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RESEARCH ARTICLE

Research on risk response mechanism of supply chain interrupt in lean production enterprises under COVID-19

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ABSTRACT

Lean production, as a production mode of continuous improvement, takes simplification as the core of improvement. The implementation of a series of epidemic prevention and control policies after the outbreak of COVID-19 has a major impact on lean production enterprises who are faced with the risk of supply chain disruption. On the basis of summarizing the operation characteristics of lean production mode, this paper analyzed the impact of COVID-19 on the supply chain of lean production enterprises from two aspects, that is, challenges and opportunities. Then, the paper put forward a coping mechanism to prevent supply chain disruption. The results show that in terms of challenges, the implementation of epidemic prevention and control policies has led to difficulties in resumption of work and production, challenges to timely supply and cost control, reduced customized demand and difficult commodity sales. In terms of opportunities, COVID-19 can promote the optimization and integration of the selection of employees and suppliers in lean production, promote the industrial upgrading of lean production enterprises, and enhance the risk management ability of supply chain managers. In order to effectively prevent supply chain interruption, lean production enterprises should start from the three dimensions of prior prevention, in-process control and post improvement of supply chain risk management, strengthen the coordination and cooperation of all links of the supply chain of lean production enterprises, and jointly resist the occurrence of supply chain interruption risk.

Keywords: supply chain risk management; lean production; supply chain interruption; response mechanism

1. Introduction

The COVID-19 that broke out during the Spring Festival in 2020 has been identified by the World Health Organization as a “sudden public health event” and a “global epidemic”. The rampant epidemic has had a huge impact on people's lives, and the development of China's industrial economy has also suffered huge losses. After the Spring Festival holiday, in order to avoid the spread of the COVID-19 caused by the wave of rework, enterprises were forced to postpone the resumption of work. On February 10, 2020, after the Spring Festival holiday, areas with less impact from the epidemic began resuming work and production. However, the actual resumption of work nationwide has restricted non local employees from leaving their place of residence, and non local employees who can reach the factory are also restricted from entering the factory to a certain extent[1]. In addition, due to the impact of policies such as epidemic prevention and control lockdowns and traffic control, the logistics activities of enterprises are subject to certain restrictions, resulting in a certain degree of raw

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material procurement and difficulty in outputting finished products, leading to supply chain disruptions in lean production enterprises.

In order to avoid the adverse effects of supply chain disruptions on lean production enterprises, some scholars in China have conducted extensive research on the identification and response measures of supply chain interruption risks. Among them, Zhu Xinqiu[2] pointed out that the frequent occurrence of emergencies has led enterprise managers to pay more attention to the losses caused by supply chain interruptions. In order to better cope with the impact of supply chain interruption risks, he divided supply chain risks into three types: internal risks, external risks, and internal risks, and pointed out that all three types of supply chain risks may cause supply chain interruptions; Pan Liuli[3] and others analyzed the impact of the COVID-19 on the logistics and supply chain industry, proposed that the application of blockchain technology to the logistics supply chain field can reduce the occurrence of supply chain disruptions, and suggested that enterprise managers should pay attention to mining the application value of blockchain technology in the logistics and supply chain field. Liu Fan[4] pointed out that the global procurement and lean production strategies adopted by enterprises not only improve the efficiency of the supply chain, but also increase the risk rate of the supply chain. In order to better identify and resolve the risk of supply chain interruption, he reviewed relevant literature from the perspectives of supply chain response time, response subjects, and response strategies. With the idea of collaborative innovation among all participants in the supply chain, he provided a theoretical basis for the study of supply chain interruption.

2. Related theories

2.1. Supply chain risk management

Supply chain risk refers to unexpected events that affect and disrupt the normal operation of supply chain enterprises during the operation process, resulting in the inability to achieve expected goals. The existence of supply chain risk may lead to a decrease in collaboration efficiency, an increase in operating costs, and even interruptions in the operation of collaborative enterprises on the supply chain. In order to reduce supply chain risks, enhance the competitiveness of enterprises, and gain competitive advantages, enterprises need to attach great importance to supply chain risk management. This is not only an important content of the theoretical system research of supply chain management, but also a practical requirement for enterprises to carry out supply chain management[5].

