Evaluation of Indicators for Developing Supply Chain Resilient in the Healthcare Industry of Indonesia

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Abstract

Since Covid-19 had been declared a global pandemic by the World Health Organization (WHO) on March 12, 2020, various policies have been made by governments around the world, one of which is a lockdown. This policy interrupts companies from being able to manufacture and distribute their products causing supply chain disruptions. The healthcare industry is one of the supply chains that has been significantly impacted by the pandemic. There are severe shortages of personal protective equipment (PPE) and other medical supplies for Covid-19 treatment in hospitals around the world. One of the countries that experienced a disruption in the healthcare supply chain was Indonesia, due to its dependence on medical supplies from other countries, there was a ban on exports during the lockdown. It is important to adopt Supply Chain Resilience (SCR) because of the dependencies in the supply chain. When SCR is adopted, a Key Performance Indicator (KPI) is required as a tool to monitor and measure supply chain resilience performance. In this study, the indicators collected from the literature review, there are 9 indicators which are: security, knowledge management, visibility, risk management, collaboration, agility, flexibility, redundancy, market position, and 42 sub-indicators for supply chain resilience. Afterward, the indicators and sub-indicators were validated by several experts by filling out questionnaires. Using modified kappa (k*) for validation, eight healthcare experts validated 41 sub-indicators with a value of k* is more than 0.60.

Keywords
Supply Chain Resilience, Indicator, Modified Kappa, Healthcare, Pandemic

1. Introduction
COVID-19 is an infectious disease of the respiratory system caused by the SARS-CoV-2 virus. The disease was first confirmed in December 2019 in Wuhan, China. Due to the rapid spread and infection of most of the world's population, the World Health Organization (WHO) declared COVID-19 a global pandemic on 12 March 2020 (Ciotti et al. 2020). As a result, various policies were adopted, one of which was a lockdown to control the spread of COVID-19 (Rehman and Ali 2022). The lockdown was enforced by prohibiting residents from leaving their homes and closing public spaces such as recreation centers, restaurants, schools, and workplaces (Romdiati and Noveria 2022). This policy led to the closure of many suppliers, manufacturers, and distributors around the world (Rehman and Ali 2022). The closure of many of these companies caused supply chain disruptions in the industry (Agarwal et al. 2020).

The healthcare industry is one of the supply chains that has been significantly affected by the pandemic. Hospitals around the world are experiencing severe shortages of personal protective equipment (PPE) and other medical supplies for Covid-19 treatment. Meanwhile, manufacturers of medical supplies are facing shortages of materials and components needed for production due to export bans, and many suppliers have shut down due to mobility restrictions that have limited their production capacity (Spieske et al. 2022).

China is one of the world's most important manufacturing and distribution centers for PPE. According to data from the Peterson Institute for International Economics (PIIE) in 2018, China accounted for more than 50 % of global PPE for respirators and surgical masks, medical goggles, and protective clothing (Chad P. Bown 2020). In January and February 2020, as the number of COVID-19 cases increased rapidly, the Chinese government implemented a lockdown. One of the areas affected by the lockdown is Wuhan, which is the center of non-woven fabric manufacturing, the raw material for PPE production. As a result of the lockdown in Wuhan, the global PPE supply chain has been disrupted. The disruption is exacerbated by the Chinese Government's policy of banning PPE from leaving China to meet rapidly growing domestic demand (Falagara Sigala et al. 2022). As a result of this policy, China's supply of PPE to the rest of the world has been reduced. Export restrictions on PPE from China naturally disrupt the availability of PPE in Indonesia, as almost half of imported PPE comes from China. To make matters worse, the increasing number of positive COVID-19 cases has led to a surge in demand and a tendency for people to panic-buy and hoard, which has disrupted the PPE supply chain in Indonesia (Chad P. Bown 2020).

Due to supply chain dependencies, Maleki & Cruz (2012) suggest the implementation of supply chain resilience (Scala & Lindsay, 2021). Although there are various definitions of supply chain resilience, it is typically defined as the ability of the supply chain in preparing for, respond to, and recover quickly from existing disturbances by keeping the continuity of operations (Ash et al. 2022). Developing supply chain resilience requires clear performance measurement. Therefore, a Key Performance Indicator (KPI) is required as a tool to monitor and measure supply chain resilience performance. This KPI helps describe the current supply chain condition, allowing the company to monitor and evaluate its operations (Karmaker and Ahmed n.d.).

