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Original Article

Case Study on the Supply Chain Resilience of Potential Hidden-Champion Enterprises in Taiwan

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Abstract *- Enterprises will face the risk of disrupted supply chains in the case of major crises. In recent years, global industries have suffered major economic losses and even mass casualties in many events, such as the 2011 earthquake and tsunami in Japan and the COVID-19 pandemic, from which many economic and commercial activities have not completely recovered. Global major crises are happening more frequently due to a number of factors, such as environment, climate, politics, and pandemic factors, among others. To this end, the supply chain resilience issue is attracting great attention from various industries. Taiwan enterprises play a vital role in the global manufacturing supply chain and are so-called hidden champions. This research implemented a case study on three potential hidden-champion enterprises in Taiwan to analyze their supply chain vulnerabilities and capabilities, respectively, and further identify their supply chain resilience. In addition, this study summarized the five resilience features of these three enterprises through the interview and questionnaire contents for reference of various industries.*

Keywords *- Disrupted supply chain, Supply chain resilience, Hidden champions, Vulnerabilities, Capabilities.*

1. Introduction

The U.S. investigated China for infringing intellectual property rights pursuant to Section 301 of the U.S. Trade Act in 2017, thus starting the China–U.S. trade war. In the same year, China also imposed a tariff of USD30 billion on 128 types of American goods.[1] Both parties raised tariffs on imported goods, causing a great impact on the global economy. Then, at the end of 2019, COVID-19 quickly spread over the world, causing a surge in the number of confirmed cases and deaths. To control the spread of the pandemic, all countries in the world implemented lockdown measures, which also significantly disrupted the global supply chain.

The global supply chain mode has transferred from a centralized mode to a distributed manufacturing mode.[2] Enterprises are distributing their production sites in their home countries or Southeast Asian countries to respond to the demands of end customers in real-time and reduce the risk of disruptions due to the pandemic. Taiwan's export-oriented economy has also been impacted by supply chain restructuring. Supply chain restructuring is inevitable. Most Taiwanese enterprises are small- and medium-sized enterprises. However, many of these enterprises play a vital role in supplying key components in the global supply chain and are recognized as "hidden champions" that are resilient in the global supply chain. This study aimed to find an appropriate supply chain resilience measuring method by discussing supply chain resilience. This study also attempted to understand the degree of supply chain resilience for potential hidden-champion enterprises in Taiwan through case studies. Further, it summarized these enterprises' supply chain resilience principles for the reference of current industries.

2. Literature Review

2.1. Supply Chain Resilience

In the past two decades, supply chain vulnerabilities and corresponding supply chain risk management have gained extensive attention from enterprises and academia.[3,4,5] Christopher and Peck (2004) suggested that supply chain resilience provides enterprises with the ability to address unavoidable crises, return their operation to the original state, and transform into a better state during and after disruptions.[6] BCG, a consulting firm, developed a tool that can quickly measure supply chain resilience by scoring the immunity and the level of recovery in the supply chain. Scores correspond to different quadrants in the matrix and corresponding actions, as shown in Figure 1. [7]

Fig. 1 Supply chain resilience matrix quadrants

Table 1. Definitions of supply chain resilience

Source	Definition
Rice & Caniato (2003)	A resilient supply chain has the ability to respond to unexpected disruptions and return to normal operations.
Sheffi (2005)	A resilient supply chain can prevent and recover from disruptions.
Fiksel (2006)	A resilient supply chain has the ability to survive, adapt, and grow in the face of drastic changes.
Mckinsey &Company	A resilient supply chain has the ability to recover from difficulties quickly.
Harvard Business Review	A resilient supply chain has the ability to absorb and withstand pressure, recover key functions, and thrive in a changing situation.
British Standards Institution	Supply chain resilience is not used to measure the degree of optimism of enterprises but to present the ability of organizations to adapt to, respond to, and recover from a shock event.