2.2. Supply chain interruption risk management

Supply chain interruption is a common form of supply chain risk, which refers to the risk event that an enterprise cannot meet the minimum requirements for business activities due to sudden human events or natural disasters during the operation process. To prevent the occurrence of supply chain interruption risk, it is usually necessary to integrate and optimize the system structure of the supply chain. In order to reduce the losses caused by supply chain interruption risk, effective remedial measures are generally taken in a timely manner after it occurs to restore the flow of funds, information, and materials between enterprises on the supply chain.

2.3. Main responsibilities of supply chain risk management

The main responsibility of supply chain risk management needs to be borne by the relevant personnel of supply chain risk management. Therefore, in order to carry out supply chain risk management work, it is necessary to first clarify the responsible party, that is, determine the management personnel of supply chain risk. In the current supply chain risk management work, the responsible parties can be divided into three categories. The first category is that the core enterprises on the supply chain undertake the supply chain risk management work. The second category is that the relevant enterprises on the supply chain form a specialized

risk management organization to be responsible for supply chain risk management[6]. The third category is to outsource supply chain risk management work to professional third-party companies. From the perspective of the responsible party, if the core enterprise of the supply chain is chosen to exercise the management power of supply chain risk, and the managed enterprise is all related enterprises on the supply chain, it will inevitably make other non core enterprises doubt the operational activities taken by the core enterprise, which will affect the unity and cooperation among related enterprises on the supply chain, and thus affect the stability of the supply chain. If the management of supply chain risks is outsourced to external third-party companies for operation, although it can avoid the occurrence of disharmony between related enterprises in the supply chain, outsourcing behavior carries great risks and may lead to the leakage of commercial information of related enterprises in the supply chain.

Through the above analysis, it is not difficult to find that adopting the second type of supply chain risk management team composed of relevant enterprises on the supply chain to be responsible for supply chain risk management can effectively compensate for the drawbacks brought by the other two types of responsibilities. Choosing the second type of responsibility requires personnel from relevant enterprises in the supply chain to form a risk management team. The risk management team has a better understanding of the work of various enterprises, and can more realistically analyze the links that may have risks in the supply chain, as well as the types of risks that may arise. At the same time, it can ensure the fairness of risk management work and reduce the risk of commercial secrets leakage. A scientific supply chain risk management organization should not only consist of some operators and irrelevant personnel, but also include a certain proportion of management personnel with real power within the organization, so as to ensure that various enterprises attach importance to this work and implement relevant policies.

After selecting staff, it is necessary to clarify institutional responsibilities. In order to strengthen the supply chain's ability to resist risks and effectively promote the continuous development of supply chain risk management, the supply chain risk management team needs to undertake the following responsibilities:

2.3.1. Regular risk assessment

Supply chain risk assessment is the pre estimation of potential risks and their impacts on the supply chain, in order to take timely measures for prevention and resolution. Risk assessment includes two aspects: one is to predict the potential risks that may arise and the consequences of the risks. The second is to evaluate the supply chain's resilience against predicted risks. If the supply chain itself can withstand this risk and the impact of the risk on it is minimal, the supply chain risk management team does not need to develop response measures; If the resilience of the supply chain itself is insufficient to mitigate this risk, and the impact of the risk may cause significant damage to the relevant enterprises in the supply chain, the supply chain risk management team should develop mitigation or response measures before the risk occurs, in order to minimize the losses caused by this risk as much as possible. For the supply chain risk management team, the various supply chain risks they face are dynamic, so it is necessary to regularly predict the potential risks they may face. When weak links or unexpected situations occur in the supply chain, timely coordination and resolution should be carried out.

2.3.2. Timely transmission of risk information

After the supply chain risk assessment work is completed, the supply chain risk management leadership group should timely transmit information such as the expected occurrence and impact of risks to relevant enterprises in the supply chain, so that they can timely understand the potential risks they may face and be prepared for risk prevention. At the same time, all relevant enterprises should provide timely feedback on the

relevant risks, so as to enable the supply chain risk management leadership group to effectively command and respond reasonably to the hazards caused by risks.

