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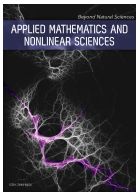

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Factors Influencing the Cooperative Relationship between Enterprises in the Supply Chain of China's Marine Engineering Equipment Manufacturing Industry-An study based on GRNN-DEMATEL method

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Abstract

Based on the data of China's Marine engineering equipment industry, in this Paper, the key influencing factors are identified by using Grounded theory and GRNN-DEMATEL method. The study results show the key influencing factors include enterprise's operational, technical capabilities, enterprise's social recognition, enterprise's willingness to cooperate, trust between enterprises, communication and collaboration, opportunism and external environment. Second, enterprise's operational and technical capabilities are the most important and critical factors, external environment is an irresistible factor. This study enriches and develops the study of supply chain management, and provides theoretical guidance and reference for improving the industry competitiveness.

Keywords:cooperative relationship between enterprises in the supply chain; GRNN-DEMATEL; Grounded Theory; marine engineering equipment manufacturing industry
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1 Introduction

Marine engineering equipment manufacturing industry (hereinafter referred to as "marine industry") is the important prerequisite and foundation for the development of marine economy, and has great strategic significance for promoting the transformation and upgrading of marine manufacturing industry and accelerating the pace of building a maritime power [1]. Since 2010, China has successively formulated multiple plans, including *Innovation and Development Strategy for Marine Engineering Equipment Industry, Medium- and Long-term Development Plan for Marine Engineering Equipment Manufacturing Industry (2011 2020), and Made in China 2025*. At present, China's marine engineering equipment manufacturing industry has made great progress, but

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its development is still in at the middle and end of the world's marine industry development chain, and technology, products, etc. need to be improved. Along with the increasingly fierce global competition, the increasingly shortened product life cycle, and the enhancement of market demand drive function, one of the main problems to be solved for China's marine industry enterprises is to improve their own competitive advantages and the core competitiveness of the entire supply chain.

Supply chain is based on the premise of meeting customer demands, and centers on the core enterprises to win the market with the lowest cost, the fastest speed, the best quality, the best service through the control over information flow, material flow and capital flow throughout the process from the purchase of raw materials to completion of intermediate products and final products [2]. At present, the cooperation between enterprises in supply chain has changed from one-to-one cooperation to multi-enterprise cooperation, with strategic cooperation alliance among enterprises in supply chain formed finally [3]. Ma Shihua [3] pointed out that, inter-enterprise competition is no longer the competition launched by a single enterprise in a certain time and space to compete for market share of certain terminal markets, but the overall competition across time and space and based on product design, manufacturing, delivery and distribution, sales and services, and has transformed into supply chain efficiency competition. The supply chain mainly reflects the enterprise orientation based on market demand. In the processes of technology research and development, processing and production, the modularization and standardization degree of products are increasingly improved, and the integrated utilization of internal and external resources as well as the flexibility and agility in response to the market are enhanced [5]. Selective cooperation between nodal enterprises in the supply chain is the only way for enterprises to grow cooperatively. Supply chain cooperative relationship refers to the cooperative relationship in which both parties in the cooperation undertake a series of exchange activities under the mode of sharing risks and benefits, with a complete set of monitoring mechanism established and implemented [6,7]. Therefore, based on the characteristics of marine engineering equipment manufacturing industry, this Paper proposes that the relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry refers to the close connection between the upstream and downstream enterprises of the marine industry in a certain form of cooperation, and a development system to enhance the core competitiveness of enterprises and achieve the overall strategic objectives of China's marine industry shall be established. The building of cooperative relationship between enterprises in the supply chain of marine industry is of great theoretical and practical guidance significance to China's marine industry in terms of improving the overall competitiveness, and enterprise's technological and management ability and comprehensive strength.

Currently, the studies on the marine industry are mostly studies on the strategic countermeasures of industrial development, on evaluations for industrial development potential, and on industrial mechanism. Based on the in-depth study on the development status of China's marine engineering equipment manufacturing industry, Zhao Jinlou has explored the problems in the marine industry development and put forward relevant strategies [1]. With SWOT-AHP analysis method, Zhang Wei has proposed the development strategy and policy for China's marine engineering Marine engineering equipment manufacturing industry (hereinafter referred to as "marine industry") is the important prerequisite and foundation for the development of marine economy, and has great strategic significance for promoting the transformation and upgrading of marine manufacturing industry and accelerating the pace of building a maritime power [1]. Since 2010, China has successively formulated multiple plans, including Innovation and Development Strategy for Marine Engineering Equipment Industry, Medium- and Long-term Development Plan for Marine Engineering Equipment Manufacturing Industry (2011 2020), and Made in China 2025. At present, China's marine engineering equipment manufacturing industry has made great progress, but its development is still in at the middle and end of the world's marine industry development chain, and technology, products, etc. need to be improved. Along with the increasingly fierce global competition, the increasingly shortened product life cycle, and the enhancement of market demand drive function, one of the main problems to be solved for China's marine industry enterprises is to improve their own competitive advantages and the core competitiveness of the entire supply chain. Supply chain is based on the premise of meeting customer demands, and centers on the core enterprises to win the market with the lowest cost, the fastest speed, the

best quality, the best service through the control over information flow, material flow and capital flow throughout the process from the purchase of raw materials to completion of intermediate products and final products [2]. At present, the cooperation between enterprises in supply chain has changed from one-to-one cooperation to multi-enterprise cooperation, with strategic cooperation alliance among enterprises in supply chain formed finally [3]. Ma Shihua [3] pointed out that, inter-enterprise competition is no longer the competition launched by a single enterprise in a certain time and space to compete for market share of certain terminal markets, but the overall competition across time and space and based on product design, manufacturing, delivery and distribution, sales and services, and has transformed into supply chain efficiency competition. The supply chain mainly reflects the enterprise orientation based on market demand. In the processes of technology research and development, processing and production, the modularization and standardization degree of products are increasingly improved, and the integrated utilization of internal and external resources as well as the flexibility and agility in response to the market are enhanced [5]. Selective cooperation between nodal enterprises in the supply chain is the only way for enterprises to grow cooperatively. Supply chain cooperative relationship refers to the cooperative relationship in which both parties in the cooperation undertake a series of exchange activities under the mode of sharing risks and benefits, with a complete set of monitoring mechanism established and implemented [6, 7]. Therefore, based on the characteristics of marine engineering equipment manufacturing industry, this Paper proposes that the relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry refers to the close connection between the upstream and downstream enterprises of the marine industry in a certain form of cooperation, and a development system to enhance the core competitiveness of enterprises and achieve the overall strategic objectives of China's marine industry shall be established. The building of cooperative relationship between enterprises in the supply chain of marine industry is of great theoretical and practical guidance significance to China's marine industry in terms of improving the overall competitiveness, and enterprise's technological and management ability and comprehensive strength.