Source: [8-13]

In terms of supply chain resilience, an enterprise's tolerance against external risks [14-17] and its capabilities to cope with such risks are key factors [18-22]. To this end, this study defined supply chain resilience as the ability to avoid the risk of disruptions in a fast-changing environment, quickly recover operations, and keep growing in the face of shock events. Pettit et al. (2013) found a relationship between supply chain vulnerabilities and capabilities in discussing supply chain disruptions and proposed the resilience fitness space scatter diagram. [28] The study suggested that a supply chain can maintain the fittest resilience range only when a balance is struck between the internal development of capabilities and vulnerabilities in withstanding external risks. This study used this model to discuss supply chain resilience practices.

2.2. Hidden Champions

Simon (2009) stated in Hidden Champions of the 21st Century: The Success Strategies of Unknown World Market Leaders that the secret behind the rise of German manufacturing was the existence of hidden-champion enterprises. [24] As defined in the study, hidden-champion enterprises are focused, excellent, and take the lead in a segment but are barely noticed by the outside world. In 2012, Taiwan promoted selected resilient enterprises to the selection of hidden champions. It expected to identify and support them through the selection process so that the industries could be more competitive. [25]

3. Methods

3.1. Research Method and Objects

This study adopted the case study method by distributing questionnaires and interviewing enterprises on supply chain resilience. Samples were selected from 42 potential hidden champions in Taiwan. The selected industries included the electronics, automobile, outdoor equipment manufacturing, healthcare, textile, component manufacturing, machinery, network communication, and semiconductor fields. At last, three enterprises with the most typical international supply chain operation models were selected. These enterprises came from the outdoor equipment manufacturing, metal components manufacturing, and automotive component manufacturing industries.

3.2. Tool for measuring Supply Chain Resilience

This study applied the supply chain resilience assessment and management (SCRAM) model proposed by Pettit, Fiksel, and Croxton (2013) as the measuring tool. [26] This tool comprises seven supply chain vulnerability factors and 14 supply chain capability factors, as listed in Table 2 and Table 3. A five-point Likert scale (with answers ranging from 1 to 5 indicating strong disagreement to strong agreement) is used for measurement.

Table 2. Supply chain vulnerability evaluation factors

	Vulnerability factor	Definition
1	**Turbulence**	Environments characterized by frequent changes in external factors beyond the company's control
2	**Deliberate Threats**	Intentional attacks aimed at disrupting operations or causing personal or financial harm.
3	**External Pressures**	Influences that create business constraints or barriers
4	**Resource Limits**	Constraints on output based on the availability of the factors of production
5	**Sensitivity**	Importance of carefully controlled conditions for product and process integrity
6	**Supplier /Customer Disruption**	Susceptibility of suppliers and customers to external forces or disruptions
7	**Connectivity**	Degree of interdependence and reliance on outside entities

3.3. Case Study Description

This study implemented the case study interview based on four dimensions, as described below:

3.3.1. Define the scope and background of the disruptions of interviewed enterprises

This study measured disruptions of these enterprises according to their business scopes and made the following classifications:

Table 3. Supply chain capability factors

	Capability Factor	Definition
1	**Flexibility in Sourcing**	Ability to quickly change inputs or the mode of receiving inputs
2	**Flexibility in Order Fulfillment**	Ability to quickly change outputs or the mode of delivering outputs
3	**Capacity**	Availability of assets to enable sustained production levels
4	**Efficiency**	Capability to produce outputs with minimum resource requirements
5	**Visibility**	Knowledge of the status of operating assets and the environment
6	**Adaptability**	Ability to modify operations in response to challenges or opportunities
7	**Anticipation**	Ability to discern potential future events or situations
8	**Recovery**	Ability to return to a normal operational state rapidly
9	**Dispersion**	Broad distribution or decentralization of assets
10	**Collaboration**	Ability to work effectively with other entities for mutual benefit
11	**Organization**	Human resource structures, policies, skills, and culture
12	**Market Position**	Status of a company or its products in specific markets
13	**Security**	Defense against deliberate intrusions or attacks
14	**Financial Strength**	Capacity to absorb fluctuations in cash flow

- Supply chain disruption: the feasibility of supplying and delivering products and services at the required time and place
- Production disruption: the process of producing products and services
- Demand disruption: producing and selling products to customers or end customers, including downstream manufacturers in the manufacturing chain.

