

Analysis of supporting factors of the successful implementation of green manufacturing for Indonesian Manufacturing SMEs

Untung Setiyo Purwanto^{1*}, Aryo Sahid Sujiwo¹, and Marcely Susanti¹

¹Faculty of Engineering, University Islam Jakarta, Indonesia

*Corresponding author: usp.usm@gmail.com

KEYWORDS

factor analysis
green manufacturing
manufacturing SMEs
MICMAC analysis

ABSTRACT Many manufacturing SMEs experience difficulties in finding a practical framework for building green manufacturing systems for production and operations activities. The study aims to identify the elements that support the successful implementation of green manufacturing systems in SMEs, develop a conceptual hierarchical model of elements based on the ISM approach, and identify and analyze the dominant elements. This study uses a survey method to obtain data relevant to the research objectives. The respondents were 32 managers/owners of manufacturing SMEs in Tegal Regency, Central Java Province of Indonesia. The study results show 39 supporting elements for successfully implementing green manufacturing in SMEs. Factor analysis shows that these elements can be simplified into 12 common elements. MICMAC analysis shows that five elements can be categorized as dependent elements; lower production costs, environmental knowledge, Improved waste management, investing in innovation and technology, and new market opportunities; seven elements can be categorized as independent elements, namely green supply chain, government promotion and regulation, pressure from the market, organizational culture, involvement of various business stakeholders, top management commitment, and environmental specialist assistance. ISM analysis shows four elements that can be categorized as dominant: green supply chain, involvement of various business stakeholders, top management commitment, and government promotion and regulation.

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1. INTRODUCTION

The manufacturing industry sector significantly contributes to achieving development goals in the economic sector in national development. The manufacturing industry also plays a vital role in the global economy by supplying goods and services. In Indonesia, the contribution of the manufacturing industry sector to the Gross Domestic Product (GDP) shows an increase from year to year. Since 2010, the manufacturing industry sector has made the most considerable contribution to the national GDP, even at the pandemic's peak in 2020-2021. In 2021, the manufacturing industry will record a contribution to GDP of Rp. 2,946.9 trillion, an increase from 2020, which reached Rp. 2,760.43 trillion. This shows that the manufacturing industry sector is vital to a country's social and economic development (Ghazilla et al., 2015). Therefore, the manufacturing industry sector needs to be developed in a balanced and integrated manner by increasing the active participation of the community and optimally utilizing all natural resources, human beings, and available funds.

One manufacturing industry category that needs attention is the small and medium-scale manufacturing industry (Naveed et al., 2022) (after this, referred to as manufacturing IKM). In this case, manufacturing IKM refers to the manufacturing industry with a permanent workforce

of 20 - 99 people. The development of IKM is seen as necessary for developing the industrial sector. The national industrial development master plan states that SMEs have a strategic role in the national economy. This can be seen from the number of business units which amount to 3.4 million units and constitute more than 90 percent of the national industrial business units. This role is also reflected in the absorption of IKM workers, which absorbs more than 9.7 million people and constitutes 65.4 percent of the total employment in the non-oil and gas industrial sector. In addition, SMEs also have a wide variety of products, can fill a broad market area, become a source of income for the wider community, and have resilience against various crises. With these characteristics, the growth and development of SMEs will enormously contribute to realizing a stable and advanced national economy characterized by democracy (Gherghina et al., 2020).

On the other hand, the manufacturing industry is accused of using many natural resources and polluting the environment by releasing pollutants into the surrounding environment. With increasing environmental problems, the manufacturing industry must develop systems that can reduce the use of natural resources and environmental pollution in their operations (Shrivastava & Shrivastava, 2017). As a result, the application of green manufacturing systems has received much attention and study in recent decades.

In summary, green manufacturing can be referred to as a manufacturing system that minimizes waste and pollution. The emphasis is on minimizing raw materials' use and reusing components (Elshaer et al., 2023).