This research will determine which indicators are relevant to the healthcare industry in Indonesia for measuring resilience performance in the supply chain. In this research, the indicators collected from the literature review were validated by subject matter experts by completing questionnaires, then data processing was performed using modified kappa (k*).

1.1 Objectives

As global supply chains have been disrupted by pandemics in various countries, the resilience of supply chains has become an important issue, one of which is the healthcare industry. Therefore, this research aims to develop indicators to measure supply chain resilience performance in the healthcare industry in Indonesia. The objectives were translated into the following research questions

- What are the relevant indicators for measuring supply chain resilient performance in the healthcare industry in Indonesia?

2. Literature Review

2.1 Supply Chain Resilience (SCR)

Supply chain resilience is a refinement of supply chain risk management, which is inadequate to solve increasingly complex supply chain problems, increasing vulnerabilities, uncertainties, and unexpected disruptions. When supply chains are disrupted, a new approach and a new way of thinking are required for the development and management of supply chains so that they can be protected from disruption. Therefore, developing supply chain resilience is an important supply chain strategy (A. Ali et al. 2017). Supply chain resilience is the ability of the supply chain to anticipate unexpected disruptions and then respond to emerging disruptions while maintaining operations and recovering the supply chain after a disruption to its original position or repositioning the company in a better position than before and taking advantage of disruptions (Hussain et al. 2022), (Sawyerr and Harrison 2022).

2.2 Key Performance Indicators

The supply chain requires comprehensive performance measurements. This is useful to measure the effectiveness of the strategies implemented in the supply chain and to identify future opportunities. With the presence of performance measurement in the supply chain, the management or stakeholders can find out the activities that are not suitable so that they can determine the corrective action plan that can be implemented (Widyarto et al. 2019). Key performance indicators (KPIs) are one of the management tools used to measure performance. KPIs are measurable metrics that reflect indicators that the supply chain needs to monitor and evaluate in order to be successful (Kenanga and Ardi

n.d.). In order to generate relevant KPIs for processes and requirements, each supply chain sets its KPIs based on the supply chain strategy used (Karl et al. 2018).

2.3 Content Validity

Content validation is an assessment of instrument items to determine the relevance and representation of an instrument item to the objectives of a particular study. Experts who play a role in the assessment of instrument items are asked to carry out content validation. These experts are considered to be people who have extensive knowledge of the topic under discussion, either because of their educational background, work experience, or knowledge of the topic (Fernández-Gómez et al. 2020).

In this research, the instrument can be interpreted as a questionnaire and the items are indicators from the literature review. These indicators are assessed by experts to know the relevance and representation of an indicator in the measurement of supply chain resilience performance. In this assessment, the experts used a quantification measure that is a Likert-type rating scale with 4 points to avoid midpoints or ambivalence. The scores are as follows: 1=not relevant, 2 somewhat relevant, 3=moderately relevant, and 4 highly relevant (Polit et al. 2007).

The general method commonly used is the Content Validity Index (CVI), but the CVI has limitations with the proportion of agreement where scales 1 and 2 become irrelevant categories and scales 3 and 4 become relevant categories. According to Cohen in 1960, this method was described as a primitive approach when an agreement ratio existed. For this reason, Cohen introduced a new approach, known as the kappa coefficient (k), to assess the agreement between the experts. The kappa statistic is a description of the agreement that remains after the removal of the probability of agreement (Almanasreh et al., 2019). In 2007, Polit et al. modified kappa (k*); this approach removes the probability of agreement from each I-CVI. This method captures the agreement between the experts on the relevance of the item, but the agreement on its irrelevance is not calculated (Polit et al. 2007).