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tors and 34 second-level indicators [14]. Cheng Yifei and Jia Xiangfeng have studied the exit mechanism of marine engineering equipment enterprises under environmental control from the perspective of public security interests and on the basis of analyzing the characteristics and policy institution of marine engineering equipment manufacturing industry [15]. With the structural equation model, Jia Xiaoxia and Xiahou Shuqin have concluded the influencing mechanism of network embedding on enterprise's technological innovation ability by taking 105 marine equipment manufacturing enterprises as the study objects [16, 17]. With non-parametric Malmquist production efficiency method,Hong Xinyang has explored the reasons for the changes in enterprise's technological innovation efficiency from the perspective of technological progress and technological efficiency and by taking 10 listed companies in marine engineering equipment manufacturing industry as the study objects [18].

At present, scholars have studied the development strategy and industrial evaluation of China's marine industry. However, there are few studies on the cooperative relationship between enterprises in the supply chain of marine industry. Under such background of study, in this Paper, China's marine engineering equipment manufacturing enterprises are selected as the study objects, and the Grounded Theory qualitative study method is used to identify the factors influencing the cooperative relationship between enterprises in the supply chain of China's marine industry. Meanwhile, based on traditional DEMATEL method, GRNN (Generalized Regression Neural Network) is used in this Paper [19]. GRNN can effectively improve the feasibility of the direct correlation matrix analysis results. Besides, G-M method inherits and retains the "D-R" and "D+R" in traditional DEMATEL method to judge the importance of indicators, which has certain reference and expansion value for the relevant decision-making in the management for cooperation between enterprises in the supply chain of China's marine engineering equipment manufacturing industry.

2 Literature Review

The study on the factors influencing the cooperative relationship between enterprises in the supply chain is mainly divided into two perspectives: theoretical study and empirical study.

In terms of theoretical study, Zhang Cuihua et al. have proposed that the factors influencing the collaborative relationship between enterprises in the supply chain include inter-alliance-partner strategic factor and technical implementation factor [20], and based on B-S relationship, Ling Hong et al. [21] have proposed that organizational factor, environmental factor and technical factor are important factors influencing the cooperative relationship in the supply chain. Meanwhile, based on the above studies, it is pointed out that the degree of trust, the degree of information sharing and the quality of information sharing are important factors for the sustainable development of inter-enterprise relationship. Myhr has pointed out that the cooperative relationship between enterprises in the supply chain is affected by internal and external factors, where the external influencing factors include trust between enterprises, supply chain reliability, high-level support, common interests, information sharing, etc., and internal influencing factors include inter-enterprise commitments, enterprise cognition, internal management, etc. [22]. Zeng Wenjie and Ma Shihua have studied the factors influencing the collaborative relationship between node enterprises in the supply chain from the perspective of relationship in the supply chain, mainly including four measuring angles, i.e. communication, trust, commitment and cooperation [23]. Besides, product quality, delivery cycle, cost and inter-enterprise effective communication and service are important factors influencing the cooperative relationship between node enterprises in the supply chain. In addition, the supplier's product development and production, external environment of supply chain and other factors [24, 25] also shall be included. Based on a friendship cooperation model between enterprises in the supply chain, Drake has pointed out that the inter-enterprise communication, trust mechanism and performance are the key links for the orderly maintenance of the friendship inter-enterprise cooperative relationship [26].

In terms of empirical study of specific industries or enterprises in the supply chain, basing on the empirical study on inter-enterprise cooperative relationship, AKkermans et al. have pointed out that trust, commitment and rights are also important factors affecting inter-enterprise cooperation [27]. Through studying the performance of inter-enterprise cooperation, Pan Wen'an [28] has proposed that inter-enterprise partnership is affected by

organizational trust, relationship commitment and interdependence. Based on the study on manufacturing enterprises in the supply chain in Pearl River Delta of China, Ye Fei proposed that trust and commitment in supply chain partnership have a positive impact on the performance of inter-enterprise cooperation [29]. Based on the study on the manufacturing industry, Song Hua et al. have pointed out that the quality of inter-enterprise cooperation is an important indicator to ensure the maintenance of cooperation, and in addition, inter-enterprise cooperation conflicts are inevitable and must be solved in cooperation, and can point out the direction for future cooperation [30]. Through studying the manufacturing industry, service industry, information technology industry, real estate industry, etc, Li Yi believed that environmental dynamics, supplier dependence, willingness to commit and trust were important considerations affecting the selective cooperation among enterprises, and also affected the time dimension of cooperation among enterprises [31]. Dang Xinghua [32], based on the study on influencing factors under supply chain collaborative alliance mode, proposed that environmental factor, technological factor and internal organization are the important factors affecting the cooperative relationship, and refined these three factors into 11 second-level factors. Qiao Yanfen [33], based on the study on the factors influencing relationship between node enterprises in the supply chain from the perspective of taking manufacturer as the core, proposed three categories: product factor, technical factor and human factor.

There are few studies on the factors influencing the cooperative relationship between enterprises in the supply chain of China's marine industry, and the confidentiality of marine industry itself leads to the lack of relevant materials and historical data. Grounded Theory is a kind of inductive study on phenomena, and its essence lies in a series of spiral cycle progressive lifting processes of induction, comparison and analysis based on scientific logic [34], which ultimately form outline concept and theory; Grounded Theory has systematic and procedural characteristics, and its collection of relevant study data does not need to rely on historical data.

