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Digital Control Tower Empowers Supply Chain Resilience Improvement from a Dynamic Capability Perspective

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Abstract. The market volatility caused by the new crown epidemic and trade protectionism has highlighted the important role that supply chain resilience plays in business development, while the development of emerging technologies has led to changes in business development strategies, and market competition has escalated from competition between traditional enterprises to competition between supply chains. Today's supply chain management is very complex, with countless partners distributed in different regions, and this intertwined trade ecosystem is unprecedented. The chain reaction of epidemic control in early 2020 has triggered a strong interest in supply chain resilience among many scholars. At the 20th National Congress in 2022, General Secretary Xi clearly pointed out that "efforts should be made to enhance the supply chain resilience and security of the industrial chain", raising supply chain resilience to the level of national strategy for the first time. The emergence of digital control tower concept provides a new management idea to improve the supply chain resilience. So what exactly is digital control tower? How does digital control tower improve supply chain resilience? This paper investigates the mechanism of digital control tower in Leader Harvest plant with the help of dynamic capability theory, and explores an innovative path to improve supply chain resilience, which can provide reference for other enterprises' supply chain management development..

Keywords. dynamic capability perspective, digital control tower, supply chain resilience

1. Introduction

With the continuous development of new technologies such as Internet of Things, big data and artificial intelligence, the supply chain of enterprises has been transformed and upgraded in the direction of networking, intelligence and digitalization. The development of emerging technologies has led to changes in the development strategy of enterprises, and the market competition has been upgraded from the competition among traditional enterprises to the competition among supply chains. In the meeting of the 20th Party Congress, General Secretary Xi pointed out clearly that "efforts should be made to improve the supply chain toughness and security of the industrial chain", which raised the supply chain toughness to the level of national strategy for the first time, however, how to build a supply chain toughness system has become a problem that needs to be

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solved in various industries. Supply chain resilience is mainly composed of three parts: absorption capacity, robustness and recovery capacity, and the establishment of these capacities is closely related to the operation strategies of enterprises in the supply chain, therefore, the improvement of supply chain resilience needs different supply chain enterprises to cooperate with the implementation. Since each enterprise is unwilling to give up its own interests to maintain the maximum efficiency of the whole supply chain operation, how to balance the overall goal of the supply chain with the behavior of individual enterprises has become a difficult point in supply chain management. The emergence of digital control tower provides the possibility for supply chain management to overcome the above management challenges and improve the resilience of supply chain. So what is digital control tower? How can digital control tower improve supply chain resilience? Based on the review of existing research, this paper constructs a digital control tower model from the dynamic capability theory, analyzes its inner operation mechanism, and finally explores the mechanism of control tower to improve supply chain resilience by combining with the application example of control tower in Leader Harvest enterprise, so as to provide theoretical support and path for establishing supply chain resilience.

2. Review of Literature

2.1. Dynamic Capability Theory

The dynamic capabilities perspective is an emerging management theory that was first extended from the theory of firm capabilities and is at the forefront of research in the field of strategic management. early in the 20th century, economists noted that firms would creatively disrupt existing competitive practices in order to adapt to dynamic external environments, and this idea of innovative competition was the basis for the emergence of dynamic capabilities theory [1]. Helfat (1997), from the perspective of knowledge integration, considers dynamic capabilities as the ability of a firm to integrate and reorganize its core technical knowledge with physical assets to create new products and businesses [2]. Eisenhardt and Martin (2000) argue that dynamic capabilities are an evolutionary mechanism of firm capabilities, i.e., they are optimized and upgraded over time and in response to dynamic changes in the market environment [3]. Different schools of thought have taken very different paths to study dynamic capabilities of firms, such as process and mechanism evolution perspective, value discovery perspective, and management cognition perspective. Moreover, in terms of research methods, secondary data research method, questionnaire survey method, case study method, and experiment-based research methods are commonly used in the field of dynamic capabilities research. Dynamic capability theory has theoretical advantages in solving the problems of corporate strategy formulation and adaptability to dynamic environment, and provides useful assistance to the research in related fields.

