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Resilience Index Development for the Manufacturing Industry based on Robustness, Resourcefulness, Redundancy, and Rapidity

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Abstract. The manufacturing industry has always been one of the most significant GDP contributors globally, accounting for approximately 15% of the global GDP. However, with unknown future challenges, the industry must begin to consider and improve its underlying resilience capability in order to survive. This study offers a fundamental resilience index that can be applied to different manufacturing industries to guide them in developing a strategy to increase their resiliency. Resilience refers to a company's ability to bounce back to its original or targeted state after being disrupted or exposed to a risk. In this study, resilience has four main factors: robustness, resourcefulness, redundancy, and rapidity. This study combines these four factors with the four typical organizational functions in most organizations: operations, finance, strategy, and human resources. Each resilience factor has a set of indicators obtained through literature studies and in-depth interviews with experts. This study indicates that the most influential factor and resilience indicator are redundancy and reserve funds, respectively. Furthermore, this study found that reserve funds, customer satisfaction, and demand forecasts are the top three indicators in terms of the highest weighted value.

Keywords: Business organizational functions; Business resilience; Manufacturing industry; Performance resilience index

1. Introduction

Indonesia currently ranks 15th in the world's gross domestic market, and the UK-based Center for Economics and Business Research (2020) predicted that Indonesia will become the eighth strongest economy in the world by 2035, with a predicted gross domestic product (GDP) of USD 4.03 billion and a market share of 3.17%. This shows that the Indonesian economy will continue to strengthen from year to year. Manufacturing currently dominates Indonesia's GDP, with a contribution of 19.7% (Badan Pusat Statistik [BPS], 2020). With the growing contribution of this industry, it is hoped that better attention will be paid to its progress to improve Indonesia's economic growth in the future.

In reality, the projection of economic growth faces many challenges. One such challenge was the financial crisis and the increase in the world's economic instability in 2008. In two years, this crisis caused a 9.14% decrease in the number of processing and manufacturing industries in Indonesia, with around 2,349 businesses becoming bankrupt, closing, or merging with other companies (BPS, 2020). Another challenge to Indonesia's current

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economic growth projections was the economic crisis of 2020 that resulted from the COVID-19 pandemic. As a result, Indonesia's GDP fell due to decreased economic activities, such as household consumption and investment in Indonesia. Similar to the 2008 economic crisis, the sector most affected by this economic crisis was the manufacturing industry. Data from the central statistics agency show that the manufacturing industry had the most extensive layoffs (BPS, 2020).

These challenges show that the manufacturing industry was the sector most affected by these crises and thus has the greatest need to prepare for future crises by developing resilient capacity. Strong resilience-supporting factors are necessary for industries to withstand the impacts of crises. This research aims to determine a resilience indicator in the product industry, which starts with understanding the organizational function and general business model of the manufacturing industry. This simple and unique approach has not been found in the many studies on company resilience. By understanding the manufacturing industry's business model, we can identify critical points to increase its ability to survive in the face of disturbances. These critical points can then be translated into a resilience index to give complete and balanced views to guide strategy development and prioritize resources to strengthen the industry itself.

2. Literature Review

2.1. Manufacturing Industry Business Model based on Four Basic Functions of Organizations

A business model is the basis for how an organization develops, delivers, and collects value (Osterwalder and Pigneur, 2010). The manufacturing industry's business model, according to this description, has concentrated on the fabrication or assembly of more or less specialized items and generating money from their sale. As a result of the high fixed costs associated with the requisite machines, materials, and qualified workers, supply chain management and efficiency significantly impact competitiveness. Standardization, automation, and technical advancements are crucial markers of a manufacturing company's success (Boyer and Freyssenet, 1995). However, the global harmonization of technology standards and lowering trade barriers have put pressure on these conventional manufacturing business models. As a result, manufacturers in affluent countries face competition from manufacturers in underdeveloped countries with cheaper production costs. Though emerging nations have a cost advantage in terms of labor and commodities, developed economies have a competitive advantage in talent-driven innovation and supplier networks. The manufacturing sector contributes to around 15% of the current global GDP, making the manufacturing industry one of the highest revenue-generating sectors. China, the United States, Germany, Japan, and South Korea lead the global manufacturing output, with Indonesia, India, and Italy on their way to becoming global manufacturing superpowers.