In view of the above studies, Grounded Theory analysis method has good tacit agreement with the study on the factors influencing the cooperative relationship between enterprises in the supply chain of China's marine engineering equipment manufacturing industry. First, most of the existing literatures directly determine the factors influencing the cooperative relationship between China's marine engineering equipment manufacturing enterprises on the basis of static analysis and scenario hypothesis, and hereby propose the strategies for improving management level for supply chain of marine engineering equipment manufacturing industry, lacking effective identification and analysis for the influencing factors. Because there are many factors influencing the cooperative relationship between enterprises in China's marine engineering equipment manufacturing industry, different factor analysis methods can bring diverse study conclusions. Second, based on the technological confidentiality, dynamics and complexity of marine engineering equipment manufacturing industry, Grounded Theory is very suitable for extracting the factors influencing the cooperative relationship between enterprises of China's marine engineering equipment manufacturing industry, identify the key influencing factors, and hereby build the corresponding theoretical model. Third, through the case analysis for China's marine engineering equipment manufacturing enterprises, it is easier to explain the role of the factors affecting the cooperative relationship between enterprises in the supply chain. Therefore, in this Paper, China National Offshore Oil Corp (CNOOC), Shanghai Waigaoqiao Free Trade Zone Group Co., Ltd., CIMC Raffles Offshore Co., Ltd., Dalian Shipbuilding Industry Group Co., Ltd., COSCO (Nantong) Shipyard Co., Ltd. and the subsidiaries of these corporations are taken as the main study objects, the Grounded Theory is used to collect and analyze data, and explore and construct the model study on the factors influencing the cooperative relationship between enterprises of China's marine engineering equipment manufacturing industry, and meanwhile G-D method is adopted to judge the identified key influencing factors.

3 Study Design

3.1 Study method

Grounded Theory was first proposed by Glaser and Strauss [34, 35]. It is a process of transforming data into concepts by inductive method after systematic data collection and mining and hereby establishing theory, and a more scientific qualitative study method. Grounded Theory emphasizes the collection and collation of data, and starts with ensuring the correctness and credibility of study conclusions. Its main purpose is to describe the properties and significance of the phenomenon from the theoretical level, and hereby establish a theory to collate, summarize, deduce and normalize various documents [36, 37].

3.2 Sources and collection of data

Based on the theoretical sampling principle, in this Paper, the data is collected from multiple channels to improve the reliability, credibility and validity of study conclusions. The main sources of data selected are as follows: (1) enterprise's official website [data collation covers the development history, profile, annual report, major news, organizational structure, and core technologies (including submersible drilling platform, 981 drilling platform, jack-up drilling platform, deep-water pipe-laying crane vessel) of enterprises, as well as R&D team building, infrastructure supporting, etc.]; (2) TV, network and other media: to collect character interviews about marine engineering equipment manufacturing enterprises, to read/watch relevant articles and videos; (3) Network and TV media: to collect the development trend information, statistical yearbooks, news reports, industrial policies, regional policies and industrial development reports of marine engineering equipment manufacturing industry; (4) Phone call or face-to-face interviews with middle and senior enterprise managers: to collect relevant information about inter-enterprise cooperation. In order to ensure the heterogeneity and reliability of data collected, there are four main stages in data collection [38], as shown in the Figure 1 below.

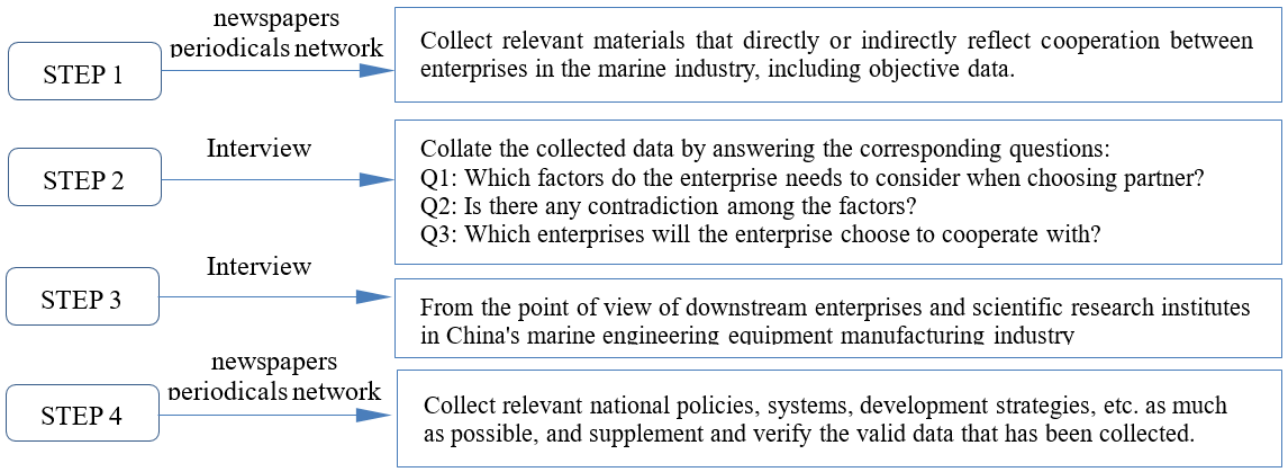

Fig. 1 Data collection and processing steps based on Grounded Theory

In the above steps, the work on collection and collation of relevant data lasted 12 months. In the early stage, the data on development background, growth process, major adjustment, etc. of upstream and downstream enterprises including 6 marine engineering final assembly enterprises and 18 final assembly enterprises were collected and collated. Besides, based on the company profile, rules and regulations, and important development strategies on the enterprise websites and brochures, data totaling 20,000 words was collated. In-depth interviews with senior and middle managers of four cooperative upstream and downstream enterprises were conducted, based on which interview memorandum (including outline, notes, summary, etc.) totaling 60,000 words was formed. Major corporations for whom the relevant data is collated are as shown in the following Table 1.