Literature review shows that many attempts have been made to implement green manufacturing systems in large and established companies. However, research investigating green manufacturing systems in small and medium enterprises remains relatively limited. According to Elshaer et al. (2023), SMEs are a relevant research context in green manufacturing systems for many reasons. First, SMEs usually do not realize that green manufacturing systems are best practices for sustainable manufacturing systems. This is related to the lack of extensive knowledge, human resources, time, and budget. Second, global competitiveness and industrialization force SMEs to strengthen their organizational structures and adopt environmentally friendly manufacturing practices, regulations, and standards. So far, many SMEs have been accused of being a source of environmental pollution. A few SMEs are still implementing green manufacturing systems to reduce their environmental burden. Third, SMEs are usually poorly informed about the benefits of investing in green manufacturing systems. Green manufacturing systems will generally benefit companies in the long run. Meanwhile, SMEs generally rely on short-term economic benefits.

Furthermore, (Elshaer et al., 2023) suggest that green manufacturing systems for SMEs need to be investigated by country to explain the similarities and differences in green manufacturing systems in various countries. Based on this opinion, this study sets four objectives as follows. First, identify the supporting elements for successfully implementing green manufacturing systems in IKM. Second, based on the ISM approach, developing a conceptual hierarchical model of elements supporting the successful implementation of green manufacturing systems in IKM. Third, identify and analyze the elements that support the successful implementation of the dominant green manufacturing system. Fourth, provide recommendations for industry practitioners and policymakers. This research believes that the findings reported will contribute to developing theory and practice in green manufacturing systems, especially in manufacturing SMEs.

2. METHOD

2.1 Research Design

This research aims to evaluate the contextual relationship between several factors that influence the successful implementation of green manufacturing in Indonesian manufacturing SMEs. Based on the relationship between these elements, this research then builds a conceptual model of the hierarchical structure of elements that becomes the framework for manufacturing IKM in implementing green manufacturing systems. The research method is a survey and exploration method carried out according to the stages shown in Figure 1.

2.2 Data Collection

First, this research conducts a literature review to identify elements supporting the successful implementation of green manufacturing in Indonesian SMEs. After these elements have been accumulated, this study consulted a team of experts to verify whether or not these elements are valid

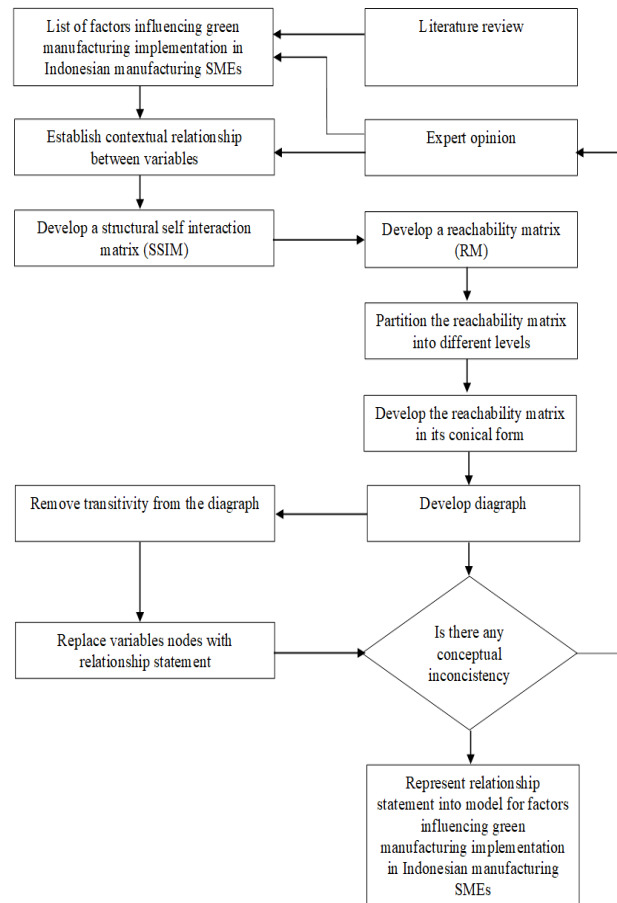


FIGURE 1. The ISM methodology followed in this study (adapted from Singh et al., 2020)

to use in the context of Indonesian manufacturing SMEs. In total, 12 elements are valid for implementing green manufacturing in Indonesian manufacturing IKM. Table 1 shows the 12 elements examined in this study. A questionnaire survey was then created and distributed directly to 32 managers or owners of IKMs operating in machinery, electrical components, automotive components, and paper/plastics.