2.2. Digital control tower

While traditional control towers provide visibility into operational activities to direct trading partners, modern supply chain intelligence control towers are hubs of visibility, decision making and action, based on monitorable real-time analytics to manage and control cross-functional and cross-company decision making and execution to optimize

the entire network. Goldner defines a control tower as follows, a digital control tower is a concept that provides end-to-end holistic visibility and near real-time information and decision making across the supply chain. Accenture sees the digital control tower as a shared service center that monitors and directs activities across the end-to-end supply chain to create a collaborative, consistent, agile and demand-driven supply chain. Capgemini Consulting defines a digital control tower as a central hub with the technology, organization and processes needed to capture and use supply chain data to provide visibility into short- and long-term decisions aligned with strategic objectives. Ebenezer considers the digital control tower as a system-supported data center whose role is the collection, real-time sharing, and integrated management of information across the supply chain to enable demand-driven end-to-end control of the supply chain [4]. The digital control tower is not a real physical building like an airport control tower, but a new concept in supply chain management, more like a central hub with the technology, organization and processes needed to access and use data to provide better and broader visibility and decision support in line with strategic objectives and short- and long-term decisions.

2.3. Supply Chain Resilience

The term resilience is a multidisciplinary and multidimensional crosscutting concept widely used in engineering, ecology, and physics, and refers to the maximum degree to which a system can converge or deviate from its equilibrium state after a disturbance without changing its own properties [5]. And the emergence of the term supply chain resilience heralds a new application of resilience arising in supply chain management. The study of supply chain resilience has gradually received wide attention from scholars in 2004.Helen and Martin argued that supply chain resilience is the ability of a system to recover to its original or better state after a disruption or disturbance [6].Timothy et al. (2013) argued that managing the risk of an uncertain future is an important challenge, and building supply chain resilience is building the ability of supply chains to survive, adapt, and grow in the face of turbulent change [7]. Jacob et al. (2020) consider supply chain resilience as the ability to make a supply chain less prone to disruption and recover more quickly [8]. Andreas and Christian (2021) propose that supply chain resilience is the ability of a supply chain to persist, adapt, or transform in the face of change [9]. Sheng Zhaohan et al. (2022) considered supply chain resilience as a sign of the ability of the supply chain system behavior and function as a whole to adapt to changes in environmental complexity [10]. The definition of supply chain resilience in this paper prefers the set of absorptive capacity, robustness, and resilience.

To sum up, the business improvement of individual enterprises in previous studies can no longer meet the increasingly fierce market competition, and the improvement of the whole supply chain resilience has become a necessary issue for the future survival and development of enterprises, and how to use the emerging technology to complete the improvement of the supply chain management level is a difficult problem for every enterprise. Due to the variability of the internal and external environment of the supply chain and the complexity of the supply chain network, a powerful central system is needed to process the relevant information in order to realize the effective scheduling and rational allocation of supply chain resources, and the emergence of digital control tower just solves this technical problem. This study breaks through the boundaries of enterprises in previous studies and integrates all the resources in the supply chain by building a digital control tower to eliminate the duplication of resources and maximize

the utility of resources in the supply chain. Under the perspective of dynamic capability, the management idea of control tower is applied to the process of establishing supply chain resilience, and the supply chain resources are integrated through the control tower to break the boundary of enterprises, and the formation of absorptive capacity, robustness and recovery capacity is implemented into specific enterprise behaviors, so as to explore an innovative path of supply chain resilience enhancement and provide reference for the development of supply chain management theory.

3. Study Design

3.1. Research ideas

The research idea is to decompose the supply chain resilience according to three processes: ex-ante, ex-ante and ex-post, and divide them into absorption capacity, robustness and recovery capacity, and then decompose the overall goal of the supply chain into individual enterprise operation behaviors starting from the three capacities. If all enterprises in the supply chain agree to implement the action plan after evaluation, the control tower will continuously follow up through the data of the enterprise operation process, and The deviations and risks in the process are monitored in real time to ensure the smooth implementation of the plan, thus realizing the improvement of supply chain resilience, as shown in Figure 1.