Manufacturing business models are centered on selling physical products through traditional supplier–buyer relationships in traditional market sectors. According to Gospel and Sako (2009), four organizational functions lie in every manufacturing industry. The first function is operations. It includes end-to-end supply chain operations, such as sourcing, production, distributions, and after sales. The second function, human resources, manages every worker inside the company. The third function is finances, which acquires and utilizes funds for efficient and effective operations inside the company. The fourth function is strategy, which includes marketing, customer acquisition, and the flow of information. Manufacturing companies require the four organization functions to construct a new and competitive business model.

2.2. *Defining Resilience*

According to Holling (1973), resilience is the ability of natural systems to deal with change. Bruneau et al. (2003) defined resilience as the system's ability to limit the likelihood of shocks, absorb shocks with a rapid recovery of performance, and recover rapidly from aftershocks or restore performance to normal conditions. Bruneau et al. (2003) further argued that resilience has several important goals, including decreasing the probability and impact of risk as well as the time it takes for a system to recover after a disturbance or risk. The notion of resilience has been used in various domains, including social studies, institutional resilience, disaster management, and abnormal situations (Twigg, 2007). When it comes to resilience, there are not many differences in definitions across industries. For example, in recent years, the concept of resilience has evolved as a critical element of the manufacturing business. In that definition, resilience is an organization's vulnerability or capacity to endure, adapt, defend, and respond to a business opportunity (Välikangas, 2010).

Proposing the concept of a resilience framework, Bruneau et al. (2003) stated that four types of resilience factors are the basis for assessing resilience performance. These resilience factors, commonly referred to as the 4R, are robustness, resourcefulness, redundancy, and rapidity. Robustness refers to a system's ability to sustain a given amount of strain or demand without losing functionality. The extent to which a system can be replaced or can meet functional requirements following a breakdown or loss of functionality is referred to as redundancy. Redundancy is also defined as the presence of a backup. When situations threaten to disrupt the system, resourcefulness refers to a system's ability to identify problems, define priorities, and mobilize resources. Finally, rapidity or speed refers to the ability to meet priorities and achieve goals to avoid future distractions. These four resilience characteristics identified by Bruneau et al. (2003) can be utilized to generate indicators that affect resilience performance (Ammar et al., 2020).

2.3. *Resilience Indicators*

Resilience indicators vary widely, and not all indicators can be used for every sector or scope. If the scope of research on resilience performance is a company, it is especially necessary to know which indicators suit its needs. The combination of these indicators will produce a resilience index that can assess the resilience performance of a company. Table 1 shows the indicators for operational functions in the manufacturing industry, grouped by the four resilience factors. Based on the literature review, seven indicators are commonly related to operational functions.

Table 1 Indicators and definitions of operational organizational functions

Resilience Factor	Indicators	Source	Definition
Resourcefulness	Supplier delivery rate	Chan and Qi (2003)	The percentage of orders delivered on or before the due date.
		Gunasekaran et al. (2004)	The faster introduction of a product now considerably depends on the reliability and quick responsiveness of suppliers.
		Cho et al. (2012)	The adaptability of the service process in meeting different customer needs in terms of speed of response or customer processing.
	On-time delivery	Betts and Tadisina (2009)	The reliability and consistency of the delivery.
		Gunasekaran et al. (2004)	On-time delivery determines whether perfect delivery has taken place or not and measures the level of customer service.

Resilience Factor	Indicators	Source	Definition
Redundancy	Supplier delivery lead time	Gunasekaran et al. (2004)	A reduction in the order cycle time leads to a reduction in the supply chain response time.
		Bhagwat and Sharma (2007)	The total order cycle time, called order lead time, refers to the time that elapses between the receipt of the customer's order and the delivery of the goods.
		Cho et al. (2012)	The time that elapses between the receipt of the customer's order and the delivery of a service to the customer.
	Manufacturing lead time	Khan and Pillania (2008), Betts and Tadisina (2009), Yauch (2011)	The end-to-end manufacturing process cycle time.
Rapidity	Power cuts (recovery from shutdown) or other extraordinary event	Elleuch et al. (2016)	The ability of a system to keep functioning despite a major disturbance and recover its operation after a major disturbance.
Robustness	Capacity utilization	Slack et al. (1995), Wild (1995)	All the operations planning takes place within the framework set by capacity decisions; by measuring capacity, gains in flexibility, lead-time, and deliverability will be achieved.
		Cho et al. (2012)	Resources are organized effectively and efficiently and operate at optimum capacity.
		Fitzgerald et al. (1991)	A factor that indicates how well capacities are used in the delivery of services.
	Stock level	Gunasekaran et al. (2001)	The stock availability at all times.
		Chan and Qi (2003)	The number of goods that are able to be stored and delivered in a storage facility.
		Bhagwat and Sharma (2007)	Stock availability and delivery (management).
		Sjøbakk et al. (2015)	The ability to tackle lost orders due to stockouts.