Table 1: Basic sample description

Enterprise name	Establishment time	Overview
China National Offshore Oil Corp. (CNOOC)	**1982**	China National Offshore Oil Corp. (CNOOC), a super large state-owned enterprise directly affiliated to the State-owned Assets Supervision and Administration Commission of the State Council of China, is China's largest offshore oil and gas producer. Since its establishment, CNOOC has maintained a good development trend. The "Ultra-deepwater Semi-submersible Drilling Platform Development and Application" project jointly completed by CNOOC and other units won the special prize of 2014 National Science and Technology Progress Award.
CIMC Raffles Offshore Co., Ltd.	**1982**	CIMC Raffles Offshore Co., Ltd. ("CIMC Raffles") is a wholly-owned subsidiary of CIMC Group. It has four marine research institutes (which are respectively located in Yantai, Shanghai, Norway and Sweden) and three construction bases (which are respectively located in Yantai, Haiyang and Longkou) to form the overall industrial structure of "four institutes and three bases", and has nearly 10,000 employees. Its main businesses include the design, construction, maintenance and renovation of different marine equipment such as drilling platforms, production platforms, marine engineering vessels, offshore support vessels, marine ranch platforms, offshore wind turbine vessels, luxury yachts and high-end cruise ships, and offshore complexes, the operation and leasing of equipment, and "turnkey" general contracting services for customers.
Shanghai Waigaoqiao Shipbuilding Co., Ltd.	**1999**	Shanghai Waigaoqiao Shipbuilding Co., Ltd. is a listed company under China State Shipbuilding Corporation - a wholly-owned subsidiary of China CSSC Holdings Limited. The Company wholly owns SWS Offshore, and holds the controlling share of Shanghai Jiangnan Changxing Heavy Industry Co., Ltd., SWS Offshore Design Co., Ltd., etc.
Dalian Shipbuilding Industry Co., Ltd.	**1898**	Dalian Shipbuilding Industry Co., Ltd. (Dalian Shipbuilding Industry) belongs to China Shipbuilding Industry Corporation. It is a domestically leading and internationally renowned shipbuilding enterprise and can provide users with life cycle services ranging from product research and development, design and construction to product maintenance, refitting and green disassembly.
COSCO (Nantong) Shipyard Co., Ltd.	**1977**	COSCO (Nantong) Shipyard Co., Ltd. is one of the core enterprises of COSCO Shipyard under COSCO. The Company was founded in December 1977, and has undergone three major development stages: Nantong Shipyard of the Ministry of Communications, Nantong Ocean Shipping Engineering Co., Ltd. and COSCO (Nantong) Shipyard Co., Ltd. Marine Engineering Technology Research and Development Center of COSCO (Nantong) Shipyard Co., Ltd., a national enterprise technology center specializing in the technical design and development of marine engineering equipment.

Remarks: such relevant data is extracted from the enterprise profile on related enterprise websites.

3.3 Identification of the Factors Influencing the Cooperative Relationship Between Enterprises in the Supply Chain of China's Marine Engineering Equipment Manufacturing Industry

In this Paper, the Grounded Theory study method is used to collate and analyze the collected data and to refine the concepts, categories and their internal relationships from a large number of surveys and collected network self-intersections [38] to relatively, comprehensively and objectively identify the factors influencing the cooperative relationship between enterprises in the supply chain of China's marine engineering equipment manufacturing industry. At present, the most widely used Grounded Theory study method is procedural grounded theory study method.

3.4 Open coding

Open coding refers to the process of gradually conceptualizing and categorizing the acquired data records, and then correctly reflecting the data content with the concepts and categories, and breaking, crushing and re-integrating the data records and the abstracted concepts. The main purpose of open coding is to identify phenomena, define concepts and discover categories, i.e., to deal with the problem of data convergence [18]. Defining concepts refers to the process of summarizing different original data, establishing different free nodes and finally naming them unifiedly. Discovering categories refers to the process of converging and naming similar concepts. Based on above related original data, in this Paper, the data is coded and modeled, and meanwhile, the reserved part of the original data is used for theoretical saturation test. In order to ensure the correctness of understanding, through collating and classifying the original data and reading and analyzing the interview data of marine engineering equipment manufacturing industry and the related industry news trends word by word with the help of NVIVO 10.0 program, 316 original sentences are sorted out and more than 600 nodes are abstracted from the original sentences, based on which 100 concepts are synthesized. Category is the re-classification and re-integration for many concepts, i.e. category is the subsequent analysis focus [19].

3.5 Axial coding

Axial coding is a better development category based on the property and dimension of category. In this Paper, the relevance of different categories is obtained through studying the open coding, and further summarization and integration is performed to form a more conceptual fundamental category. Based on the analysis for the current situation of technological innovation and development and inter-enterprise cooperative relationship in China's marine engineering equipment manufacturing industry, 34 categories were summarized into 7 fundamental categories.

3.6 Selective coding

Selective coding is to systematically link the core category with other categories by logical relations, and to complete the categories that are not fully developed. The main task of this process is to identify the core category [40] which can dominate other categories. All concepts are explained concisely by developing story lines, canonical relation structure and developed categories. In this Paper, the canonical relation structure is used to determine the core category, i.e. cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry, and three fundamental categories, i.e. selection of partners for cooperation between enterprises in the supply chain, behavior for cooperation between enterprises in the supply chain, and external environment, based on which the story line of the core category is described. The behavior for cooperation between enterprises in the supply chain of marine engineering equipment manufacturing industry determines the development of the cooperative relationship between enterprises. The performance of the core enterprises in the supply chain is used to check the quality of the cooperative relationship. Some uncontrollable external factors are also important influencing factors for the development of enterprises.

Table 2: Canonical relations of fundamental categories

Selection of partners for cooperation between enterprises in the supply chain factor influencing the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry	The technical capability and operation situation of marine engineering equipment manufacturing enterprises are the important prerequisites and primary considerations for choosing partners for cooperation between enterprises in the supply chain of marine engineering equipment manufacturing industry. Enterprise's social recognition and willingness to cooperate are the necessary and sufficient conditions for the final determination of the cooperative relationship between enterprises.
Behavior for cooperation between enterprises in the supply chain factor influencing the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry	Trust, communication and collaboration, and opportunism between enterprises in the supply chain are important behaviors for cooperation between enterprises in the supply chain, and they are also important means to affect the maintenance and development of cooperation between enterprises in China's marine engineering equipment manufacturing industry.
External environment factor influencing the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry	External environment mainly refers to the policy environment and market environment, etc. faced by the industry. The guidance from the government and the support from financial institutions are the basic guarantees for the technological innovation of marine engineering equipment manufacturing enterprises. The constant changes in market demand play an important guiding role in the technological innovation of marine engineering equipment manufacturing industry.

3.7 Theoretical saturation test

The so-called saturation means that the data collection can be stopped if data on the characteristics of a certain category cannot be further developed, that is, theory tends to be saturated. In order to ensure the creditability of the study, in this Paper, theoretical saturation test is performed for above conclusions. In this study, open coding, axial coding and selective coding were performed for the reserved 1/3 of original materials, and no frequent new concepts and categories were found in the testing process, so above theoretical model is saturated.