2.3.3. Strengthen supply chain analysis and take effective response measures

The causes of risks in each link of the supply chain are different, and the harm caused is also different. Different measures should be taken to address the impact of different links. This requires the supply chain risk management team to strengthen the analysis of different links and processes in the supply chain, timely identify potential problematic links and processes, take optimization measures to prevent interruption risks, and notify relevant enterprises to implement the formulated optimization measures. If the impact of the risk is not something that a single enterprise can independently resolve, or if for some reason the relevant enterprise is unable to implement relevant measures in a timely manner, the supply chain risk management team should contact other enterprises in a timely manner to cooperate and provide assistance, in order to ensure that the measures formulated by the supply chain risk management team can play their due role.

3. Lean production model

With the development of economic globalization, competition in the international market is becoming increasingly fierce. Some enterprises have started implementing lean production in order to improve the efficiency of their supply chain. They only retain key processes and transfer the supply and assembly of supporting components to first tier suppliers, and set clear requirements for the quality and time of supply from first tier suppliers to establish long-term cooperative relationships. Based on this, first tier suppliers will develop second and third tier suppliers to ensure the timeliness of material supply and production, forming a multi-level supply pyramid supply model[7].

Toyota was the first company in Japan to propose the lean production model, a production system designed to shorten the production cycle and provide customers with timely and satisfactory products. Lean production is a production system and corporate culture that emphasizes simplification and pursues the minimization of enterprise costs. Its specific implementation is characterized by the following characteristics:

3.1. Pursuing zero inventory and emphasizing just in time production

In the lean production model, enterprises pursue zero inventory and implement a just in time production method for procurement, which means delivering suitable products at the right time and in the right quantity to the right location, thus minimizing inventory. The lean production theory believes that a company's high inventory reserves will occupy a large amount of working capital and also cover up some problems in business management. Therefore, it regards zero inventory as an effective means to solve these problems. Although enterprises do not have high inventory reserves, lean production has high requirements for timely supply of raw materials and semi-finished products. Therefore, enterprises that adopt lean production will place orders with suppliers in advance during production to ensure timely supply and production. Therefore, it is required for manufacturing enterprises and suppliers to maintain a good strategic cooperation relationship[8].

3.2. Pursue simplification and focus on optimizing production processes

The core of lean production is to pursue simplification and eliminate unprofitable businesses in the design and production process as much as possible. Enterprises usually transfer these unprofitable businesses to suppliers by optimizing production processes, and this phenomenon is most prominent in automotive manufacturing enterprises[9]. In automobile manufacturing enterprises that implement lean production, they usually only retain processes such as stamping, welding, painting, and final assembly, and transfer some component assembly processes to suppliers to complete. For example, in the automobile assembly plant, only

the final assembly process of the car is completed, while some sub assembly of parts such as the dashboard and seats are usually completed by the first tier supplier. In the material supply of automobile manufacturing enterprises, they usually limit the delivery time and the time is very short. In order to save material transportation time, if conditions permit, the first level supplier will set the assembly line in the automobile assembly plant to ensure timely supply of parts and semi-finished products[10].

3.3. Ensure production standardization and adopt Kanban style production management

In lean production enterprises, the production management department of the enterprise will issue production instructions based on market forecasts and the number of orders, and break down the instructions into kanban for each process. Each kanban clearly indicates the quantity, time, destination, and delivery location of each production and transportation process, tracing back from the subsequent process. Operators must strictly follow the quantity indicated on the kanban to carry out relevant operations. Without the kanban, operations are not carried out. Each kanban is bound to the physical object and must be placed on it to achieve visual management[11]. The use of Kanban management can effectively prevent material waste in production and prevent the occurrence of excessive production, thereby achieving cost savings and improving management efficiency.

3.4. Meeting customer needs and implementing pull production

Enterprises that adopt lean production can adjust their production plans according to customer needs at any time. They generally adopt a pull production method to produce according to customer orders, and do not produce until orders are received. They also issue purchase orders to suppliers based on order requirements, requiring them to provide timely supply to ensure the normal progress of production plans and timely provision of required products to customers[12]. Enterprises that adopt lean production models will focus their research and development on market demand, implement customized production models, and create high market profits.