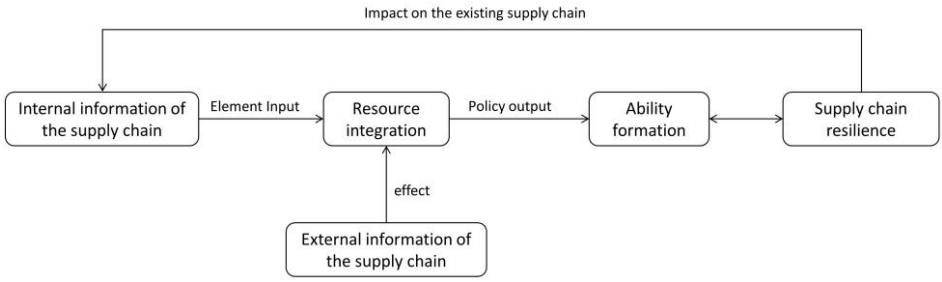

Figure 1. The formation of supply chain resilience from a dynamic capability perspective

3.2. Research Methodology

This paper focuses on answering the "what is a digital control tower" and "how does a digital control tower improve supply chain resilience", which are questions about "what" and The "how" questions are suitable for a case study. A single case can provide in-depth analysis and detailed explanation of a single situation, and the strong storytelling can be fascinating and bring unusual new insights and inspiration, so a single case is selected for the study. Root theory is an inductive study of a phenomenon designed to help the researcher develop further into a theory based on primary sources. Therefore, this paper adopts a single-case study approach, combined with the Grounded Theory, to analyze the collected case data in a bottom-up coding process, so as to conduct theoretical model construction.

3.3. Data collection and analysis

The data collection for this study took three months and was obtained mainly through semi-structured interviews, field observations and official websites, news, propaganda films, documentaries, and archival materials, and the primary and secondary data from different sources were verified against each other, and the relevant information is shown in the table. Referring to the research method of Wang Ning (2020), the obtained data and information were coded in three levels with the help of NVIVO 12 [11]. In the first step, open coding. An ongoing "dialogue" with the collected empirical information was conducted to understand the important initiatives to enhance supply chain resilience, and a total of 34 concepts were obtained and named (coded with the prefix "aa"). The second step was spindle coding. Analyze the relationship between the first-level concepts and organize them together based on common attributes to form the second-level themes. 12 themes (coded with the prefix "A") were extracted in this paper. The third step, selective coding. Three capability clustering dimensions are formed from three stages of the supply chain before, when and after being disturbed to reflect the role of digital control tower in enhancing supply chain resilience. To ensure the reliability of the data coding, the three researchers worked together to proofread the coded data as a whole, reaching theoretical saturation and stopping the collection of material when the collection of fresh data no longer yielded new theories and concepts. When continuing to select the relevant reported materials from Leader Harvest for theoretical saturation test, no new concepts and relationships were obtained, therefore, the coding in this paper was theoretically saturated and the case coding results are shown in Table 1.

Table 1. Case coding data structure

Cluster dimension	Secondary Theme	First level concept
Absorptive capacity	A1 Risk Warning	aa1 production warning, aa2 inventory warning, aa3 order warning
	A2 Capacity Redundancy	aa4 spare parts management, aa5 personnel allocation
	A3 Supplier Management	aa6 supplier separation, aa7 supplier reserve, aa8 supplier assessment
	A4 real-time monitoring	aa9 position positioning, aa10 process control
Robust ability	A5 Flexible Manufacturing	aa11 personnel adjustment, aa12 workstation scheduling, aa13 customer expectation management, aa14 supplier change
	A6 Flexible Design	aa15 parts replacement, aa16 modular structure, aa17 customized production
	A7 Flexible Procurement	aa18 multiple sources of goods, aa19 diversified products, and aa20 multiple supply methods
	A8 Flexible transportation	aa21 diversified delivery, aa22 equipment leasing, aa23 owned equipment, aa24 third-party outsourcing
	A9 Communication and Coordination	Aa25 requirement communication, aa26 fault feedback, aa27 command release
Resilience	A10 Business Adjustment	aa28 process update, aa29 budget transfer, aa30 strategy replacement
	A11 Risk Management	aa31 response mechanism, aa32 feedback mechanism
	A12 Knowledge Management	aa33 handling plan, aa34 response experience

4. Case Study

From 2017, Leader Harvest started to comprehensively deploy the "smart manufacturing" strategy and gradually built a digital control tower system, using the digital control tower to solidify the concept of lean production, continuously optimize operational processes, realize end-to-end visual management, improve management efficiency, and greatly improve the competitiveness of enterprises. Analyzing the collected data according to the research idea shown in Figure 1, the digital control tower is considered as the implementer of the resource integration function, taking the role of receiving internal and external information of the supply chain and transforming it into specific operational strategies. Through the collation of the case data, it is found that the process of digital control tower to improve the supply chain resilience through operational decisions is the development process of supply chain dynamic capability. Strategies such as risk warning, capacity redundancy, supplier management and real-time monitoring promote the establishment of absorption capability in supply chain resilience, strategies such as flexible manufacturing, flexible design, flexible procurement, flexible transportation and communication and coordination promote the establishment of robust capability in supply chain resilience. The strategies of business adjustment, risk handling, and knowledge management promote the establishment of recovery capability in supply chain resilience, as shown in Figure 2.