3. RESULTS AND DISCUSSION

3.1 Structural Self-interaction Matrix (SSIM)

Investigate the relationship between elements supporting the successful implementation of green manufacturing in manufacturing SMEs. This study chose the contextual relationship type "facilitating for". This procedure says that one support element facilitates another support element. This research builds a structural self-interaction matrix based on this contextual relationship to show the pairwise relationships between successful green manufacturing implementation elements. For this purpose, the following four symbols indicate the relationship between elements that support the successful implementation of green manufacturing.

V : is used if factor "i" helps to achieve factor "j".

A : is used if factor "j" helps to achieve factor "i".

X : is used if factor "i" and factor "j" help to reach each other

TABLE 1. The Occurrence of Conjunction

Coding	Elements
E1	Green supply chain
E2	Lower production costs
E3	Environmental knowledge
E4	Improved waste management
E5	Invest in innovation and technology
E6	Government promotion and regulation
E7	Pressure from the market
E8	Organizational culture
E9	Involvement of various business stakeholders
E10	Top management commitment
E11	New market opportunities
E12	Environmental specialist assistance

Source: (Elshaer et al., 2023; Ghazilla et al., 2015; ?, Yacob et al., 2018)

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12
E1	V	O	O	O	O	O	O	O	X	A	O	O
E2		O	A	A	O	O	O	O	A	A	O	O
E3			O	O	O	O	A	O	A	O	O	A
E4				X	O	A	A	O	A	V	A	
E5					A	O	O	O	A	V	O	
E6						O	O	O	O	O	V	
E7							X	O	O	V	O	
E8								O	A	V	O	
E9									X	V	O	
E10										O	O	
E11											O	
E12												O

FIGURE 2. Initial reachability matrix showing the contextual relationship between elements supporting the successful implementation of green manufacturing in Indonesian manufacturing SMEs

O : is used if the factor "j" and factor "i" are not related to each other

Referring to the literature, this study involved a team of experts in developing a structural self-interaction matrix. The expert team consists of five experts from managers/company owners with more than ten years of experience and two academics with experience in teaching and research in Industrial Engineering. Figure 2 shows the structural self-interaction matrix resulting from discussions with this team of experts.

3.2 Initial Reachability Matrix (IRM)

This research builds an initial reachability matrix based on the structural self-interaction matrix built before. At this stage, the structural self-interaction matrix containing symbols X, A, V, and O is converted into an initial reachability matrix by substituting the symbols X, A, V, and O with 1 and 0. Table 2 shows the initial reachability matrix resulting from converting entries in the structural self-interaction matrix with binary numbers following the conversion rules. Referring to the literature, the rules for this conversion process are as follows following:

3.3 Final Reachability Matrix (FRM)

This study constructs the final reachability matrix by applying the transitivity rules in the initial reachability matrix, as suggested in the literature. Table 3 shows the final reachability matrix due to applying transitivity rules to the final reachability matrix.

3.4 Level Partitioning

Furthermore, this study establishes the reachability and antecedent sets of the final reachability matrix, as the literature suggests. The reachability set contains the element itself and other elements that could be affected by the element. On the contrary, the antecedent set includes the element itself and other elements that could affect it. Table 4 shows the final result of the iteration process of the level partition of supporting details for successfully implementing green manufacturing in Indonesian manufacturing SMEs.

3.5 ISM Model Development

This study builds a diagram with the help of the FRM matrix that was formed in the previous stage. Furthermore, this study develops a conceptual model based on the diagram. The relationship between the supporting elements for successfully implementing green manufacturing in manufacturing SMEs is shown by arrows. As shown in Figure 3, it is known that four elements occupy the lowest position of the model structure, namely Element 1 (Green supply chain), Element 9 (Involvement of various business stakeholders), Element 10 (Top management commitment), and Element 6 (government promotion and regulation). The next level is occupied by three elements, namely Element 7 (Pressure from the Market), Element 8 (Organizational culture), and Element 12 (Environmental specialist assistance). This research establishes these seven essential elements for implementing green manufacturing in manufacturing SMEs. Two elements occupy the next level, namely Element 4 (Improved waste management) and Element 5 (Invest in innovation and technology), while the highest level is occupied by three elements, namely Element 2 (Lower production costs), Element 3 (Environmental knowledge), and Element 11 (New market opportunities).