3.3.2. Measure the Current Supply Chain Resilience

This study used the supply chain resilience scale for measurement. In terms of vulnerability, if the score were less than 3, the supply chain would be less likely to be affected by the external environment and be more resilient. If the score were greater than 3, the supply chain would be more likely to be less resilient and affected by the external environment. In terms of capability, if the score were greater than 3, the Enterprise and the supply chain would be able to adapt to external environment shocks and be resilient fully; if the score were less than 3, the Enterprise and the supply chain would not be resilient. This study then computed the resilience index to understand the degree of resilience of each interviewed case.

$$\text{Resilience index equation: } R=\frac{C-V+4}{8} \quad (1)$$

C: mean of the vulnerability factors
V: mean of the capability factors

When R = 50%, the overall enterprise supply chain would have complete resilience. When R moved upper left (R = 75% to 100%), the overdevelopment of capabilities in the supply chain would undermine profits. When R moved lower right (R = 25% to 0%), the underdevelopment of capabilities in the supply chain would expose the supply chain to great external shocks.

3.3.3. Analyze Resilience Measurement Items

This section analyzes and describes resilience measurement items: Through measuring the vulnerability, this study identified the highest external threats to the supply chain and provided enterprises with external vulnerability threats that enterprises should pay attention to in the future. Through measuring the capability, this study also identified the strongest and weakest capability factors and provided suggestions on internal capabilities that management should improve in the future.

Table 4. Disruptions of the three cases

	Industry	Disruption content	Disruption Type
A	Outdoor sports equipment	The infrastructure in the place where the factory was located was poor. As a result, insufficient power supply led to inefficient production.	Production disruption
B	Metal components processing	The COVID-19 pandemic in the place where the factory was located led to inefficient production.	Production disruption
C	Automotive components manufacturing	The COVID-19 pandemic led to the shutdown of production lines in Mainland China.	Production disruption

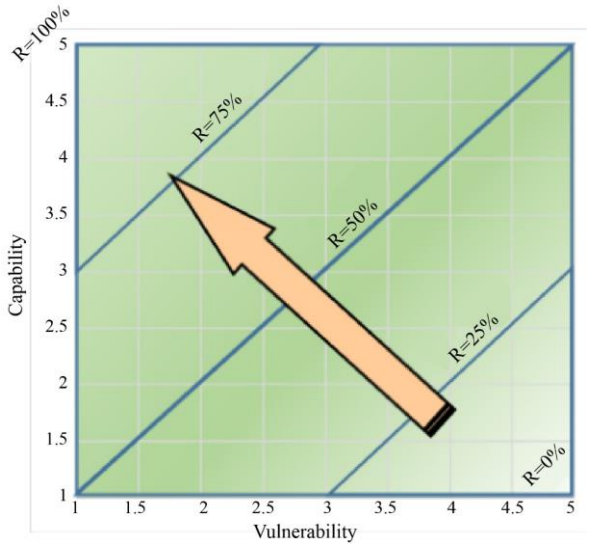

Fig. 2 Quantification of the degree of resilience

3.3.4. Validate case Interviews

This study qualitatively measured resilience and investigated the current situation of the three cases.

4. Results and Discussion

The three enterprises interviewed in this study were denoted as enterprises A, B, and C. Table 4 lists the supply chain disruption types of the three enterprises.