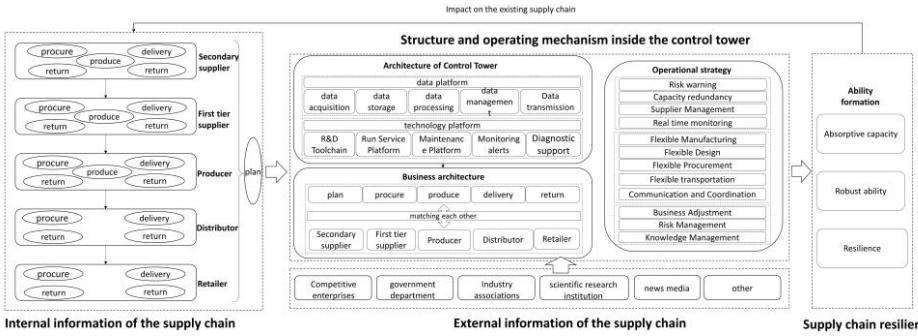

Figure 2. Mechanisms of digital control tower action on supply chain resilience.

4.1. Absorptive capacity in supply chain resilience

Absorptive capacity in supply chain resilience refers to the ability of a system to absorb or withstand the effects of systemic disturbances and minimize the negative consequences of disruptions with a relatively low level of energy or effort before external shocks act on the supply chain [12]. The absorption capacity of supply chain resilience is mainly to be expressed in four aspects: risk warning, capacity redundancy, supplier management, and real-time monitoring. Risk warning refers to the early warning of possible external shocks, sensing the risk in advance and leaving sufficient reaction time for the system. Capacity redundancy is to make the maximum capacity far exceed the demand capacity through the redundant reserve of personnel and products, so that the system has the ability to withstand greater fluctuations in production. Supplier management is the rational allocation of the quantity, quality and distribution of suppliers. Real-time monitoring is to monitor and upload parameters such as product location and production process to the visualization platform in real time through various digital

hardware devices, so as to realize the whole traceability of products. The coding process of the acquired case information is shown in Table 2.

Table 2. Example of Absorptive Capacity in Supply Chain Resilience Case Materials

Secondary Theme	First level concept	Label
A1 Risk Warning	aa1 Production warning	Material abnormality
		Abnormal production equipment
		Inventory forecast, shortage rate below 5%
	aa2 Inventory warning	Low inventory
		Low turnover rate and backlog of goods
	aa3 Order alert	Exceeding maximum production capacity, order prompt
A2 Capacity Redundancy	aa4 Spare Parts Management	Sufficient production capacity and spare parts production
	aa5 Staffing	Contract based employees, flexible work arrangements
A3 Supplier Management	aa6 supplier separation	Unit market area and suppliers of the same type
		Geographic location, natural disasters
	aa7 Supplier Reserve	Regular evaluation and information updates
	aa8 Supplier Assessment	Data analysis and performance scoring
A4 real-time monitoring	aa9 Location Positioning	One item,one code, full tracking
	aa10 Process Control	Production process inspection

4.2. Robustness in Supply Chain Resilience

Robustness in supply chain resilience refers to the ability to maintain the continuity of expected operational levels and structural and functional stability when external shocks act [13], which in this case study is specified in four aspects: flexible manufacturing, flexible design, flexible procurement, flexible transportation, and communication and coordination. Flexible manufacturing refers to the existence of greater flexibility and agility in personnel adjustment, workstation scheduling, customer expectation management, and changing suppliers, which can greatly improve the production flexibility of the supply chain. Flexible design is to achieve a high degree of flexibility in product design through part replacement, unitized structure, customized production and other measures, which effectively reduces the unfinished rate caused by out-of-stock and maximizes the satisfaction of customers' individual needs. Flexible procurement is to ensure the timely arrival of purchased products from multiple sources, diversified products and multiple delivery methods. Flexible transportation means comprehensive diversified delivery, equipment leasing, own equipment, third-party outsourcing and other methods to meet different transportation needs. Communication and coordination are mainly reflected in demand communication, fault feedback and instruction issuance. The coding process of the acquired case information is shown in Table 3.