3. Methods

In this research, validation data is obtained from expert judgment by completing questionnaires. The questionnaire data are then processed using the modified kappa (k*) method with the formula below. The calculation of k* starts with the calculation of the probability of agreement with equation number 1, where N is the number of experts and A is the number of experts who are in agreement on relevance. Then, calculate the I-CVI with equation number 2, and after calculating the I-CVI, calculate the modified kappa (k*) with equation number 3 (Almanasreh et al. 2019).

$$Pc = \left[\frac{N!}{A!(N-A)!}\right] \text{ x } 0.5^N \quad (1)$$

$$\text{I-CVI} = \frac{Number\ expert\ of\ agreeing}{Total\ Expert} \quad (2)$$

$$k^* = \frac{I-CVI-Pc}{1-Pc} \quad (3)$$

Table 1. Evaluation of Modified Kappa Values

Values	Agreement Level
< 0.40	Poor
0.40 – 0.59	Fair
0.60 – 0.74	Good
0.74 – 1.00	Excellence

Source: (Barbosa and Cansino 2022)

The (k*) results are evaluated based on Table 1, the accepted kappa value is the value above 0.60, which is the good category. If the item is in the good and excellent category, the item is accepted or relevant, but if the item is in the fair and poor category, the item is not accepted or irrelevant (Almanasreh et al., 2019).

4. Data Collection

Indicators and sub-indicators have been identified based on the literature review on supply chain resilience. In total, 9 indicators and 42 sub-indicators were identified from the literature review, as shown in Table 2.

Table 2. Indicators and sub-indicators of Supply Chain Resilience

Indicators	References	Definition	Sub Indicators
Security	(A. Ali et al. 2017), (Autry and Michelle Bobbitt 2008), (Echefaj et al. 2022), (Han et al. 2020a) (Singh et al. 2019) (Williams et al. 2009)	Implementing strategies, procedures, and technologies to secure supply chain management against cyber or physical intentional attacks.	Cyber security, physical security, access restriction, security culture
Knowledge Management	(A. Ali et al. 2017), (Han et al. 2020b), (Scala and Lindsay 2021), (Tukamuhabwa et al. 2015)	Ability to learn from past changes or disruptions to develop better plans and solutions for the future	Learning ability, sharing knowledge, experienced employees, supply chain re-design
Visibility	(Echefaj et al. 2022), (Han et al. 2020b), (Hossain et al. 2022), (Tukamuhabwa et al. 2015)	Capability to view upstream and downstream inventory, demand and supply conditions, and production and purchasing plans along the entire supply chain	Upstream visibility and downstream visibility, monitoring and maintenance, strong IT system, accuracy, information sharing, reliability
Risk Management	(A. Ali et al. 2017), (Barroso et al. 2009), (Echefaj et al. 2022), (Liu et al. 2021), (Rehman and Ali 2022), (Tukamuhabwa et al. 2015)	Supply chain awareness to deal with disruptive events, and a risk management culture is gradually established through various actions	Risk awareness, contingency planning, vulnerability mapping, Supply Chain Risk Management Team

Collaboration	(M. H. Ali et al.2021), (Hussain et al. 2022), (Mandal and Sarathy 2018), (Tukamuhabwa et al. 2015)	Capacity to work in an effective and mutually beneficial manner with other entities in the supply chain	Trust, Communication, risk, and revenue sharing, joint decision-making, supplier development
Agility	(Echefaj et al. 2022), (Han et al. 2020), (Singh et al. 2019), (Zamiela et al. 2022)	The capability to react quickly to unexpected changes in demand or supply from the market, as customer needs are constantly shifting.	Lead time, velocity, on-time delivery, quick responses
Flexibility	(Bauer and Göbl, n.d.), (Hossain et al. 2022), (Scala and Lindsay 2021), (Tukamuhabwa et al. 2015), (Zamiela et al. 2022)	The ability for companies and supply chains to adapt quickly and easily to change when faced with disruptive events, and to operate more efficiently under normal circumstances.	Sourcing flexibility, labor flexibility, distribution flexibility, order fulfillment flexibility, product flexibility, production flexibility
Redundancy	(A. Ali et al. 2017), (M. H. Ali et al. 2021), (Han et al. 2020b), (Karl et al. 2018b), (Park and Komuniecki, 2011), (Singh et al. 2019), (Tukamuhabwa et al. 2015)	Strategic and selective use of backup capacity and inventory that can be used to mitigate disruptions	Safety stock, inventory management, capacity utilization, inventory level
Market Position	(Ali et al. 2017), (Han et al. 2020b)	A strong market position strengthens the company's capability to recover from supply chain disturbances through financial strength, organizational efficiency, and market share.	Efficiency, financial performance, the performance of fulfilling customer requirements, damage of disruptions

