are basically authorized.	2
The inspection and test records that the product complies with the acceptance criteria; the authorized release personnel (such as the signature of the inspection, the inspection stamp); the relevant product certification and inspection, test records and records of quality problems or failures; emergency exception release shall be subject to the consent of the customer.	3
The release of products and services has been continuously and fully implemented strictly, without obvious deviation, and the completion status is excellent.	4
The comprehensive and scientific analysis, evaluation and improvement of the monitoring results on the release of products and services reflect the best practices in the industry.	5
Result/comments:	

(6) Non-conforming product management

Evaluation content	Maturity level
The relevant requirements for the review of non-conforming products are not specified, and the reviewers are not authorized.	1
The trial of non-conforming products is carried out initially, and the trial personnel are basically authorized.	2
The organization forms a document in accordance with GJB 571 requirements, compile non-conforming product control procedures, clarify the authorization of non-conforming product personnel, and conduct non-conforming product trial in strict accordance with the procedures; Meanwhile, key features are not allowed to be used concessions. Most of the above content has been implemented, and significant results have been achieved.	3
The management of non-conforming products has been continuously and fully implemented strictly, without obvious deviation, and the completion status is excellent.	4
The comprehensive and scientific analysis, evaluation and improvement of the monitoring results in the management of nonconforming products reflect the best practices in the industry.	5
Result/comments:	

(7) After-sales service

Evaluation content	Maturity level
The process of after-sales service and the relevant provisions of after-sales guarantee are not clarified, and the construction of the after-sales personnel team is not clarified.	1
After-sales service are initially carried out, after-sales service procedures are determined, and after-sales organization and after-sales personnel management are clarified.	2
The organization completes technical training on product use and maintenance as required, ensures that technical documents related to product use and maintenance are controlled and updated, ensures to provide technical support and resources, and appoint technical service personnel to provide on-site services. When problems are found after delivery, appropriate measures such as investigation, handling and reporting should be taken, and their effectiveness should be verified. Most of the above content has been implemented and achieved obvious results.	3
After-sales service are continuously and fully implemented strictly, without obvious deviation, and the completion is excellent.	4
The comprehensive and scientific analysis, evaluation and improvement of the after-sales service monitoring results have resulted in high customer satisfaction, reflecting the best practices in the industry.	5
Result/comments:	

IV. Result

1. Quality management result

(1) Customer satisfaction results

Evaluation content	Maturity level
The relevant requirements for customer satisfaction information collection, statistics, analysis, and disposal are not clearly defined. There is a small amount of customer satisfaction information collection, and there lacks relevant evidence for statistics, analysis, and disposal.	1
The relevant requirements for customer satisfaction information collection, statistics, analysis and disposal are clarified, customer satisfaction information is collected to perform statistics and analysis and form closed-loop management.	2

The current level and trend of the key performance indicators of customer satisfaction are good, KPI include customer satisfaction, customer complaint rate and timely after-sales service rate; benchmarking results include comparison of segmented data; customer loyalty KPIs include recognition from customers and evaluation agencies. No customer complaints during the year, and customer satisfaction is above 85%.	3
The current level and trend of key performance indicators of customer satisfaction are excellent, the results of customer satisfaction compared with competitors and industry benchmarks are excellent, the current level and trend of key performance indicators of customer loyalty are excellent. No customer complaints during the year, and customer satisfaction is above 90%.	4
The comparison of customer satisfaction with competitors and industry benchmarks achieves industry benchmarks and is sustainable. Customer satisfaction is above 95%.	5
Result/comments:	

(2) Quality management system results

Evaluation content	Maturity level
The current level and trend of the organization's key performance indicators reflect that the effectiveness and efficiency of key processes are poor.	1
The current level and trend of the organization's key performance indicators reflect that the effectiveness and efficiency of key processes have reached a general level (including all-employee labor productivity, quality, cost, cycle time, supplier and partner performance, and other effectiveness measurement results).	2
The current level and trend of the organization's key performance indicators reflect that the effectiveness and efficiency of key processes have reached a good level (including all-employee labor productivity, quality, cost, cycle time, supplier and partner performance, and other effectiveness measurement results).	3
The current level and trend of the organization's key performance indicators reflect that the effectiveness and efficiency of key processes have reached an excellent level (including all-employee labor productivity, quality, cost, cycle time, supplier and partner performance, and other effectiveness measurement results).	4
The current level and trend of the organization's key performance indicators reflect the effectiveness and efficiency of key processes have reached benchmark levels (including all-employee labor productivity, quality, cost, cycle time, supplier and partner performance, and other effectiveness measurement results).	5
Result/comments:	

(3) Products and services results

Evaluation content	Maturity level
The current KPI of main products and services is poor. KPI include six indicators such as the function and reliability of products and services, delivery cycle, after-sales service or technical support; results of comparison with competitors, comparison with international and domestic similar products; achievements, patents, brands, trademarks related to main products and services, advantages in energy conservation and environmental protection.	1
The current KPI of main products and services is average. KPI include six indicators such as the function and reliability of products and services, delivery cycle, after-sales service or technical support; results of comparison with competitors, comparison with international and domestic similar products; achievements, patents, brands, trademarks related to main products and services, advantages in energy conservation and environmental protection.	2
The current KPI of main products and services is good. KPI include six indicators such as the function and reliability of products and services, delivery cycle, after-sales service	3

or technical support; results of comparison with competitors, comparison with international and domestic similar products; achievements, patents, brands, trademarks related to main products and services, advantages in energy conservation and environmental protection.	
The current KPI of main products and services is excellent. KPI include six indicators such as the function and reliability of products and services, delivery cycle, after-sales service or technical support; results of comparison with competitors, comparison with international and domestic similar products; achievements, patents, brands, trademarks related to main products and services, advantages in energy conservation and environmental protection.	4
The results of products and services are comprehensively and scientifically analyzed, evaluated, improved, and innovated, and the results have reached a benchmark level.	5
Result/comments:	