4. Analysis of the impact of COVID-19 on the supply chain of lean production enterprises

The supply chain of lean production enterprises has the characteristics of long and complex chains, which increase the probability of supply chain interruption risk. Once a problem occurs in a certain link of the supply chain, the entire supply chain will be affected. The simplified production process leads to multi-level supply, close cooperation among suppliers at all levels, and low substitutability[13]. However, the outbreak of the COVID-19 not only restricted traffic, but also restricted people's travel and mobility, which had an important impact on the supply chain of lean production enterprises.

4.1. Challenge analysis

4.1.1. The implementation of epidemic prevention and control policies has restricted the resumption of work and production

After the outbreak of the COVID-19, many provinces in China have introduced epidemic prevention measures to restrict people's travel in order to effectively prevent the spread of the epidemic. Although lean production enterprises began to return to work gradually after February 10, the actual situation is not optimistic, because February 10 was a critical period for epidemic prevention and control, and the epidemic prevention and control measures in most provinces have not been lifted, which led to only a few local employees participating in the resumption of production and commencement, while a large number of non local employees were faced with practical problems such as being unable to leave their places of residence or enter the enterprise's location[14]. The supply chain of lean production enterprises is closely coordinated with various

links. As long as there is a link where the supplier cannot convene employees to resume work or fails to pass the resumption audit of relevant departments, it will have a fatal impact on the entire supply chain, leading to production interruption and inability to deliver on time in lean production enterprises.

The outbreak of the epidemic coincides with the Spring Festival period, and many lean production enterprises consider that they only reserve very little inventory and finished products during the Spring Festival holiday. Due to the impact of the epidemic, warehouse management personnel are unable to return to work on time, unable to conduct timely statistical analysis of inventory data, and may miss the best ordering period to prevent supply chain interruption, which may also cause supply chain interruption[15]. In addition, most enterprises implementing lean production are manufacturing enterprises. Due to the impact of epidemic prevention and control policies, workers from other regions are unable to return to work in a timely manner, while local workers may only be some office workers or some operators, unable to effectively operate the production machines in the workshop, which affects the production efficiency of the enterprise.

4.1.2. Challenges in timely supply and cost control

Lean production enterprises achieve timely supply by closely cooperating with suppliers, thereby reducing inventory and saving costs, and achieving enterprise benefits. Due to the impact of the epidemic, many provinces in China have implemented traffic controls, and truck traffic is restricted during logistics transportation. In some areas, in order to ensure the timely supply of epidemic prevention and control materials and prevent the entry of foreign populations, only vehicles transporting epidemic prevention materials and local transportation vehicles are allowed to pass through. Strict epidemic prevention and control policies have led to a shortage of transportation vehicles and drivers in the logistics market, while strict traffic controls have hindered road traffic in some areas. For suppliers of lean production enterprises, resuming work and production on time and producing relevant raw materials and parts according to order requirements may not be able to deliver them to designated locations on time, which poses a challenge to the timely supply of lean production enterprises. In order to timely deliver raw materials and finished products to designated locations, raw material suppliers will choose other transportation methods to ensure the supply of materials and maintain long-term strategic relationships[16]. Opening up new routes and choosing new transportation methods will inevitably lead to an increase in freight costs, and freight prices will continue to fluctuate due to the impact of the epidemic. The increase in transportation costs will cause suppliers to increase the prices of raw materials or components, thereby increasing the costs of lean production enterprises.

4.1.3. Reduced demand for customization and difficulties in selling goods

Lean production enterprises produce customized valuable goods. Due to the impact of the epidemic, people were quarantined at home in the first quarter, resulting in reduced outdoor activities, income, and shopping. As a result, the demand for valuable goods also sharply decreased. Therefore, in the first quarter, lean production enterprises will have a significant decrease in orders compared to the same period, and the original logistics system of the enterprise will be more difficult to sell due to traffic restrictions[17]. The reduction of orders can lead to conflicts between lean production enterprises and suppliers at all levels, as maintaining the supply chain of lean production enterprises requires significant costs for suppliers at all levels. The reduction of orders may cause losses for departmental enterprises in the supply chain, and the emergence of hidden contradictions may increase the risk of supply chain interruption.