Table 3. The List of Experts in the Healthcare Industry

Experts	Sector	Experience
Expert 1	Academia	5 – 10 years
Expert 2	Consultant	5 – 10 years
Expert 3	Medical	10 – 15 years
Expert 4	Medical	> 20 years
Expert 5	Distributor	10 – 15 years
Expert 6	Distributor	5 – 10 years
Expert 7	Distributor	5 – 10 years

Expert 8	Manufacture	> 20 years

After collecting indicators and sub-indicators from the literature review, validation was then conducted by experts in the healthcare industry who have experience working in the healthcare industry or have knowledge and understanding of the healthcare industry for at least 5 years, have knowledge and understanding of medical supplies, have an undergraduate educational background, and can provide well-educated and informed opinions. These indicators and sub-indicators were validated by 8 experts, as shown in Table 3.

5. Result and Discussion

Of the 9 indicators and 42 sub-indicators evaluated by 8 experts and processed with the modified kappa, it was found that all of the indicators and 41 of the sub-indicators were validated. This means that 41 sub-indicators have a value (k*) > 0.60, in other words, there are 41 sub-indicators that can be classified into good and very good categories based on Table 1. The results of the validation using the modified kappa method are shown in Table 4.

Table 4. List of valid indicators and sub-indicators by expert

Indicators	Sub Indicators	number of experts agreeing	I-CVI	Pc	K*	Category
Security	Cyber Security	7	0,875	0,031	0,87	Excellent
	Physical Security	8	1	0,004	1	Excellent
	Access Restriction	8	1	0,004	1	Excellent
	Security Culture	8	1	0,004	1	Excellent
Knowledge Management	Learning Ability	7	0,875	0,031	0,87	Excellent
	Sharing Knowledge	7	0,875	0,031	0,87	Excellent
	Experienced Employees	7	0,875	0,031	0,87	Excellent
Visibility	Upstream Visibility	7	0,875	0,031	0,87	Excellent
	Downstream Visibility	7	0,875	0,031	0,87	Excellent
	Monitoring and Maintenance	7	0,875	0,031	0,87	Excellent
	Strong IT System	8	1	0,004	1	Excellent
	Accuracy	8	1	0,004	1	Excellent
	Information Sharing	6	0,75	0,109	0,72	Good
	Reliability	8	1	0,004	1	Excellent
Risk Management	Risk Awareness	8	1	0,004	1	Excellent
	Contingency Planning	8	1	0,004	1	Excellent
	Vulnerability Mapping	7	0,875	0,031	0,87	Excellent
	Supply Chain Risk Management Team	7	0,875	0,031	0,87	Excellent
Collaboration	Trust	6	0,75	0,109	0,72	Good
	Communication	6	0,75	0,109	0,72	Good
	Risk and Revenue sharing	7	0,875	0,031	0,87	Excellent
	Joint Decision Making	6	0,75	0,109	0,72	Good
	Supplier development	7	0,875	0,031	0,87	Excellent
Agility	Lead Time	8	1	0,004	1	Excellent
	Velocity	8	1	0,004	1	Excellent
	On-Time Delivery	8	1	0,004	1	Excellent

	Quick Response	8	1	0,004	1	Excellent
Flexibility	Sourcing Flexibility	7	0,875	0,031	0,87	Excellent
	Labor Flexibility	7	0,875	0,031	0,87	Excellent
	Distribution Flexibility	7	0,875	0,031	0,87	Excellent
	Order Fulfillment Flexibility	7	0,875	0,031	0,87	Excellent
	Product Flexibility	6	0,75	0,109	0,72	Good
	Production Flexibility	6	0,75	0,109	0,72	Good
Redundancy	Safety Stock	7	0,875	0,031	0,87	Excellent
	Inventory Management	8	1	0,004	1	Excellent
	Capacity Utilization	8	1	0,004	1	Excellent
	Inventory Level	8	1	0,004	1	Excellent
Market position	Efficiency	8	1	0,004	1	Excellent
	Financial performance	8	1	0,004	1	Excellent
	Performance of Fulfilling Customer Requirements	8	1	0,004	1	Excellent
	Damage of disruptions	8	1	0,004	1	Excellent

In this study, 9 indicators and 41 indicators were validated by healthcare industry experts, with the results shown in Figure 1 and Figure 2.

