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STRATEGIC ENVIRONMENTAL PRACTICES MODEL FOR GREEN SUPPLY CHAIN MANAGEMENT USING THE DEMATEL METHOD

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Abstract: Environmental practices in the supply chain is a key strategic evaluation in green supply chain management (GSCM). Thus, manufacturers need to understand the role of each factor and the relationship between them to effectively implement GSCM. A lack of understanding of these factors can potentially make it more difficult to adopt GSCM practices. Using the multicriteria decision-making (MCDM) technique, the evaluation of the decision-making processes can potentially improve the successful implementation of GSCM. Through MCDM, the priority of the elements in GSCM that contributes to the establishment of strategic environmental practices has been identified based on the data gathered from seven experts. Next, by using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method, a causal model was developed. In this model, each element was prioritised based on the cause and effect analysed. The findings reveal that activities, such as packaging recycling, process optimisation to reduce solid waste, and the use of environmentally friendly raw materials, are critical factors that must be prioritised.

Keywords: Green supply chain management, strategic environmental practices, DEMATEL, prioritised, causal model, manufacturing.
Abbreviations: Strategic Environmental Practices (SEP).

Introduction

In the modern era, manufacturers need to be more competitive by considering the elements of the environmental, social, and governance aspects of sustainability in their supply chain management (Sachin & Rajesh, 2022). This has led to manufacturing firms adopting the strongest combinations of standard supply chain risk management measures, such as agility, flexibility, and surplus inventory, to cope with unpredictable situations, such as the COVID-19 pandemic, which can cause abrupt and intense disruptions in manufacturing operations (Ibrahim, 2021). Supply chain management (SCM) was conceived as a result of the changes due to this crisis (Montoya-Torres *et al*., 2021). From end-users to original suppliers, SCM is the integration of important business operations that offer products, services, and information to consumers and other stakeholders (Abdel-basset *et al*., 2018; Chang *et al*., 2019). This study used a hospital's emergency department crowding (EDCSorooshian & Panigrahi, 2020).

The implementation of GSCM in modern management mode systematically influences resource utilisation efficiency for economic benefits (Liu *et al.,* 2018). GSCM not only reduces business costs, but also increases the supply chain reaction speed and improves the standards of customer service (Liu *et al*., 2020). This management style ensures that manufacturing companies and their suppliers comply with environmental laws and regulations. The use of environmental characteristics in supplier selection will aid in the GSCM process improvement (Mohamed *et al*., 2019). For example, through effective management, suppliers might reduce transaction costs by using recycled materials. By considering the above situations, this paper aims to:

- Investigate the elements influencing the performance of GSCM
- Rank the prioritised elements that affect the performance of GSCM
- Identify the causal factors of the prioritised elements' performance

Literature Review

In order to establish sustainable development that is environmentally friendly, the use of resources needs to be controlled, which minimises the negative impacts on the environment (Suryanto *et al*., 2018). According to Fernando *et al*. (2019), the application of green technology becomes a reference for adapting the concept of GSCM to all manufacturing activities. This eventually extended the scope and coverage of GSCM with dissimilar definitions and concepts of GSCM (Lee & Lim, 2020). Environmental factors are the major attributes in the implementation of GSCM by optimising the product design, and the upstream and downstream of SCM, involving the coordination of various material choices, the product manufacturer, the product sales, and the entire recycling process (Shipeng, 2011).

There are several series of regulations and policies for SCM, whereby GSCM managed to minimise the environmental impact through a waste reduction within the industrial system, while lessening material consumption, saving energy, and preventing hazardous materials enter the environment (Ahmed *et al*., 2018). The word "green" generally refers to "eco-friendliness" or "sustainability", and its primary focus is reactive compliance with environmental rules or public demand. The green idea was seldom included in the supply chain performance metric, reflecting this deficiency in the actual world, and so it was not viewed as a value-added activity or a competitive edge, according to most literature (Zhou *et al*., 2019).

Besides, manufacturing firms could avoid violating environmental protection laws, reduce related handling and transportation business costs, and thus, increase resources-use efficiency. This incidentally could meet customers' expectations and demands for environmental protection. As a result, the corporate image and investors' confidence increased. In other words, it could promote an organisation's environmental and financial efficiency. From the review, it is evident that several manufacturing companies still lack effort in implementing GSCM into their operations (Shamsuddin *et al*., 2017). Thus, the focus in identifying the dominant elements of environmental practices must be emphasised by determining the causal relationship between the identified elements in the implementation of successful GSCM.