3.8 Determination of influencing factors and model interpretation

Through open coding, axial coding, selective coding and analysis and study on the canonical relationship structure, the core category (i.e. cooperation between enterprises in the supply chain of marine engineering equipment manufacturing industry) is determined, and on this basis, model of the factors influencing the cooperative relationship between enterprises of China's marine engineering equipment manufacturing industry is constructed (as shown in Fig. 2). The study indicates that the 7 major influencing factors (i.e. fundamental categories) are respectively enterprise's operational and technical capabilities, corporate reputation, enterprise's willingness to cooperate, trust between enterprises in the supply chain, communication and collaboration between enterprises in the supply chain, opportunism and external environment.

1) Enterprise's operational and technical capabilities

Enterprise's operational capability is the comprehensive embodiment of the enterprise's own capability in its daily business activities. Especially when the operation objectives of high-tech enterprises are consistent with those of other enterprises, the enterprises will express friendly willingness to cooperate. Enterprise's operational capability reflects the timeliness, management capability, product capability and ability to react to market conditions of the enterprises for operating the cooperation in the management of cooperation. The operation cost reflects the enterprise's operational capability. Enterprise's operation management runs through the whole process of production, manufacturing and cooperation of the enterprise. Enterprises acquire advanced technology and information from the outside world, and then create new technology and information by combining such

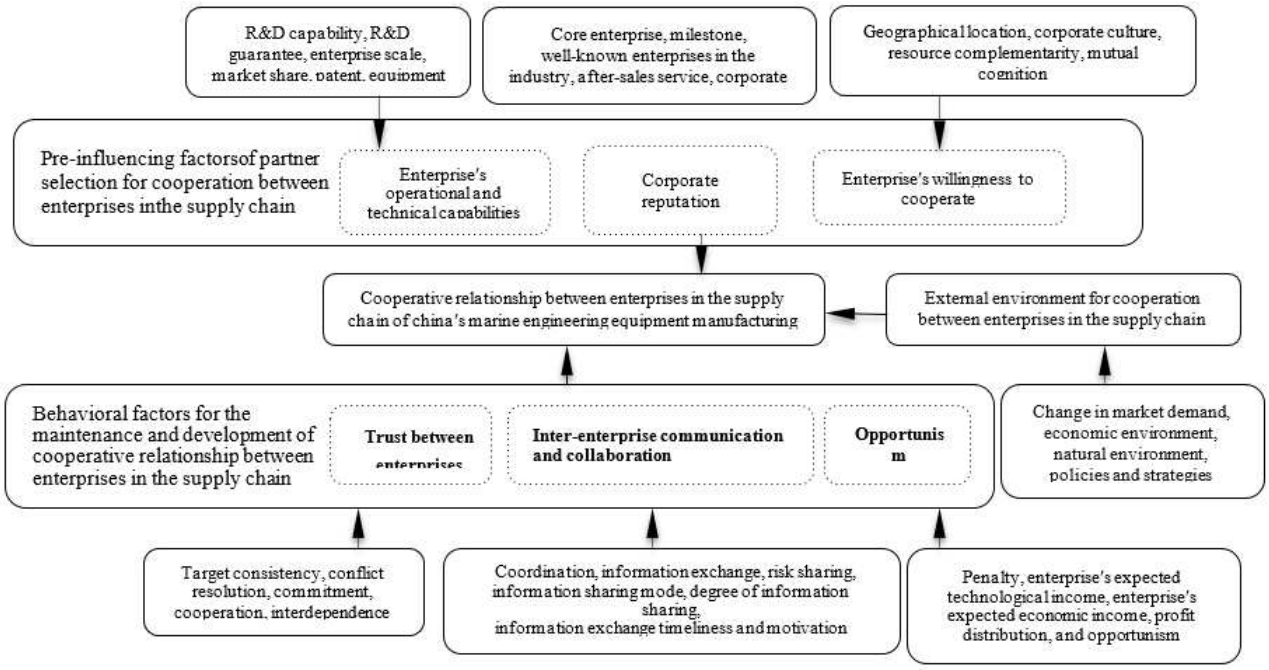

Fig. 2 Conceptual model of the factors influencing the cooperative relationship between enterprises in the supply chain of china's marine engineering equipment manufacturing industry

acquired advanced technology and information with internal knowledge to realize technological innovation and diffusion and achieve technological knowledge reserve and accumulation. This kind of technological knowledge contains lots of tacit knowledge and exists in the process of organization, so technical capability can only be acquired through learning, which is a long-term cumulative process. The effectiveness of the cumulative learning depends on the recipient's preparatory technical knowledge and effort intensity. In this sense, it is consistent with An Tongliang's enterprise's technological capability concept: An Tongliang believes that enterprise's technological capability is cumulative learning in which the enterprise chooses, acquires, digests, absorbs, improves and creates technology and integrates such technology with other resources to produce products and provide service [41]. That is to say, enterprise's technological capability is the collection of enterprise's ability to acquire information and other resources, and the technician's ability to integrate, reserve, and organize and coordinate resources. From the perspective of science and technology, enterprise's technological capability is a system integration function that is supported by enterprise's financial ability, centered on and determined by product innovation ability and process innovation ability, and serves for realization of technological innovation strategy. Technological innovation always takes place in specific economic environment, factor background, cultural background and organizational structure. Economic environment and other factors determine the technological innovation capability of different enterprises, and meanwhile determine the primary factor for enterprises in the supply chain to choose partners.

2) Corporate reputation

Corporate reputation: the company's behavior and norms have been highly recognized or convinced in the society, so the company can obtain higher social status and greater support in the economic market, and acquire the necessary resources and opportunities or the ability to withstand various uncertainties in the future. In the cooperation between node enterprises in the supply chain, corporate reputation refers to the comprehensive evaluation on the enterprise by internal and external actors, including raw material suppliers, manufacturers, equipment enterprises, governments, research institutions, media and end users. Such evaluation is based on the information transmission and interaction in the company's social network. Corporate reputation is an important source of sustainable competitive advantage, and also comprehensive evaluation on the business activities of the

enterprise in the market. Its value comes from the asymmetry of information. Firstly, enterprises with positive reputation can obtain more trust from their partners and can easily acquire more opportunities to cooperate closely with other enterprises, and vice versa. Secondly, corporate reputation can be used as a restraint and incentive mechanism between enterprises, and can reasonably reduce costs. Besides, from the perspective of enterprises themselves, in the reputation value itself, the incentive effect of corporate reputation has characteristics of perennity and complexity, far higher than the short-term interests of enterprises. Thirdly, good corporate reputation can help enterprises consolidate and promote the establishment and maintenance of transaction relationship with node enterprises in the supply chain.