4.2. Opportunity analysis

4.2.1. Promote the optimization and integration of employee and supplier selection in lean production enterprises

Although a series of prevention and control policies during the epidemic have increased the risk of supply chain interruption in lean production enterprises, they have also created opportunities for optimization and integration of lean production enterprises. During the epidemic, population prevention and control isolation have limited the resumption of work for employees from other regions, promoting the development of local workers in lean production enterprises. Behind this phenomenon, it also invisibly strengthens the ability of lean production enterprises to resist supply chain risks. Affected by traffic regulations, there are obstacles in the flow of raw materials and finished products in lean production enterprises. To solve this problem, some lean production enterprises have begun to explore new production workshops near core enterprises in the supply chain. In addition, some core enterprises have also started to develop local raw material suppliers to ensure timely supply of raw materials, thereby driving the optimization and adjustment of related industrial layout. These response measures have greatly promoted the optimization and integration of lean production enterprises.

4.2.2. Promoting industrial upgrading of lean production enterprises during the epidemic

The phenomenon of "labor shortage" seems to increase the difficulty for lean production enterprises to resume work and production. However, in order to ensure the timely supply of upstream and downstream, some enterprises have begun to introduce some advanced facilities and equipment. For example, some industrial robots and high-end automated production equipment have been well developed and used in production enterprises. The COVID-19 has forced lean production enterprises to accelerate transformation and upgrading [18]. In addition, the rapid development of 5G technology, as well as its integration with computers and the Internet of Things, provide strong support for the use of new technologies. Even if lean production enterprises resume work and production during the epidemic prevention and control period, the production workshop, as a densely populated area, is also one of the high-risk areas for epidemic transmission. In order to prevent the spread of the epidemic, contactless production processes are also valued. The realization of this result requires the integration and development of new technologies such as 5G, AI, and cloud computing to provide guarantees and support.

4.2.3. Enhance the risk management capabilities of supply chain management personnel

As a public health emergency, the occurrence of COVID-19 epidemic is difficult to predict in advance, and its time node also coincides with the Spring Festival holiday, so its impact on lean production enterprises in China is also very rare. However, from the perspective of risk management, it also provides a very rare learning opportunity for supply chain risk management personnel. Whether it is predicting the impact of events or formulating and implementing response measures after events, it has brought great challenges to the work of risk management personnel. Especially under the constraints of some epidemic prevention and control policies, smoothly organizing the coordinated operation of various links in lean production enterprises is a very difficult task. Although these challenges have affected lean production and brought difficulties to risk management work, this valuable learning opportunity will definitely accumulate rich practical experience for risk management personnel [18].

5. Mechanisms for lean production enterprises to respond to supply chain interruptions

Supply chain interruption can have a negative impact on the operational performance of enterprises. How to avoid the losses caused by supply chain interruption is a hot topic of discussion among enterprise managers. For general enterprises, it is common to increase their redundant inventory to prevent supply chain interruption. However, for lean production enterprises, maintaining a large amount of inventory contradicts their pursuit of simplification goals and just in time supply. Therefore, redundant inventory strategies are not suitable for lean production enterprises [19]. In the current supply chain risk management in our country, Chinese scholars focus on post emergency response but lack awareness of pre prevention. In order to avoid losses caused by supply chain interruptions in lean production enterprises, it is necessary to explore the response mechanism of supply chain interruptions in lean production enterprises from three dimensions: pre prevention, in-process control, and post improvement.

5.1. Pre prevention

5.1.1. Establish a supply chain risk management team

In order to prevent supply chain interruption incidents, lean production enterprises should select a group of management personnel and employees with rich experience in handling emergency events to form a supply chain risk management team. This organization is specifically designed to prevent and handle supply chain interruption incidents. In the prevention and control of supply chain interruption risks, a set of emergency plans should be developed, and responsible personnel and work processes should be clearly defined to respond[20]. Due to the wide variety of product lines and highly customized production modes adopted by lean production enterprises, the process of formulating emergency plans can be considered from three aspects: product elasticity, supply chain elasticity, and emergency management. Due to the strong uncertainty of emergencies, lean production enterprises emphasize that on-time supply cannot lead to stockouts. Therefore, the supply chain risk management team should extensively collect suppliers of alternative components for lean production enterprises, and conduct a detailed evaluation of their qualifications. In the event of supplier supply interruption caused by emergencies, the alternative supplier management database can be quickly activated to reduce the possibility of supply chain interruption.