According to Chien *et al.* (2012) and Rajesh (2022), through the measurement of environmental and financial performances, a manufacturing firm and its supply chain can be understood better. Although future sustainability performance is still unclear, businesses and their supply chains must have a prediction model as shown in Figure 1.

In determining the strategic environmental practices in GSCM, several published articles were reviewed using a systematic method. Based on the review, a total of 17 elements were identified as summarised in Table 1.

Materials and Methods

The flow of the research was guided by the appropriate method as shown in Figure 2. The main process started with a review of previous and current research, followed by the development of a questionnaire based on the literature review, an analysis of the questionnaire, and model development and validation. The element of strategic environmental practices (SEP) was developed based on the reviews (refer Table 1). The collection of data as based on questionnaire surveys involving Malaysian manufacturers. A total of 241 questionnaire surveys were distributed among manufacturing companies in Malaysia. A total of 61 questionnaires (26.14%) were returned and used for further analysis.

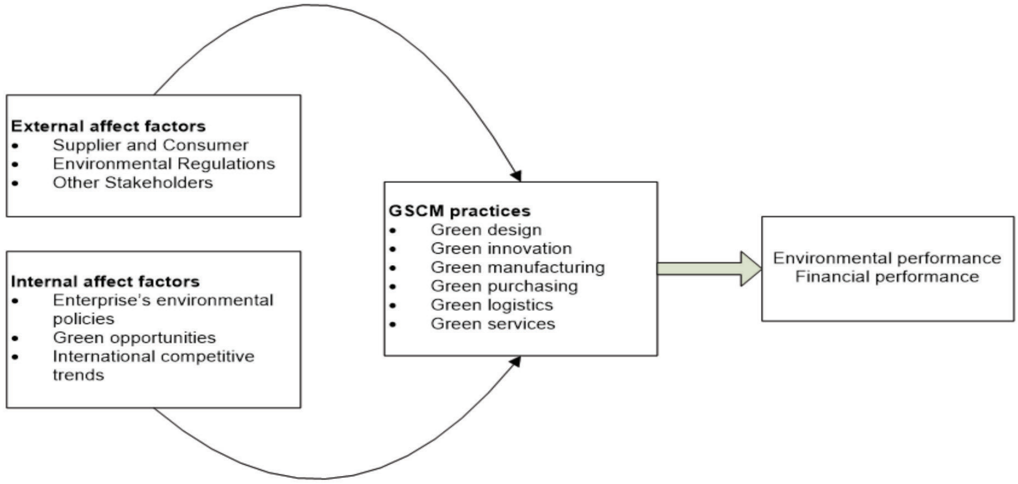

Figure 1: The operating pattern for GSCM practices (Chien *et al.*, 2012)

Table 1: Elements of strategic environmental practices

Element of Strategic Environmental Practices	**Tsoulfas & Pappis (2006)**	**Rao *et al.* (2006)**	**Holt & Ghobadian (2009)**	**Qingkui & Junhu (2009)**	**Mingqiang & Yabo (2009)**	**Chiang *et al.* (2010)**	**Zhu & Xu (2019)**	**Abdel-Baset *et al.* (2019)**	**Liu *et al.* (2020)**	**Sachin & Rajesh (2022)**
Use of raw environmental materials	x		x		x		x	x	x	x
Substitution of raw materials in the environment	x		x							
Consideration of environmental criteria by management	x		x				x		x	
Green consideration in design	x						x		x	x
Reduce solid waste through process optimisation			x	x		x	x	x		
Reduce use of water through process optimisation			x	x		x	x	x		
Reduce the spread of air pollutants through process optimisation			x	x		x	x	x		x
Reduce noise pollution through process optimisation			x	x		x	x	x		
Implement cleaner production to optimise resources (energy, water and waste)		x	x	x			x			x

Use recycled materials in operations		x	x		x	x		x		
Using alternative energy sources	x	x								x
Prolong the life of the product	x	x								
Use green labelling								x	x	
Use green packaging	x		x					x		
Provide environmentally friendly products to customers	x		x				x	x		x
Use environmentally friendly transports	x	x	x		x			x	x	