3.6 MICMAC Analysis

This study conducts a "Cross-impact matrix multiplication applied to classification" analysis, better known as MICMAC

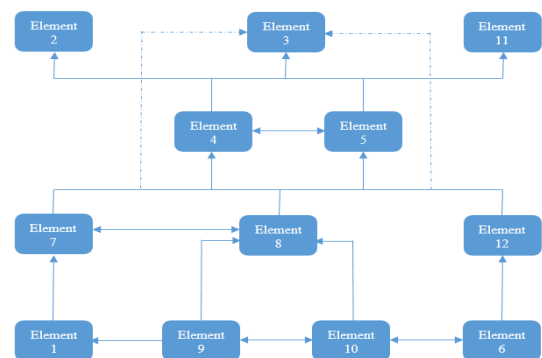


FIGURE 3. The hierarchical structure of elements supporting the successful implementation of green manufacturing within Indonesian manufacturing SMEs

TABLE 2. Initial reachability matrix showing the contextual relationship between elements supporting the successful implementation of green manufacturing in Indonesian manufacturing SMEs

Variables	1	2	3	4	5	6	7	8	9	10	11	12	Driving Power
E1	1	1	0	0	0	0	0	0	1	0	0	0	3
E2	0	1	0	0	0	0	0	0	0	0	0	0	1
E3	0	0	1	0	0	0	0	0	0	0	0	0	1
E4	0	1	0	1	1	0	0	0	0	0	1	0	4
E5	0	1	0	1	1	0	0	0	0	0	1	0	4
E6	0	0	0	0	1	1	0	0	0	0	0	1	3
E7	0	0	0	1	0	0	1	1	0	0	1	0	4
E8	0	0	1	1	0	0	1	1	0	0	1	0	5
E9	1	1	0	0	0	0	0	0	1	1	1	0	5
E10	1	1	1	1	1	0	0	1	1	1	0	0	8
E11	0	0	0	0	0	0	0	0	0	0	1	0	1
E12	0	0	1	1	0	0	0	0	0	0	0	1	3
Dependence Power	3	6	4	6	4	1	2	3	3	2	6	2	

analysis, to understand each element's war in forming the ISM model. In particular, this analysis is intended to categorize the elements supporting the successful implementation of green manufacturing in manufacturing SMEs in Indonesia according to the level of impetus and the level of dependence of these elements. The driving force level of an element refers to the score of the element itself plus the scores of the elements that the element might facilitate, while the degree of dependence of an element refers to the score of the element itself plus the scores of the elements that facilitate the element. The level of this thrust is the number of entries in the rows of the FRM matrix, while the level of dependence is the number of entries in the columns of the FRM matrix. Furthermore, the elements forming the ISM model are plotted on a graph with the level of dependence on the X-axis and the level of driving force on the Y-axis (Figure 4).

Based on this driving force level and dependency level, all elements forming the ISM model will be classified into four categories: autonomous, dependent, linkage, and independent.

a. Category I (autonomous elements)

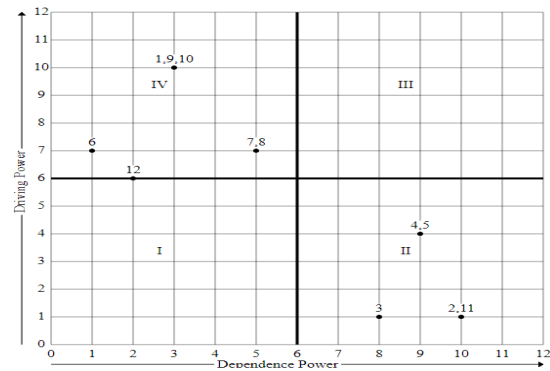


FIGURE 4. MICMAC analysis of the factors supporting the successful implementation of green manufacturing

Elements that fall into this category have a low driving force and dependency. Autonomous elements will be plotted in quadrant I. Elements included in this category will later be removed from the ISM model because they do not significantly influence the successful implementation of green manufacturing in manu-

TABLE 3. Final reachability matrix showing contextual relationships between supporting elements for the successful implementation of green manufacturing in Indonesian manufacturing SMEs