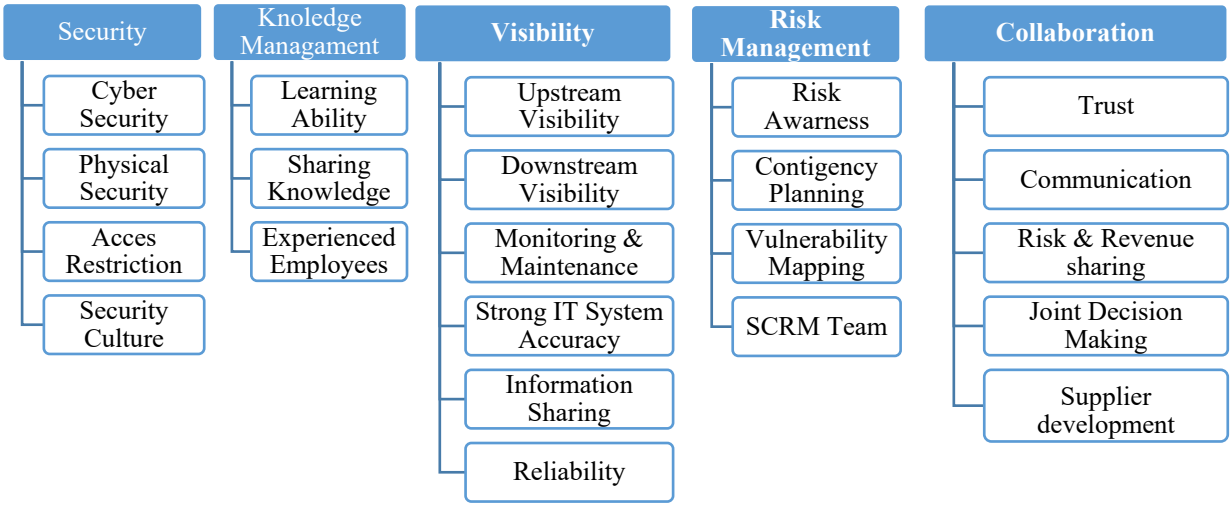

Figure 1. Validated Sub-Indicators Security, Knowledge Management, Visibility, Risk Managament and Collaboration

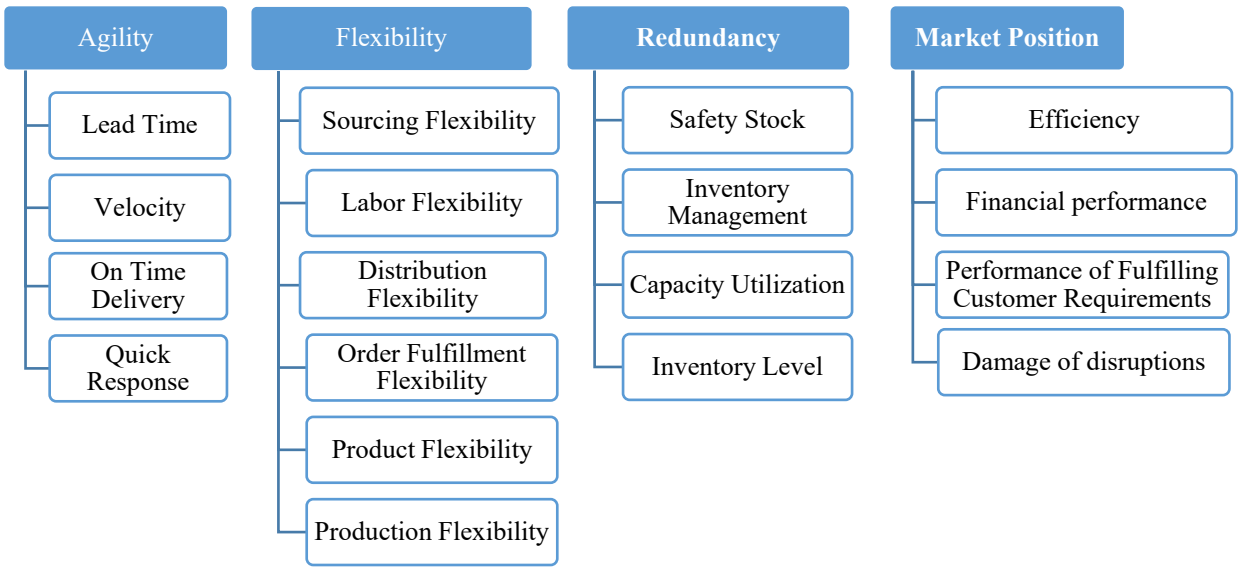

Figure 2. Validated Sub-indicators Agility, Flexibility, Redundancy, and Market Position