3) Enterprise's willingness to cooperate

Willingness to cooperate: whether the member enterprises of cooperation organization are willing to coordinate and cooperate with the other members of the organization, whether they are willing to take a series of activities beneficial to the development of the organization, and whether their behaviors can bring benefits to the member enterprises and achieve the anticipated goal of cooperation. Competition, efficiency, information and learning demands are all external manifestations of enterprises to achieve their survival goals fundamentally, while the technology, R&D and market entry demands of enterprises are classified according to their strategic intentions, which is the way to expand their survival space. For enterprises in the supply chain of China's marine engineering equipment manufacturing industry, technological upgrading and expansion for their survival space are the essential needs to expand their cooperation. Therefore, clarifying the enterprise's willingness to cooperate is conducive to achieving an effective cooperation system between enterprises, reducing the risk of research and development for both sides, reducing the cost of opportunism, and acquiring accurate cooperation information, and is an important precondition for establishing an efficient cooperative strategic alliance between enterprises

4) Trust between enterprises in the supply chain

Trust between enterprises in the supply chain: Node enterprises in the supply chain, including suppliers, manufacturers, customers, intermediaries and other organizations, believe that partners have the ability to abide by the rules and fulfill their commitments during the cooperation process and firmly believe that the partners will not betray to gain more personal benefits. Trust between enterprises is a key and core factor for enterprises to maintain and develop cooperation, which facilitates information sharing between enterprises, reduces transaction costs and opportunism, and enhances the stability of mutual cooperation and cooperation ability to respond to uncertain external environment.

5) Communication and collaboration between enterprises in the supply chain

When node enterprises in the supply chain choose to cooperate, problems such as uneven profit distribution, unsmooth information flow and asymmetric information sharing are likely to occur in the process of cooperation. Therefore, the communication and collaboration mechanism between enterprises in the supply chain is an operation mechanism that is based on the sharing of resources, technology and business strategy, brings the upstream and downstream enterprises of the node enterprises in the supply chain together, and can realize inter-enterprise sharing of information and technology, absorption and transfer of knowledge, conflict resolution, rational reduction of R&D risks, etc., and it aims to maintain the cooperation between enterprises in the supply chain and ensure the enterprises to obtain the expected benefits as stipulated in the contract and improve the overall competitive advantages.

6) Opportunism

Opportunism refers to a kind of speculative behavior that damages the interests of partners due to a cunning means like deception, concealment or distortion performed by the node enterprise in the supply chain to maximize its own benefits in the face of asymmetric information transmission in cooperation.

These fundamental categories and their corresponding categories affect the cooperative relationship between enterprises in China's marine engineering equipment manufacturing industry in varying degrees, and the fundamental categories are interrelated and interact with each other. If one of the factors is unbalanced or missing, it will lead to the decline of the cooperative relationship between enterprises, and ultimately result in the decline

of the performance of cooperation between enterprises, affecting the competitiveness of the entire supply chain. Therefore, only by identifying the factors influencing the cooperation between enterprises in marine engineering equipment manufacturing industry, can we better realize the technological innovation of enterprises and maintain the development of core competitiveness of enterprises.

3.9 GRNN-DEMATEL Based Empirical Analysis on Influencing Factors

In this paper, with qualitative study method, factors in seven levels influencing the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry are qualitatively identified, including enterprise's operational and technical capabilities, corporate reputation, enterprise's willingness to cooperate, trust, communication and collaboration, opportunism and external environment. On the basis of qualitative study results, in order to enhance the validity, operability and feasibility of qualitative study results, DEMATEL (Decision Making Trial and Evaluation Laboratory) has constructed a direct impact matrix that can reflect the logical relationship among different factors by using graph theory and matrix tools. This matrix can improve the understanding for specific interrelated problem groups and complex cluster problems and achieve sorting and causal quantitative analysis for the degree of mutual influence among different factors. However, with DEMATEL method, it is difficult to solve the realistic problem in the relationship among the factors influencing the cooperative relationship between enterprises in the complex supply chain, and besides, the subjective judgment process of experts may affect the credibility of the final result. Therefore, in this Paper, GRNN-DEMATEL empirical analysis method is used to empirically analyze the factors influencing the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry.

4 Study design and selection analysis method

4.1 GRNN (Generalized Regression Neural Network)

GRNN was proposed by American scholar Donald F. Specht in 1991, which is a radial basis neural network suitable for solving nonlinear problems, with strong nonlinear mapping ability and high degree of robustness, flexibility and fault tolerance. Compared with RBF and BP neural networks, GRNN has a strong advantage in learning speed and approximation ability in processing unstable data, especially in the case of a small number of corresponding samples, it can achieve good prediction effect [13, 14]. The structure of GRNN is composed of four layers: input layer, pattern layer, summation layer, and output layer.
Where, network input is:

$$\mathrm{X} = [x_1, x_2, ..., x_N]^T \tag{1}$$

network output is

$$Y = [y_1, y_2, ..., y_k]^T \tag{2}$$

Input layer [13, 14]
After simple distribution, each neuron is transmitted to the pattern layer as an input variable, where:
Dimension of input vector = number of neurons. The number of neurons is set to
Pattern layer
In the pattern layer, the neuron transfer function is set to:

$$L_i = \exp\left[-\frac{(X - X_i)^T (X - X_i)}{2\sigma^2}\right] i = 1, 2, ..., n \tag{3}$$

n - Number of learning samples, used to represent the number of neurons;
X - Network input variable; Xi-Learning sample corresponding to the ith neuron;
σ - Smoothing factor; i-neurons.