Variables	1	2	3	4	5	6	7	8	9	10	11	12	Driving Power
E1	1	1	1*	1*	1*	0	1*	1*	1	1*	1*	0	3
E2	0	1	0	0	0	0	0	0	0	0	0	0	1
E3	0	0	1	0	0	0	0	0	0	0	0	0	1
E4	0	1	0	1	1	0	0	0	0	0	1	0	4
E5	0	1	0	1	1	0	0	0	0	0	1	0	4
E6	0	1*	1*	1*	1	1	0	0	0	0	1*	1	7
E7	0	1*	1*	1	1*	0	1	1	0	0	1	0	7
E8	0	1*	1	1*	0	0	1	1	0	0	1	0	7
E9	1	1	1*	1*	1*	0	1*	1*	1	1	1	0	10
E10	1	1	1	1	1	0	1*	1	1	1	1*	0	10
E11	0	0	0	0	0	0	0	0	0	0	1	0	1
E12	0	1*	1	1	1*	0	0	0	0	0	1*	1	3
Dependence Power	3	10	8	9	9	1	5	5	3	3	10	2	

TABLE 4. The results of the level partition of the supporting elements for the successful implementation of green manufacturing in Indonesian manufacturing SMEs

Elements (Mi)	Reachability set R(Mi)	Antecedent set A(Ni)	Intersection set $R(Mi) \cap A(Ni)$	Level
1	1,9,10	1,9,10	1,9,10	4
2	2	1,2,4,5,6,7,8,9,10,12	2	1
3	3	1,3,6,7,8,9,10,12	3	1
4	4,5	1,4,5,6,7,8,9,10,12	4,5	2
5	4,5	1,4,5,6,7,8,9,10,12	4,5	2
6	6	6	6	4
7	7,8	1,7,8,9,10	7,8	3
8	7,8	1,7,8,9,10	7,8	3
9	1,9,10	1,9,10	1,9,10	4
10	1,9,10	1,9,10	1,9,10	4
11	11	1,4,5,6,7,8,9,10,11,12	11	1
12	12	6,12	12	3

facturing IKM. As shown in Figure 3, none of the elements examined in this study are autonomous elements. This indicates that all the elements studied are elements that do have a significant influence and contribution to the successful implementation of green manufacturing in manufacturing SMEs.

b. Category II (dependent elements)

Elements that fall into this category have a weak driving force and high dependency. These dependent elements will be plotted in quadrant II. As seen in Figure 4, the elements that fall into this category are:

1. E2 (Lower production costs)
2. E3 (Environmental knowledge)
3. E4 (Improved waste management)
4. E5 (Invest in innovation and technology)
5. E11 (New market opportunities)

c. Category III (linkage element)

Elements that fall into this category have a high driving force and dependability. In other words, these elements can support the successful implementation of green manufacturing in manufacturing SMEs, although these elements also require support from other elements. These linkage elements will be plotted in quadrant III. As shown in Figure 4, none of the elements examined in this study are autonomous elements.

d. Category IV (independent element)

Elements that fall into this category have high driving forces and low dependency. In this category, an element has a high level of driving force and a low level of dependence. Autonomous elements will be plotted in quadrant IV. As seen in Figure 4, the elements that fall into this category are:

1. E1 (Green supply chain)
2. E6 (Government promotion and regulation)
3. E7 (Pressure from the market)
4. E8 (Organizational culture)
5. E9 (Involvement of various business stakeholders)
6. E10 (Top management commitment)
7. E12 (Environmental specialist assistance)

Literature review shows that the average consumption pattern of the global community continues to increase even though this consumption pattern differs from region to region. Globalization, population size, and technological developments have also significantly impacted the growth of the manufacturing industry, including manufacturing SMEs. The growth of the manufacturing industry has resulted in increased competition for markets, both at the regional and global levels. On the other hand, the growth of the manufacturing industry also affects the need for more energy and natural resources to produce more products. This condition has created a very worrying condition because energy consumption and excessive consumption of natural resources can harm the environment. Increasing attention and awareness of the growing impact of the manufacturing industry on the environment has encouraged the manufacturing industry to implement green manufacturing practices in their business activities. Green manufacturing is a process or system that minimizes negative impacts on the environment or processes or systems that do not cause negative impacts on the environment.

Building a green manufacturing system in a manufacturing industry is a complex problem, so many small and medium-scale companies have difficulty dealing with it. This problem arises because several elements are required to build green manufacturing and the interactions between these elements. To build green manufacturing, it is necessary to develop a methodology that can assist management in identifying the structural elements supporting the successful implementation of green manufacturing.