5.1 Security

Security has 4 sub-indicators that are valid, namely cyber security, physical security, access restrictions, and security culture. Cyber security is the practices, policies, and technologies used to protect confidential or sensitive digital data or information from unauthorized access or use that could result in the disclosure, exploitation, deletion, or destruction of digital data or information. Physical security is the practices, policies, and technologies used to protect products, facilities, equipment, and personnel from theft, smuggling, damage, sabotage, or terrorism (A. Ali et al. 2017), (Echefaj et al. 2022), (Han et al. 2020). Access restriction is screening employees and limiting the rights of unauthorized employees to access, use, and manipulate company data, assets, and resources, and providing the necessary assurance that internal security efforts are effective (Singh et al. 2019). Security culture, on the other hand, creates a supply chain security mindset among all personnel, ensures that supply chain security remains at the forefront of all personnel's minds, and ensures that all personnel have an awareness of supply chain security (Williams et al. 2009).

5.2 Knowledge Management

Knowledge management has 3 sub-indicators that are valid, namely the ability to learn, to share knowledge, and to have experienced people. Learning from disruptions brings important knowledge into the supply chain, allowing the supply chain to better plan for the next almost inevitable disruption. The ability to share knowledge and experience in dealing with disruptions in the supply chain through activities: (education, training, and socialization) to develop better plans and solutions in the future (A. Ali et al. 2017), (Han et al. 2020). In addition, having experienced employees is essential in crisis management, as their experience with disruptions will help the supply chain develop better plans and solutions (M. H. Ali et al. 2021).

5.3 Visibility

Visibility has 7 sub-indicators that are valid, namely: upstream visibility, downstream visibility, monitoring and maintenance, strong IT systems, accuracy, information sharing, and reliability. Upstream visibility is the ability to see upstream inventory and supply conditions, while downstream visibility is the ability to see downstream inventory and demand conditions. Monitoring and maintenance services for control and monitoring of supply chain planning activities (Han et al. 2020). Strong information technology (IT) systems can improve the visibility and accuracy of data in the supply chain as a whole (Echefaj et al. 2022). Accuracy refers to the accuracy of inventory, the accuracy of order fulfillment, the accuracy of order delivery, etc. Whereas reliability is the ability to fulfill demand immediately before risk mitigation, prevention, or post-disruption events (Han et al. 2020).

5.4 Risk Management

Risk management has 4 sub-indicators that are valid, namely: risk awareness, contingency planning, vulnerability mapping, and supply chain risk management team. Risk awareness identifies all relevant risks and recognizes future uncertainties to successfully manage supply chain risks (Rehman and Ali 2022). Contingency planning predicts potential risks and takes mitigation measures before supply chain risks/disruptions emerge (Echefaj et al. 2022). Mapping the supply chain's vulnerability to disruption should identify the main supply chain barriers, the relative contributions of each supply chain element, and the dynamics and complexity of the supply chain (Barroso et al. 2009). Establish a team with expertise in supply chain risk management, consisting of members from internal organizations and supply chain partner companies. This team is tasked with facilitating and supporting the sharing of knowledge and information specific to supply chain risks, and can more easily coordinate supply chain risk management activities across the supply chain together (Tukamuhabwa et al. 2015).

5.5 Collaboration

Collaboration has 5 sub-indicators that are valid, namely: trust, communication, risk and revenue sharing, joint decision-making, and supplier development. Trust underpins supply chain network relationships, meaning that partners are expected not to behave opportunistically despite short-term incentives (Hussain et al. 2002). In addition, there may be a need for the sharing of critical information and valuable knowledge, and the building of collaborative behavior between firms (Mandal and Sarathy 2018). Risk and revenue sharing throughout the network are important for long-term collaboration between supply chain partners (Hussain et al. 2022). One effective way to deal with disruption is through shared decision-making, which should have the same characteristics as co-created knowledge (M. H. Ali et al. 2021). Supplier development is achieved through the promotion of suppliers with incentives such as finance, training, and technical skills to improve efficiency, commitment, and reliability (Tukamuhabwa et al. 2015).