4.1. Enterprise A

Enterprise A was a world-famous bicycle brand. Its supply chains comprised tier-one suppliers providing product materials and components. The interviewee was the general manager of the operation's headquarters. The measurement and interview were completed on September 17, 2021.

4.1.1. Measurement of the Degree of Resilience for Enterprise A

Measurement of the Overall Supply Chain Resilience

For enterprise A, the average overall supply chain vulnerability was 2.63 (<3), the average overall supply chain capability was 3.91 (>3), and the supply chain resilience index was 66% (falling within the range of 50% to 75%). According to the fittest supply chain resilience range (shown in Figure 3), Enterprise A was slightly resilient.

4.1.2. Measurement of Vulnerabilities

As listed in Table 5, compared with other vulnerability factors, reliance on external supply chain networks (connectivity) was a significant risk for Enterprise-A. However, for enterprise A, supplier/customer disruptions had a low compact of vulnerability.

Among the external vulnerability factors, connectivity showed the highest score for Enterprise A's supply chains, indicating that Enterprise A relied heavily on external suppliers. Therefore, Enterprise A needs to share information between supply chains at all times. In cases of low information transparency, Enterprise A will face the risk of external resource disruptions.

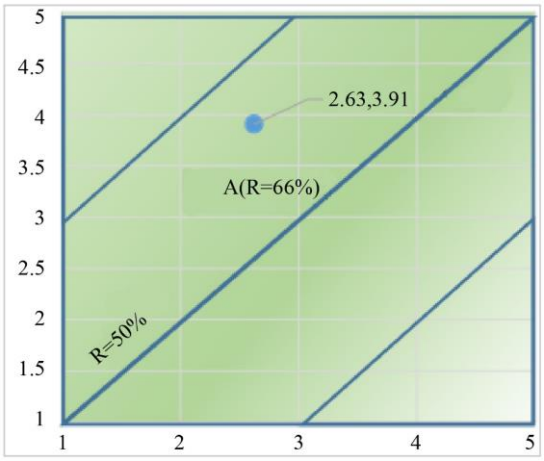

Fig. 3 Distribution of supply chain resilience of Enterprise A

Table 5. Measurement of Enterprise A's vulnerabilities

Rank	Vulnerability Measurement Dimension	Average Score
1	Connectivity	3.75
2	Sensitivity	2.71
3	Resource Limits	2.67
4	Turbulence	2.67
5	Deliberate Threats	2.33
6	External Pressures	2.33
7	Supplier/Customer Disruption	2

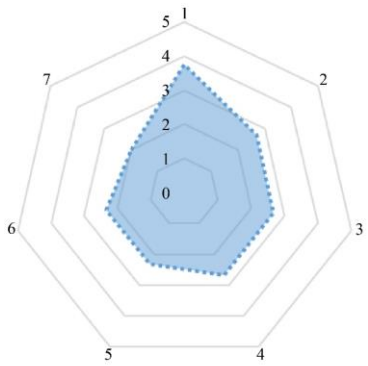

Fig. 4 Spider chart of vulnerabilities for Enterprise A

In terms of external disruptions, Enterprise A did not suffer severe disruptions due to the COVID-19 pandemic and maintained normal operations. Customer demands for related products also increased due to the pandemic.

(3)Measurement of capabilities

As listed in Table 6, the top four capabilities of Enterprise A were recovery, collaboration, market position, and dispersion.

Table 6. The rank of capabilities of Enterprise A measurement

Rank	Capability Measurement Dimension	Average Score
1	Recovery	4.75
2	Collaboration	4.33
3	Market Position	4.33
4	Dispersion	4.25
5	Capacity	4
6	Efficiency	4
7	Visibility	4
8	Anticipation	4
9	Organization	3.67
10	Security	3.67
11	Flexibility in Sourcing	3.6
12	Adaptability	3.5
13	Financial Strength	3.5
14	Flexibility in Order Fulfillment	3.2