ISM is the methodology used in this study. ISM identifies elements relevant to the supporting factors for successfully implementing green manufacturing in Indonesian SMEs. Next is the identification of contextual relationships between elements. After the elements involved and the contextual relationships between these elements have been determined, the next step is to develop a structural self-interaction matrix. The next step is to change the structural self-interaction matrix into an initial reachability matrix and examine its transitivity. The next step is determining the final reachability matrix (RM) and partitioning the elements into the ISM model.

The ISM model places the green supply chain element at the level I, indicating that this element can be the dominant element in implementing a green supply chain in Indonesian manufacturing SMEs. The research results indicate that the green supply chain can be classified as an independent element. Thus, this element has a significant role in facilitating other elements in the ISM model. This finding aligns with the understanding found in the literature that manufacturing organizations need to establish collaborative relationships with other companies in a supply chain that are mutually synergistic. Literature generally cites that building a supply chain can improve company performance and competitiveness.

Each supply chain member must be highly committed to the quantity and quality of production. Such conditions will improve the operational performance of manufacturing IKMs, their understanding of market regulations, and green manufacturing good practices. Manufacturing SMEs generally operate as minor actors in a broader value chain. Manufacturing SMEs are also usually very dependent on other, larger companies. When manufacturing SMEs try to implement green manufacturing in their production and

operations activities, they often encounter various problems. Therefore, manufacturing SMEs are required to establish cooperative relationships with manufacturing organizations in the larger value chain to take the necessary actions to implement sustainable green manufacturing. The ranking of these elements indicates that green supply chains can be viewed as the starting point for the successful implementation of green manufacturing in manufacturing SMEs (Elshaer et al., 2023).

Furthermore, this study found that government support and regulation is one of the dominant elements that support the successful implementation of green manufacturing in Indonesian manufacturing SMEs. This finding aligns with the idea in the literature that adequate government support and regulation is the dominant element in implementing green manufacturing in manufacturing SMEs. The findings have implications that the government must establish fair and effective laws and policies and provide better definitions, understanding, and frameworks to industry players in implementing green and sustainable manufacturing in their production and operational activities (Yacob et al., 2018). The ISM methodology places government support and regulation as one of the independent elements and is one of the main drivers of the system. The ISM model shows that government support and regulation elements will facilitate other essential elements, namely the Involvement of various business stakeholders and Pressure from the market. Literature indicates that this element has a significant influence on Investment in Innovation and Technology element. Appropriate government support and regulations can direct industry players to find new approaches to innovation sustainably because there are incentives for raw material sources, management and technology, and support to compete in the market (Elshaer et al., 2023).

4. CONCLUSION

Building a green manufacturing system in a manufacturing industry is a complex problem, so many small and medium-scale companies have difficulty dealing with it. This problem arises because several elements are required to build green manufacturing and the interactions between these elements. To build green manufacturing, it is necessary to develop a methodology that can assist management in identifying the structural elements supporting the successful implementation of green manufacturing.

ISM and MICMAC are the methodologies used in this study. The results show that the structure of the ISM model consists of four levels. At the level I, four elements are Green supply chain elements, Involvement of various business stakeholders, Top management commitment, and Government promotion and regulation). Level II is occupied by three elements, namely elements of pressure from the market, organizational culture, and environmental specialist assistance. Furthermore, level III is occupied by two elements: Improved waste management and Invest in innovation and technology. Furthermore, level IV is occupied by three elements, namely elements of Lower production costs, Environmental knowledge, and New market opportunities.

Meanwhile, the results of the MICMAC analysis show that no elements are classified as autonomous elements, namely elements with the low driving force and depen-

ency. These elements do not significantly influence the successful implementation of green manufacturing. This finding indicates that all the elements examined in this study are elements that do have a significant influence and contribution to the successful implementation of green manufacturing. Similar findings also apply to linkage elements with a high driving force and dependability. This study did not find any elements classified as linkage elements.

Furthermore, the results of the MICMAC analysis show that five elements are classified as dependent elements, namely elements with a weak driving force and a high degree of dependency. These five elements are elements of Lower production costs, Environmental knowledge, Improved waste management, Invest in innovation and technology, and New market opportunities. Lastly, this study found seven elements classified as independent, namely elements with a high driving force and low dependency. The seven elements are elements of the Green supply chain, Government promotion and regulation, Pressure from the market, Organizational culture, Involvement of various business stakeholders, Top management commitment, and Environmental specialist assistance.

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