Table 3. Case example of robustness in supply chain resilience

Secondary Theme	First level concept	Label
A5 Flexible Manufacturing	aa11 Personnel Adjustment	Personnel assessment and job adjustment
	aa12 workstation scheduling	Visualization processing, reasonable configuration, and workstation utilization
	aa13 Customer Expectation Management	Production scheduling, on-time delivery, customer feedback
	aa14 Change supplier	Backup supplier
A6 Flexible Design	aa15 Part Replacement	Replaceable parts, unified design
	aa16 Unitized Structure	Structured product design

	aa17 Customized production	Customer customization and personalized needs
A7 Flexible Procurement	aa18 multiple sources of goods	Same material, multiple sources of goods
	aa19 Diversified products	Same source of goods, multiple products
	aa20 Multiple Supply Methods	VMI, JIT, consignment system, parts procurement
A8 Flexible transportation	aa21 Diversified Delivery	Home delivery, self pickup at production site, and temporary storage in warehouse
	aa22 Equipment Rental	Different models of vehicles and batches of goods
	aa23 Own Equipment	Equipped with vehicles, reducing call time
	aa24 third-party outsourcing	Special needs, professional logistics companies
A9 Communication and Coordination	aa25 Requirement Communication	Expected delivery time, actual delivery time, procurement and production arrangement
	aa26 Fault Feedback	Order delay and problem feedback
	aa27 Instruction Release	Bill of materials Disassembly, Purchase Order

4.3. Resilience in supply chain resilience

Resilience in a supply chain is the ability to adjust the supply chain back to its normal operating state after a disruption or interruption caused by an external shock [6]. Operational alignment, risk treatment, and knowledge management are the main components in supply chain resilience. Among them, business adjustment includes three components such as process update, budget shift, and strategy turnover, which can adjust the business direction in time after a disaster. Risk management mainly includes response mechanism and feedback mechanism, which can effectively help supply chain reduce the destructiveness of risk by taking active response and feedback measures to the risk events that have occurred. Knowledge management, on the other hand, systematically classifies and organizes the handling solutions and response experiences of supply chain crises, which can help the supply chain recover from such events. The coding process of the acquired case information is shown in Table 4.

Table 4. Resilience in Supply Chain Resilience Case Example

Secondary Theme	First level concept	Label
A10 Business Adjustment	aa28 Process Update	Update methods and processes
	aa29 Budget Transfer	Equipment maintenance and personnel compensation
	aa30 strategic replacement	Top down, strategic promotion
A11 Risk Management	aa31 response mechanism	Immediately respond and arrive at the scene
	aa32 feedback mechanism	Report and solve problems layer by layer
A12 Knowledge Management	aa33 processing plan	Institutionalization and process oriented
	aa34 coping experience	Sort, classify

5. Conclusion

The establishment of digital control tower can break the barriers between enterprises, so that the resources in the supply chain can be rationally allocated to achieve the supply chain management mode of resource sharing and information sharing, and the operation of the control tower is the process of supply chain toughness co-business, and every enterprise in the supply chain can participate in the operation and improvement of the digital control tower, eliminating as far as possible the bullwhip effect and duplication

of resource allocation due to information asymmetry In this way, we can fundamentally improve the operational efficiency of the supply chain and enhance the risk resistance of the whole system. In the field of supply chain, the digital control tower under the perspective of dynamic capacity emphasizes the absorption capacity, robustness and recovery capacity of the supply chain to cope with the impact of various internal and external factors. The digital control tower is an integrated tool that enables monitoring and coordination of all parts of the supply chain to ensure an efficient and smooth supply chain. And as the supply chain environment continues to change and global competition intensifies, enhancing the resilience of the supply chain has become a necessary choice for each company. In the future, with the continuous development of technology, the digital control tower under the perspective of dynamic capability will become an important tool to enhance the resilience of supply chain.

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