Table 2 shows the indicators for financial functions in the manufacturing industry, which are grouped into two resilience factors. Based on the literature review, three main indicators are commonly related to financial functions.

Table 2 Indicators and definitions of financial organizational functions

Resilience Factor	Indicators	Source	Definition
Robustness	Total cost (cost efficiency)	Govindan et al. (2014)	The sum of every expenditure for business purposes.
		Yauch (2011)	All spending needed for the production to run.
Redundancy	Inventory holding costs	Betts and Tadisina (2009)	Reducing the holding cost and improving its efficiency.
	Reserve funds	Cardona et al. (2008)	Resources that are reserved based on adequate loss estimation criteria (from a disaster management perspective).

Table 3 shows the indicators for human resource functions. Based on the literature review, three indicators are commonly used as the company resilience Key Performance Indicator (KPI) of the human resources functions.

Table 3 Indicators and definitions of human resources organizational functions

Resilience Factor	Indicators	Source	Definition
Resourcefulness	Employees	Jafari et al. (2014)	The number of employees working for the company.
Robustness	Well-being and job satisfaction	Jafari et al. (2014)	Job satisfaction of each individual is collected quarterly.
Redundancy	Worker productivity (value-added)	Menéndez Blanco and Montes Botella (2016)	Openness to experience, conscientiousness, extraversion, agreeableness and neuroticism, and the inverse of emotional stability.

Table 4 shows the frequent resilience indicators for strategy functions in the manufacturing industry.

Table 4 Indicators and definitions of strategy organizational functions

Resilience Factor	Indicators	Source	Definition
Rapidity	Customer satisfaction	Chan and Qi (2003)	The number of customer complaints registered.
		Bhagwat and Sharma (2007)	The number of faultless notes invoiced.
Resourcefulness	Demand forecasts	Betts and Tadisina (2009)	A set of forecast numbers based on accurate and timely historical information.
		Bhagwat and Sharma (2007)	Accuracy of forecast numbers (range).
		Kamalahmadi and Parast (2016)	Demand forecasts over time, based on historical data.
Redundancy	Customer delivery lead time	Hammami and Frein (2013)	Delivery lead time reflects whether correct or faultless delivery has been delivered on time or not.
		Gunasekaran et al. (2001)	The time required once manufacturing begins on the product until it is completely processed.
		Gunasekaran et al. (2004)	The quality of and the way the information is presented determines the delivery performance and can be used to measure and improve performance.
		Bhagwat and Sharma (2007)	The total order cycle time, called order lead time, refers to the time that elapses between the receipt of the customer's order and the delivery of the goods.
		Stewart (1995)	Reduction in lead-time is an operational strategy for improving delivery performance.

All the indicators in Tables 1–4 were collected as the basis of the manufacturing resilience index. This index was made to be used as the foundation of a company's resilience performance score primarily regarding extraordinary events such as disease outbreaks, natural disasters, global economic shutdowns, and other crises. The implementation of the index score is expected to create a safer environment both for the company and workers in the manufacturing industry.

3. Methodology

In-depth interviews were conducted to gather experts' opinions on the issue. Overall, there are eight experts interviewed worked for four different small-scale manufacturing companies. Their work experience ranged from 3 to 10 years, with positions in various organizational functions. Two experts were interviewed for every function. At the

conceptualization stage, these experts were considered sufficient to provide a starting point for the development of a fundamental resilience index based on the saturation, heterogeneity of the experts, the experts' experience, and the budget and timeline for the study (Charmaz, 2006; Mason, 2010).

The experts were asked to assign a score to each resilience indicator with an interval rating from 1 to 5. A score of 1 indicated that the item was unimportant, while a score of 5 indicated that it was very important. This approach was used to rank/sequence the indicators. The final values were averaged from the scores given by all the experts (Dehnokhalaji et al., 2010).

We then performed data processing based on these data and obtained the weighted results for each criterion and indicator of resilience. We used an averaging method in order to get the weights for each indicator and factor, which are shown in Tables 5–7. In this study, three measurements of resilience performance were obtained. The first was a resilience performance assessment based on resilience factors (Table 5). The local score for the indicator value is based on the resilience factor in question. Thus, by using this matrix, the resilience performance value for each resilience factor can be obtained, and the business can determine its strengths and weaknesses in terms of resilience factors.