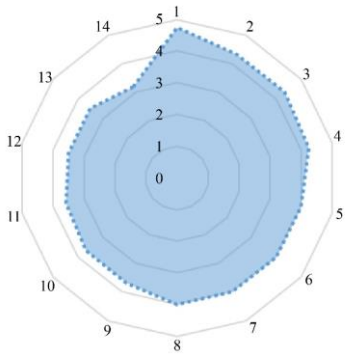

Fig. 5 Spider chart of the capabilities of Enterprise A

Recovery of the highest score (4.75), i.e., its supply chains are capable of quickly recovering to the normal operation state, indicated that an intelligent ERP system should be introduced into enterprise A's supply chains to allow management to keep abreast of all data in the supply chains and immediately organize key personnel to form a response team. In addition, enterprise A's supply chain crisis response team should maintain efficient communication with each other and quickly and efficiently deal with disruptions. Although the immediate actions taken by Enterprise-A in the face of disruptions will cause a rise in short-term costs, Enterprise-A should still take immediate measures to resolve disruptions to mitigate the impact of disruptions on Enterprise-A and its supply chains.

4.1.3. Resilience Interview Contents of Enterprise A

According to the interview data, the development of Enterprise A's supply chain resilience was understood as follows:

A multi-site Production Strategy

Due to the China–U.S. trade war, exports in the bicycle and related markets suffered the immediate impact of high tariffs in the U.S. In response, Enterprise A gradually transferred the production of orders to be exported to the U.S. from Mainland China to Taiwan. Enterprise A increased its production capacity in Taiwan to facilitate supply chain development and disperse risks while speeding up investment in intelligent production line construction. Enterprise A applied a multi-site flexible manufacturing strategy to reduce the impact on its supply chains.

Visible Operation Process

Enterprise A focused on the development trend of electric and intelligent bicycles. It diversified its machinery product categories and implemented one-stop shopping for customers through automation and intelligence. Enterprise A also introduced an intelligent ERP system in its Taiwan and Mainland China factories to visualize the supply chain operation process based on data.

Collaboration and Cooperation

Enterprise A acquired a world-famous bicycle brand as it mastered key products, making Enterprise A the leader in the industry.

4.2. Enterprise B

The business scope of Enterprise B covered metal component processing and related operational processes. Most customers of Enterprise B were famous sports equipment brands from more than 30 countries in Europe, the Americas, Asia, and Australia. The supply chains were second-order suppliers providing raw materials and related parts. The interviewee was the chairman of Enterprise B. The measurement and interview were completed on September 14, 2021.

4.2.1. measurement of the degree of resilience for Enterprise B

Measurement of the Overall Supply Chain Resilience

For enterprise B, the average overall supply chain vulnerability was 2.22 (<3), the average overall supply chain capability was 3.69 (>3), and the supply chain resilience index was 68% (falling within the range of 50% to 75%). According to the fittest supply chain resilience range (shown in Figure 6), enterprise B was slightly resilient.

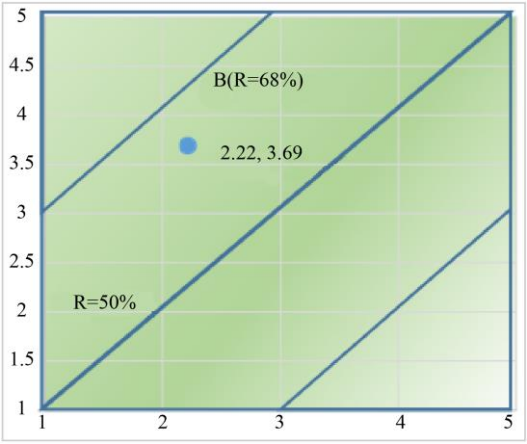

Fig. 6 Distribution of the supply chain resilience of Enterprise B

Measurement of Vulnerabilities

As listed in Table 7, the top three scores were for connectivity, external pressures, and sensitivity, while the bottom three scores were for deliberate threats, resource limits, and supplier/customer disruptions.