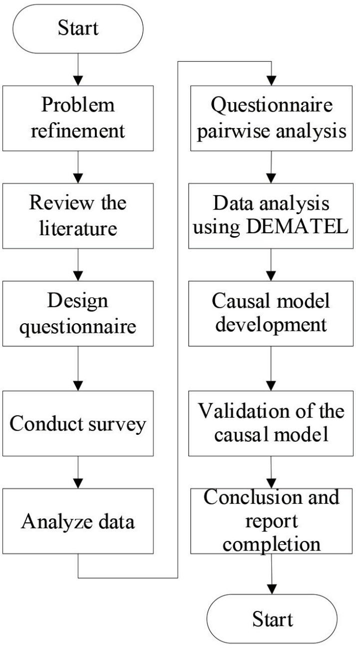

Figure 2: Research flowchart

The SPSS software was used in the initial stage of analysis. The analysis started with the screening of the data to ensure its reliability. This was followed by normality and binomial tests, descriptive analysis, correlation test, and factor analysis. The results of the factor analysis were used to develop a pairwise questionnaire. The causal model was then developed, where the DEMATEL method was used as a tool to verify the prioritised elements, which were the cause-and-effect elements. Finally, the model was validated using a semi-structured questionnaire with the participation of industrial players.

Based on the review, 16 elements were identified to be related to SEP. From the 16 elements, there are four, through the factor analysis test, that were identified as not having a high impact. The remaining 12 SEP indicators were extracted from the factor analysis and divided into three groups of factors and loaded separately to each factor structured at high loading values, ranging from 0.59 to 0.89 (refer to Table 2). Five SEP indicators (SEP1, SEP2, SEP3, SEP4 and SEP5) were aggregated in the first factor group, with factor loadings ranging from 0.77 to 0.86, eigenvalues of 3.516, and a cumulative percentage of the variance of 27.04%. All the elements in this group focus on cost reduction by recycling. Recycling is one of the practices that will slow down the need for raw materials, which would experience a sudden increase. Geiger *et al.* (2019) suggested that recycling enabled the retrieval of secondary raw materials, thereby reducing greenhouse gas emissions, which is an important criterion in GSCM practices.

Four SEP indicators (SEP6, SEP7, SEP8 and SEP9) were grouped under the second factors NU (Natural Usage), with the factor loading ranging from 0.596 to 0.896 with eigenvalues of 2.748, and cumulative percentage of 48.181%. In this factor, the consideration of natural usage in operations, such as solid wastes, energy, water, and air, was involved. All of these activities should be managed to maintain a dependable and sustainable energy supply, as well as to limit greenhouse gas emissions, which are mostly caused by the burning of fossil fuels to generate electricity (Marchi *et al*., 2019). Three SEP indicators (SEP10, SEP11 and SEP12) were grouped under the third factor, OU (Optimisation of Usage). The factor loading ranges from 0.671 to 0.820, with eigenvalues of 2.511, and a cumulative percentage of 67.497%. The results of the factor analysis have led to the development of the theoretical framework for this study as depicted in Figure 3.

All the indicators were related to the usage of substitution of materials that have an impact on the environment, selecting user-friendly raw materials, as well as suppliers who considered the environmental criteria. The ability to optimise and manage the usage of materials would produce great environmental benefits, as well as improve the manufacturing company's image. As a result, higher product sales and high societal acceptance could be achieved by the manufacturer (Effendi *et al*., 2019).

As suggested by Mohamed *et al*. (2018) the analysis using the DEMATEL method was conducted as shown in Figure 4. Despite the prioritised elements, the cause and effect should also be identified through the method.

All practices were evaluated to find the key factor that could improve the performance, and provide a novel approach to decision-making in GSCM practices. From the study, the DEMATEL method evaluated supplier's performance to find the key factor criteria to improve performance