I output is the Euler distance function between the input variable and its corresponding sample X.

$$D^2 = \|X - X_i\|^2 \tag{4}$$

4.2 Summation layer

The summation layer is to sum the outputs of two types of neurons in the pattern layer, and the transfer function is radial basis function. 1st type:

$$\sum_{i=1}^{n} \exp\left[-\frac{(X-X_i)^T (X-X_i)}{2\sigma^2}\right] \tag{5}$$

It arithmetically sums the outputs of all neurons in the pattern layer, where the connection weight between the pattern layer and each neuron is 1, and the transfer function is:

$$S_D = \sum_{i=1}^{n} \mathrm{L_i} \tag{6}$$

2nd type:

$$\sum_{i=1}^{n} Y_i \exp\left[-\frac{(X-X_i)^T (X-X_i)}{2\sigma^2}\right] \tag{7}$$

It sums the outputs of all the neurons in the pattern layer, i.e. the summation of the i[th] neuron in the pattern layer and the i[th] molecule in the summation layer. The connection weight between neurons is the j[th] element in the i[th] output sample Yi. The transfer function is:
(4) Output layer [13, 14]

$$S_{Nj} = \sum_{i=1}^{n} \mathrm{Y}_{ij} \mathrm{L_i} j, j = 1, 2, ..., k \tag{8}$$

Y_j refers to dividing each neuron by the output of summation layer, and it is a linear function, i.e.

$$S_{Nj} = \sum_{i=1}^{n} \mathrm{Y}_{ij} \mathrm{L_i} j, j = 1, 2, ..., k \tag{9}$$

Where, k represents the number of neurons in the output layer, k = dimension of output vector of learning sample.

In this Paper, the weight w is obtained by using the target output and input values in GRNN, based on which the influence degree of each index on the target output is measured, and hereby the influence degree of each influencing factor on the final result is obtained [13].

4.3 GRNN-DEMATEL model

GRNN-DEMATEL algorithm inherits and retains the values of "D-R" and "D+R" obtained by traditional DEMATEL method, and uses "D-R" index to distinguish the result group and cause group in the factor group, and uses "D+R" value to judge the importance of each index. The specific steps are as follows:
(1) Use the target index value of the tth study object as the target output vector of GRNN to obtain the weight vector:

$$\omega = (\omega_{tj}) = S \times P \tag{10}$$

Where, w_{tj} is the weight of the j[th] influencing factor of the t[th] study object on target index, $t = 1, 2, \cdots, m$.
(2) Obtain the average value wj* of the influence degree of the j[th] influencing factor on the target index:

$$\omega j^* = \frac{1}{m} \sum_{t=1}^{m} \left|\omega_{tj}\right| \tag{11}$$

Where, m is total number of study objects, and $|\omega_{tj}|$ is the absolute value of $|\omega_{tj}|$.
(3) Calculate the direct correlation matrix of each influencing factor index:

$$B = (b_{ij})_{n\times n} = \begin{pmatrix} b_{11} & \dots & b_{1n} \\ \vdots & \ddots & \vdots \\ b_{n1} & \cdots & b_{nn} \end{pmatrix} \tag{12}$$

Where, $b_{ii} = 0, b_{ij} = \frac{\omega i^*}{\omega j*}$, if $\omega j* = 0$, then $b_{ij}=0$, the importance of the i^{th} influencing factor index relative to the j^{th} influencing factor index.
(4) Normalize the direct correlation matrix:

$$X = (X_{ij})_{n\times n} = \frac{1}{\max\limits_{1\le i\le n} \sum\limits_{j=a}^{n} b_{ij}} \times B \tag{13}$$

(5) Calculate the full association matrix:

$$T = X(1-X) - 1 \tag{14}$$

where, (1-X)-1 is the inverse of, and I-X is unit matrix.
(6) Establish a causal relationship diagram. Define D as the sum of all rows of T, and R as the sum of all columns of T.

"$D_i + R_i$" is defined as the prominence of index i. The greater the prominence is, the greater the importance of this index will be. "$D_i - R_i$ " is defined as the correlation degree of index i, which can be used to distinguish the cause group and the result group. If the "$D_i - R_i$ " of index i is greater than 0, the index belongs to the cause group; if the "$D_i - R_i$ " of index i is less than 0, the index belongs to the result group. Among so many influencing factors, the influencing factors in the result group are the affecting results of the influencing factors in the cause group.

4.4 Empirical analysis

Selection of data for empirical analysis

In foregoing paragraphs, with qualitative study method, factors in seven levels influencing the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry are qualitatively identified, including enterprise's operational and technical capabilities, enterprise's social recognition, enterprise's willingness to cooperate, trust, communication and collaboration, opportunism and external environment. On the basis of qualitative study results, in order to enhance the validity, operability and feasibility of qualitative study results, in this Paper, GRNN-DEMATEL empirical analysis method is used to empirically analyze the factors influencing the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry. Besides, in this Paper, Likert 1-7 subscale is used prepare questionnaires, empirical analysis data is collected through on-site distribution of questionnaires, and 120 senior and middle managers of marine engineering equipment manufacturing enterprises are invited to respectively grade the influence degrees of "enterprise operational and technical capabilities, corporate reputation, enterprise's willingness to cooperate, trust, communication and collaboration, opportunism, and external environment on the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry. Finally, 120 study samples are collected and 120 study objects are formed. These 120 marine engineering equipment manufacturing enterprises all have over 15 years of history, and they are representative and typical large and medium-sized enterprises in eastern China. The middle and senior managers of these enterprises are familiar with the operation mode of supply chain and know well the knowledge related to the supply chain of marine engineering equipment manufacturing industry.

4.5 Empirical analysis process and results

In this Paper, on the basis of collecting the sample data of study objects, matlab programming software is used to obtain GRNN-DEMATEL method based empirical analysis results on the factors influencing the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry, as detailed in Table 3.