Table 7. Supply chain vulnerability ranking of Enterprise B

Rank	Vulnerability Measurement Dimension	Average Score
1	Connectivity	3
2	External Pressures	2.5
3	Sensitivity	2.38
4	Turbulence	2.17
5	Supplier/Customer Disruption	2
6	Resource Limits	1.83
7	Deliberate Threats	1.67

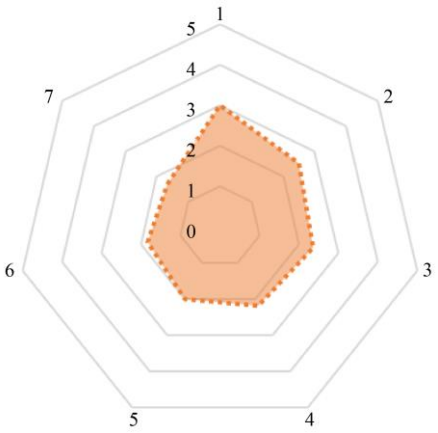

Fig. 7 Spider chart of the vulnerabilities of Enterprise B

According to the measurement of vulnerabilities, enterprise B's supply chains showed a significant connectivity risk. Enterprise B's supply chains did not contain a large number of suppliers, possibly because Enterprise B only cooperated with suppliers through long-term cooperation relationships. In addition, most products of Enterprise B could be produced without specific components. However, enterprise B's production heavily relied on continuous information transparency to respond to market changes. It was difficult for Enterprise B to reach information transparency, which posed a high risk.

For enterprise B, the most insignificant vulnerability factor was deliberate threats. Enterprise B's supply chains could run normally in terms of personnel and operation processes.

Measurement of Capabilities

As listed in Table 8, the significant capability factors for Enterprise B were dispersion and efficiency. Flexibility in sourcing, capacity, adaptability, organization, and market position scored similarly. The most insignificant capability factors were flexibility in order fulfillment, collaboration, and visibility.

Table 8. Measurement of Enterprise B's capabilities

Rank	Capability Measurement Dimension	Average Score
1	Dispersion	4.67
2	Efficiency	4.4
3	Flexibility in Sourcing	4
4	Capacity	4
5	Adaptability	4
6	Organization	4
7	Market Position	4
8	Recovery	3.67
9	Security	3.67
10	Anticipation	3.33
11	Financial Strength	3.25
12	Flexibility in Order Fulfillment	3.17
13	Collaboration	3
14	Visibility	2.5

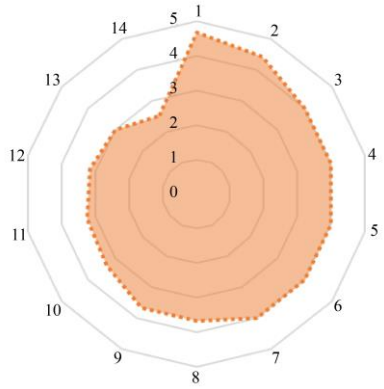

Fig. 8 Spider chart of the capabilities of Enterprise B

Due to the COVID-19 pandemic and the China–U.S. trade war, enterprise B gradually relocated its factories from Mainland China to a number of Southeast Asian countries, including Myanmar. However, due to the infrastructure instability and high employee turnover rate in this country, enterprise B decided to send production back to Taiwan to disperse the impact of disruptions. In addition, enterprise B sent senior management to each production site to understand the local problems. Its products were exported to various countries. Therefore, dispersed production sites were helpful in quickly meeting local end-customer demands. Visibility showed the lowest score. From the interviewee's understanding of Enterprise B's operation processes, considering the order scale, this Enterprise has built only partially automated and intelligent systems at present. As a result, enterprise B could not precisely track its operation processes, as its intelligent systems could not provide real-time information about suppliers' products, device states, and sites.