5.6 Agility

Agility has 4 sub-indicators that are valid: lead time, velocity, on-time delivery, and quick response. As quick response is a key practice to improve agility, lead times should be minimized in both order and delivery lead times (Echefaj et al., 2022). Velocity is characterized as a supply chain network that has reduced wasted time and streamlined processes (Singh et al., 2019; Zamiela et al., 2022). Product delivery performance is measured by looking at the percentage of orders that are shipped before the deadline (Han et al., 2020). Supply chains that respond quickly and effectively to dynamic customer need can maintain their market position (Echefaj et al., 2022).

5.7 Flexibility

Flexibility has 6 sub-indicators that are valid, namely source flexibility, labor flexibility, distribution flexibility, order fulfillment flexibility, product flexibility, and production process flexibility. Source flexibility is the capacity of an organization to have multiple suppliers for the same or similar types of input materials. Labor flexibility allows for a versatile workforce and the ability to perform different tasks by upgrading their skills. Distribution flexibility can change modes of transportation as needed and the ability to have multiple distribution and sales channel options that focus on direct and indirect customer needs. Flexibility in the order fulfillment process by providing different delivery models in terms of timing, quantity, and location of required raw materials or components. Product flexibility is the capability of accommodating future changes in products, whether new or variants of an existing product. Meanwhile, production flexibility is the ability to have machines that can perform different tasks and the ability to produce over and under the lot size or capacity planned for a particular product.a (Bauer and Göbl n.d.).

5.8 Redundancy

Redundancy has four sub-indicators, namely safety stock, capacity utilization, inventory levels, and inventory management. Safety stock refers to a firm's ability to maintain excess inventory to respond to or mitigate the negative effects of supply chain disruptions (A. Ali et al. 2017), (Park and Komuniecki 2011). Capacity utilization in the form of storage space utilization, equipment utilization, productivity utilization, and maximum labor utilization is very important during disruptions (Han et al. 2020), (Karl et al. 2018). Inventory is an essential tool in the event of an interruption, ensuring that available stock can reliably cover emergency orders (Karl et al. 2018). Inventory management is responsible for the process of managing and controlling the stock of goods or products distributed by producers to consumers. The strategic objective of inventory management is to minimize inventory risk (Tukamuhabwa et al. 2015).

5.9 Market Position

The market position has four sub-indicators that are valid, namely: efficiency, financial performance, performance in fulfilling customer requirements, and interruption damages. Efficient is capable of producing output with minimum resources (A. Ali et al. 2017). In addition, organizations need to strengthen their financial position in order to recover from disruptions. The performance of meeting the requirements of customers refers to the measurements related to the performance of managing the satisfaction of customers, especially during periods of disruptions. In order to recover from disruptions, supply chains need to be aware of the impact of disruptions; this refers to the evaluation of the severity of the disruption which focuses on the calculation and measurement of losses due to the disruption (Han et al. 2020).

6. Conclusion

Studies on supply chain resilience have grown over the years, with stakeholders showing interest in the concept because of its impact on business continuity and competitiveness. Designing supply chain resilience to cope with long-term disruptions, such as a pandemic, is essential because it can maintain demand fulfillment performance and costs. This research shows that the healthcare industry in Indonesia is still vulnerable to disruptions, this can be shown when there is a pandemic, the healthcare industry in Indonesia it is difficult to meet the demand for medical supplies such as PPE and medical devices (ventilators, tensimeters, and thermometers). Therefore, indicators are needed as performance measures to build a resilient supply chain. In this study, 9 indicators and 41 indicators were validated by healthcare industry experts using modified kappa, with the results shown in Figure 1 and Figure 2. This research aims to enable stakeholders in their field to monitor and measure supply chain performance in developing supply chain resilience.

Clearly, this study has some limitations. While this research only discusses SCR indicators collected from previous research and relevant to the healthcare industry in Indonesia, there is no research to determine the level of importance between indicators and the relationship between indicators. In addition, this study only focuses on medical supplies such as consumables and medical equipment, not pharmaceuticals. Future research should be aimed at determining the level of importance between indicators and the relationship between indicators, and this research should also focus on the pharmaceutical sector.

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