Table 5 Resilience performance assessment matrix based on resilience factors

Robustness 0.196 (19.6%)		Redundancy 0.334 (33.4%)		Resourcefulness 0.280 (28.0%)		Rapidity 0.189 (18.9%)	
Indicator	Local Score	Indicator	Local Score	Indicator	Local Score	Indicator	Local Score
Total cost (cost efficiency)	0.44	Supplier delivery lead time	0.24	On-time delivery	0.32	Power cuts (recovery from shutdown) or other KLB	0.45
Reserve funds	0.56	Manufacturing lead time	0.25	Employees	0.33	Customer satisfaction	0.55
		Worker productivity (value added)	0.27	Demand forecasts	0.34		
		Customer delivery lead time	0.24				
Robustness Score	1	Redundancy Score	1	Resourcefulness Score	1	Rapidity Score	1

The second assessment obtained was an assessment of resilience performance based on organizational functions (Table 6). Similar to the previous performance assessment, there is a local score for the indicator value based on the organization's functions. By using this matrix, companies can obtain their resilience performance values for organizational function and can determine which organizational functions have high or low resilience values.

The final assessment obtained was that of resilience performance based on all indicators, resulting in a global value. The global value of the indicator is the result of multiplying the local weighted value for the criteria by the local weighted value for each indicator (Table 7). By using this matrix, companies can determine their overall resilience performance value.

Table 6 Resilience performance assessment matrix based on organizational functions

Operations		Finance		Human Resources		Strategy	
Indicator	Local Score	Indicator	Local Score	Indicator	Local Score	Indicator	Local Score
Manufacturing lead time	0.24	Total cost (cost efficiency)	0.44	Employees	0.49	Demand forecasts	0.34
Supplier delivery lead time	0.24	Reserve funds	0.56	Worker productivity (value added)	0.51	Customer delivery lead time	0.29
On-time delivery	0.27					Customer satisfaction	0.37
Power cuts (recovery from shutdown) or other KLB	0.25						
Operations Functions Score	1	Finance Functions Score	1	Human Resource Functions Score	1	Strategy Functions Score	1

Table 7 Business resilience performance assessment matrix based on organizational functions

Business Function	Resilience Factor							
	Robustness 0.196 (19.6%)		Redundancy 0.334 (33.4%)		Resourcefulness 0.280 (28.0%)		Rapidity 0.189 (18.9%)	
	Indicator	Global Score	Indicator	Global Score	Indicator	Global Score	Indicator	Global Score
Operations 0.337 (33.7%)			Supplier delivery lead time	0.084	On-time delivery	0.089	Power cuts (recovery from shutdown) or other KLB	0.085
			Manufacturing lead time	0.079				
Finance 0.196 (19.6%)	Total cost (cost efficiency)	0.086						
	Reserve funds	0.110						
Human Resources 0.184 (18.4%)			Worker productivity (value added)	0.090	Employees	0.094		
Strategy 0.283 (28.3%)			Customer delivery lead time	0.081	Demand forecasts	0.097	Customer satisfaction	0.105

4. Conclusions

Several indicators were eliminated from the final assessment of resilience performance based on the average values obtained. Regarding the operational functions, the experts felt that seven indicators were too many. Thus, an indicator with a value above 3.0 was taken as an indicator of the operational organizational functions. Regarding the financial

organizational function indicators, the total cost and inventory holding cost indicators were considered to overlap because the total cost is the sum of the inventory holding cost and other expenses. For indicators under human resources organizational functions, well-being and job satisfaction had high values. However, the data for these indicators can only be generated through separate assessments by workers.

Based on in-depth interviews and weighing the resilience performance of business systems in the manufacturing industry, we found that the most critical resilience factor was redundancy. Meanwhile, rapidity was the factor that had the lowest weight. In terms of organizational functions, the most critical resilience factor was the operational function, followed by the strategy and finance functions, while the human resources function was the factor with the lowest weight. Based on the global weighted values, reserve funds, customer satisfaction, and demand forecasts were the top three indicators in terms of the highest weighted values. The indicators with the lowest weighted values were supplier delivery lead time, customer delivery lead time, and manufacturing lead time.

As this research is still in its conceptualization stage, future research is expected to increase or reduce the number of assumptions used, thus providing more representative results. On a larger scale, the performance index can be used as the basis of a company's resilience performance framework by creating a dynamic model that can foresee the possible resilience outcome for the industry and combine it with the resilience performance index as a quantitative score. Research can also be carried out to expand the scope of this study by including experts who work for large-scale companies, such as multinational corporations.

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