4.2.2. Resilience Interview Contents of Enterprise B

According to the interview data, the current situation of Enterprise B's development of supply chain resilience was understood as follows:

A Multi-site Production Strategy

Due to the China–U.S. trade war, European and American customers required enterprise B to relocate some of its production lines to regions outside Mainland China within three months. Then, this Enterprise established a factory in Myanmar. However, after a period of time, due to low infrastructure reliability, an unstable power supply, and high employee turnover rates, enterprise B relocated its factory from Myanmar back to Taiwan.

Digital Development

Enterprise B considered using semi-automated and automated development. However, in consideration of the scale of orders, enterprise B has only established partially automated, visualized, and intelligent manufacturing at present.

Operation Model

Enterprise B owned most of the patents used in the industry. By integrating its underlying supply chain design and manufacturing capabilities, enterprise B transferred its operation model from OEM to ODM and could outsource production to other enterprises to obtain more orders than other vendors.

4.3. Enterprise C

The business scope of Enterprise C covered automotive component manufacturing and plastic injection molding products. The customers of Enterprise C were famous global automobile brands. Its supply chains comprised tier-two suppliers. The interviewee was a deputy general manager of Enterprise C's marketing department. The measurement and interview were completed on September 19, 2021.

4.3.1. Measurement of the Degree of Resilience for Enterprise C

Measurement of the Overall Supply Chain Resilience

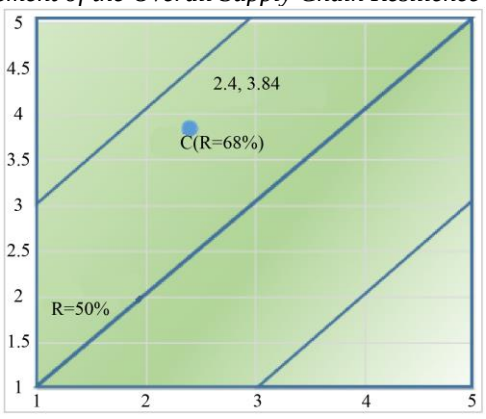

Fig. 9 Distribution of the supply chain resilience of Enterprise C

For enterprise C, the average overall supply chain vulnerability was 2.4 (<3), and the average overall supply chain capability was 3.84 (>3). The supply chain resilience index was 68% (falling within the range of 50% to 75%), which was the same as that of enterprise B. Enterprise C was slightly resilient.

Measurement of Vulnerabilities

Table 9. Measurement of the vulnerabilities of Enterprise C

Rank	Capability Measurement Dimension	Average Score
1	Connectivity	3.4
2	External Pressures	3.17
3	Sensitivity	2.56
4	Turbulence	2.5
5	Resource Limits	2
6	Supplier/Customer Disruption	2
7	Deliberate Threats	1.17

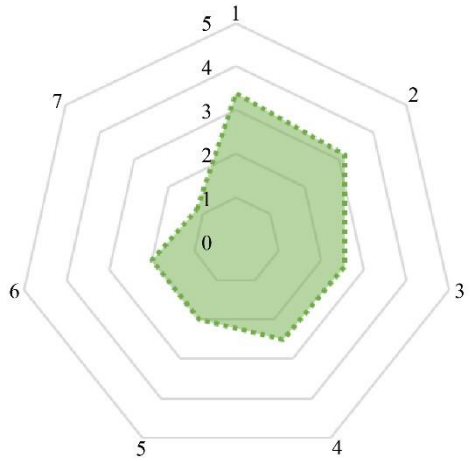

Fig. 10 Spider chart of the vulnerabilities of Enterprise C

Measurement of Capabilities

Table 10. Measurement of the capabilities of Enterprise C

Rank	Capability Measurement Dimension	Average Score
1	Visibility	4
2	Adaptability	4
3	Anticipation	4
4	Recovery	4
5	Organization	4
6	Market Position	4
7	Security	4
8	Financial Strength	4
9	Flexibility in Sourcing	3.8
10	Efficiency	3.8
11	Dispersion	3.8
12	Flexibility in Order Fulfillment	3.5
13	Collaboration	3.5
14	Capacity	3.33