Table 3 GRNN-DEMATEL method based empirical analysis results

Influencing factor	D+R value	D-R value
Enterprise's operational and technical capabilities	1.0145	1.0086
Corporate reputation	0.3942	-0.3596
Enterprise's willingness to cooperate	0.3558	-0.3387
Trust	0.1629	-0.1411
Communication and collaboration	0.1502	-0.1049
Opportunism	0.1428	-0.0975
External environment	0.1066	0.0098

The empirical analysis results in Table 3 show that: (1) D+R values corresponding to the seven factors are all greater than zero; enterprise's operational and technical capabilities, corporate reputation, enterprise's willingness to cooperate, trust, communication and collaboration, opportunism and external environment are all the factors influencing the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry, where enterprise's operational and technical capabilities are the most important and critical factors affecting the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry; According to the degree and importance of the influence on the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry, in descending order, these influencing factors are ranked as follows: enterprise's operational and technical capabilities, corporate reputation, enterprise's willingness to cooperate, trust, communication and collaboration, opportunism and external environment. (2) D-R values corresponding to enterprise's operational and technical capabilities and external environment are greater than zero, while D-R values corresponding to the other influencing factors are smaller than zero; such results further reveal that in the seven factors influencing the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry, the cause-type influencing factors include enterprise's operational and technical capabilities and external environment, and the other five factors, the influencing results from the two cause-type influencing factors (i.e. enterprise's operational and technical capabilities and external environment), are result-type influencing factors. In order to better form and promote the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry, we should focus on taking these two cause-type influencing factors (i.e. enterprise's operational and technical capabilities and external environment) as the entry point and the fundamental starting point.

Operational and technical capabilities of the enterprises in the supply chain are the necessary conditions for enterprises to choose partners. Corporate reputation and enterprise's willingness to cooperate are the sufficient and necessary conditions for the final construction of the partnership. These three factors are the pre-influencing factors for the selection of partners for cooperation between enterprises in the supply chain of China's marine engineering equipment manufacturing industry. Trust, and communication and collaboration between enterprises in the supply chain are the necessary conditions for inter-enterprise cooperation behavior to keep stable and develop in a good direction. Opportunism is an inevitable negative factor in inter-enterprise cooperation and a key factor for enterprises to choose to continue or terminate the cooperation. Therefore, trust, and communication and collaboration between enterprises, and opportunism are the built-in driving forces for alliance cooperation of enterprises in China's marine engineering equipment manufacturing industry. The external factors affecting

the cooperation between enterprises in the supply chain have typical uncertainties in their external environment, and because of such uncertainties, the changes in external environment become important links that must be considered and grasped at all times for the maintenance and development of inter-enterprise cooperation.

4.6 Study Conclusion and Inspiration

Study conclusion

Because of the important strategic position of the marine engineering equipment manufacturing industry to China's marine economic development, and the technology confidentiality and complexity of the marine industry itself, it is difficult to analyze the factors influencing the cooperative relationship between enterprises in the supply chain of marine industry through quantitative indicators. Therefore, Grounded Theory qualitative study method is adopted. Meanwhile, the Grounded Theory based data coding qualitative study method shows that the main factors influencing the cooperative relationship between enterprises in the supply chain of China's marine engineering equipment manufacturing industry are respectively enterprise's operational and technical capabilities, trust between enterprises, communication and collaboration between enterprises, opportunism and external environment, corporate reputation, and enterprise's willingness to cooperate. In the process of enterprise cooperation, these influencing factors are presented as follows: first, in the process of establishing the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry, the three factors including enterprise's operational and technical capabilities, corporate reputation, and enterprise's willingness to cooperate are the important preconditions (i.e. pre-influencing factors); second, trust, and communication and collaboration mechanism between enterprises in the supply chain are important guarantee factors for the sustainable and efficient development of inter-enterprise cooperation; meanwhile, opportunistic behavior is inevitable in the cooperation process, but opportunism is controllable in the cooperation process; third, external environment (such as the policies on the development of enterprises in the supply chain of marine industry, and market economy, etc.) is an uncontrollable factor influencing the enterprise cooperation; when discussing its impact, quantitative study is impossible, but it is an important entry point for the study.

In this Paper, we use GRNN-DEMATEL method to empirically analyze the factors influencing the cooperative relationship between enterprises in the supply chain of marine engineering equipment manufacturing industry while studying the factors influencing the cooperation between enterprises in the supply chain of marine engineering equipment manufacturing industry. The study shows that these major influencing factors are mainly divided into two major categories: cause-type influencing factors (enterprise's operational and technical capabilities and external environment) and result-type influencing factors (corporate reputation, enterprise's willingness to cooperate, trust between enterprises, communication and collaboration between enterprises, opportunism and external environment). Cause-type influencing factors are the important foundation for study on inter-enterprise cooperation and the cornerstone of inter-enterprise synthesis. Result-type influencing factors have a guiding effect on the coordinated development between enterprises. The operational and technical capabilities of the enterprises in the supply chain are the necessary conditions for enterprises to choose their partners. The corporate reputation and enterprise's willingness to cooperate are the necessary and sufficient conditions for the enterprise partnership to be finally constructed. Trust, and communication and collaboration between enterprises in the supply chain are the necessary conditions for inter-enterprise cooperation behavior to keep stable and develop in a good direction. Opportunism is an inevitable negative factor in inter-enterprise cooperation and a key factor for enterprises to choose to continue or terminate the cooperation. The external factors affecting the cooperation between enterprises in the supply chain have typical uncertainties in their external environment, and because of such uncertainties, the changes in external environment become important links that must be considered and grasped at all times for the maintenance and development of inter-enterprise cooperation.

4.7 Inspiration

First, in this study, we take China's marine engineering equipment manufacturing industry as the study object to perform in-depth study on China's currently typical factors influencing the cooperative relationship

between enterprises in the supply chain of china's marine engineering equipment manufacturing industry, and identify the important factors influencing the cooperative relationship between enterprises in the supply chain of China's marine engineering equipment manufacturing industry by systematic materials and empirical data and through Grounded Theory, long-term research data collection, tracking and study - enterprise's operational and technical capabilities, corporate reputation, enterprise's willingness to cooperate, trust between enterprises, communication and collaboration between enterprises, opportunism and external environment, etc.

Second, in this Paper, relevant data are coded and cases are studied by Grounded Theory study method, through which the unique and indispensable situational influencing factors are identified - external environment. Besides, GRNN-DEMATEL study method is used to further identify the influencing factors. The study results enrich the theoretical study on the cooperative relationship between enterprises in China's marine engineering equipment manufacturing industry, and can provide important guidance for the selection of cooperation alliance mode between enterprises in marine industry.

Thirdly, from the practical point of view, in view of the fact that the development of China's marine engineering equipment manufacturing industry is still in the middle and late stages, in this Paper, we identify and analyze the key factors affecting the cooperative relationship between enterprises based on typical enterprise practice situation. The study shows that only by scientifically and systematically identifying the influencing factors, can we accurately choose the cooperative mode and ensure the smooth development of cooperative relationship.

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