5.1.2. Purchase of supply chain interruption insurance

The risk of supply chain interruption cannot always be effectively predicted. In order to prevent losses caused by supply chain interruption, enterprises can transfer the risk by purchasing insurance. The insurance related to supply chain interruption is called business interruption insurance. Although purchasing insurance cannot reduce the probability of supply chain interruption risk, it can compensate for the losses caused by enterprise supply chain interruption.

5.2. In-process control

5.2.1. Funding supplier enterprises to build branch factories near the factory area

The COVID-19 has exposed the lack of supply chain risk management in lean production enterprises in China. After the COVID-19 broke out, lean production enterprises were very passive in the crisis. In order to avoid supply chain disruption caused by emergencies for supplier enterprises, active response strategies should be taken. However, lean production enterprises cannot adopt the multi supplier strategy and supply chain segmentation management strategy as other enterprises do. However, lean production enterprises can encourage and support suppliers to set up branches near their own factories, or plan production workshops or assembly lines for semi-finished products needed by enterprises in their own factories, and the suppliers should

outsource their operations, so that they can supply materials with the original suppliers without breaking the long-term strategic cooperation. localization of, Moreover, supplier enterprises can supply both from the main factory and from different factories, achieving the functions of a multi supplier strategy and enhancing the resistance to supply chain interruption risks in lean enterprises. For supplier enterprises, although there may be some costs involved, it is of great positive significance for them to expand new customers and save transportation costs.

5.2.2. Develop backup logistics transportation plans

Lean production enterprises implement customized production, which usually takes only a few days to complete from customer orders to delivering products to customers. Therefore, lean production enterprises also have high requirements for logistics efficiency. However, the probability of logistics interruptions increases due to factors such as weather conditions, sudden natural disasters, and public emergencies. In order to reduce the impact of uncertain emergencies on normal logistics transportation plans, lean production enterprises must develop backup logistics transportation plans in advance. The development of a backup logistics transportation plan can be considered from the following two aspects: firstly, using multiple transportation methods to complete transportation tasks, that is, flexibly using various transportation methods in the entire logistics system according to emergencies to avoid delays caused by unsmooth transportation. The second is to plan transportation routes and develop various logistics routes and channels to help smooth delivery of materials and reduce transportation risks.

5.2.3. Adopt effective marketing strategies to stimulate market demand

Whether it is a lean production enterprise or a regular enterprise, the decrease in customer demand can have a fatal impact on continuous production. In order to prevent supply chain disruptions caused by a decrease in market demand, lean production enterprises can adopt methods such as promotion, dynamic pricing, and developing substitutes to transfer market demand to change market demand for the product. Integrate supply chain management closely with marketing activities, transform uncontrollable market demand into controllable market demand, and eliminate interruption risks caused by market changes.

5.3. Post improvement

After risk events are effectively controlled, lean production enterprises need to repair the supply chain system as soon as possible to reduce the losses caused by supply chain interruptions to various links. The supply chain risk management team should analyze the root causes of supply chain disruptions, take effective measures as much as possible, and completely eliminate the root causes of the problem. If the root causes cannot be eliminated, emergency plans for supply chain risks caused by such reasons should be formulated as soon as possible to ensure that there is an effective response mechanism for such risk events in the future. In addition, enterprises can also summarize their experience in handling this risk event, transmit the experience within the enterprise and supply chain enterprises, and improve the risk management system of the entire supply chain.

6. Conclusion

Lean production is a relatively advanced enterprise management model promoted globally, which implements pull production and can produce according to customer orders, greatly meeting customer needs; Advocate for implementing a just in time production method for procurement, and pursue efficient operation of inventory; Emphasizing the optimization of production processes, maximizing profits can be achieved through minimizing costs; Advocate for collaborative operations and focus on coordination and cooperation among supply chain enterprises. The sudden attack of the COVID-19 is not only an impact on lean production

enterprises, but also a test of their continuous improvement. The epidemic will eventually end, but the risk will always exist. The management personnel of lean production enterprises should learn from the epidemic, establish and improve the risk management system of the supply chain, formulate effective response mechanisms, and comprehensively enhance the risk resistance ability of the supply chain of lean production enterprises.

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