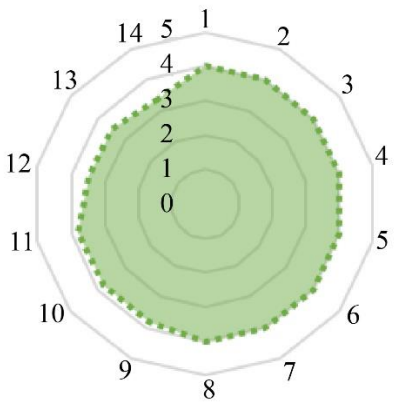

Fig. 11 Spider chart of the capabilities of Enterprise C

Among the external vulnerability factors, connectivity showed the highest score, further indicating that Enterprise C relied heavily on a small number of quality suppliers. As a result, in case of disruptions in the external environment, enterprise C would face the risk of disruptions. In terms of deliberate threats, the products, operation processes, and employees of Enterprise C would not be subject to the negative impact of specific interest groups and commercial espionage.

For Enterprise C, the degree of visibility was more significant. Enterprise C had real-time information about finished products, production statuses, and logistics in its supply chains. It could collect and exchange information with its suppliers and customers, thus allowing it to master all conditions and issues faced by customers and suppliers. Capacity had a low score, mainly because the pandemic led to inefficient production.

4.3.2. Resilience Interview Contents of Enterprise C

According to the interview data, the current situation of Enterprise C's supply chain resilience development was understood as follows:

- Enterprise C gained a lot of profit in Vietnam due to the China–U.S. trade war and therefore expanded its production capacity in Vietnam. Manufacturers in Mainland China also established factories in Vietnam to supply their downstream customers. Some managerial staff in Vietnam were from Mainland China. Many components were transferred from Mainland China for transport to the U.S. after being assembled in Vietnam.
- Enterprise C's factory in Vietnam was adversely affected by the personnel movement restriction measures taken by the local government in response to the COVID-19 pandemic. Later, although the factory was ready for work resumption, the capacity was projected to be reduced by about 80-90%. Subsequent delivery would be resumed according to the development of the pandemic.

5. Conclusion

Table 11 lists the quantitative analysis results from the questionnaire survey. Taiwan's enterprises can make huge investments in increasing their capabilities to develop their resilience. This will undermine their profits but reduce the impact of external environments. Therefore, Taiwan's overall resilience development of potential hidden-champion enterprises shows the preliminary resilience feature. These enterprises are becoming more and more resilient.

Table 11. Quantitative Data on the resilience of enterprises

Enterprise	Resilience Index	Average Vulnerability	Average Capability
A	66%	2.63	3.91
B	68%	2.22	3.69
C	68%	2.4	3.84

- Through qualitative interviews with representatives of the three enterprises, this study enhanced the description of resilience features of potential hidden-champion enterprises in Taiwan. The resilience features could be described as follows:
- Generally, enterprises can share internal information in their supply chains. However, they still do not make internal information in supply chains completely transparent.
- In terms of the dispersion of production sites, as Taiwan's enterprises are export-oriented, they set production sites in various regions. Therefore, disruptions rarely occur. In addition, they can reserve excess inventories to ensure continuous production in case of external inventory disruptions.
- Regarding recovery from disruptions, most enterprises can form an emergency response team immediately. Only a few enterprises need to improve communication between team members to improve efficiency in resolving disruptions.
- Regarding collaboration, Taiwan's enterprises and suppliers have robust operating systems. Therefore, their specialized division supply chains can supplement each other in case of disruptions.
- In terms of finance, all enterprises have redundant financial reserves to prevent them from being unable to operate in case of disruptions.

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