Table 2: Factor analysis for SEP

Factor	**Environmental Actions**	**Communalities**	**Factor Loading**	**Eigen Values**	**Cumulative (%)**
Recycling commitment	Helping suppliers establish their own electronic manufacturing services (EMS) (SEP1)	0.777	0.861	3.516	27.046
	Use of waste from other companies (SEP2)	0.742	0.853		
	Use of alternative sources of energy (SEP3)	0.799	0.851		
	Recovery of the company's end-of-life products (SEP4)	0.693	0.784		
	Taking back packaging (SEP5)	0.675	0.775		
Natural usage	Optimisation of processes to reduce solid wastes (SEP6)	0.813	0.896	2.748	48.181
	Design considerations (SEP7)	0.529	0.700		
	Use of cleaner technology processes to enhance savings (energy, water, wastes) (SEP8)	0.588	0.627		
	Optimisation of processes to reduce air emissions (SEP9)	0.508	0.596		
Optimisation of usage	Substitution of environmental questionable materials (SEP10)	0.820	0.893	2.511	67.497
	Environmentally friendly raw materials (SEP11)	0.723	0.777		
	Choice of suppliers by environmental criteria (SEP12)	0.671	0.734		

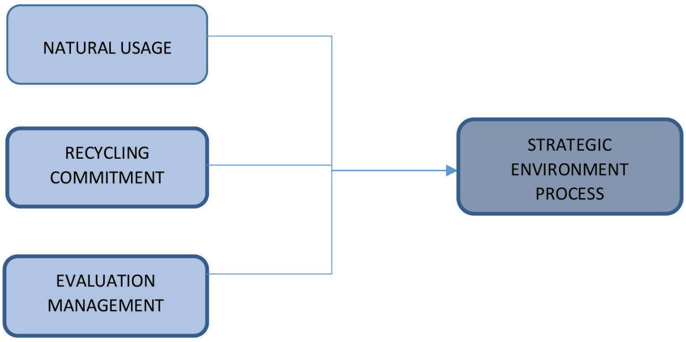

Figure 3: Theoretical framework

and provide a novel approach to decision-making in the SCM supplier selection (Chang *et al*., 2011). The DEMATEL method was selected based on its application in various fields and it has been significantly proven that the process can prioritise elements and, at the same time, successfully determine the cause and effect of each element involved. Table 3 summarises the application of DEMATEL as an analysis method of prioritising the elements in various fields.

The efficiency of the DEMATEL method suits GSCM, which examines the influence elements between the factors. Lin (2013) showed that the use of DEMATEL was useful in identifying the direct and indirect influence relationships among the criteria evaluated. The DEMATEL approach technique does not need a large amount of data and could effectively fill the gaps between the interactive relations of those criteria. Wang and Chuu (2004) stated that the DEMATEL analysis showed visual relationships among the system factors. The elements could be easily grouped into causal and affected groups. This significantly gave rise to a better understanding of the structural relationship between the system elements, and allows for the finding of solutions to complicated system problems.

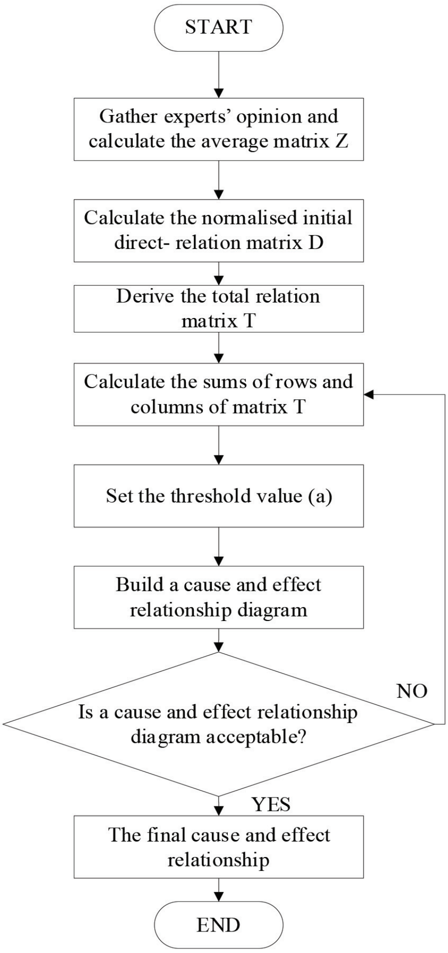

Figure 4: The DEMATEL process

Table 3: Application of DEMATEL in various fields

Fields of Study	Findings
GSCM (Electronics) (Kaur *et al*., 2017)	The study revealed three primary types of obstacles. These roadblocks stemmed from a lack of expertise, a lack of commitment, and a lack of product design. Lack of awareness of the environmental impact on businesses, a lack of courses/consultancies/institutions for training and monitoring/mentoring progress specific to each industry, a lack of technical expertise, and difficulty identifying environmental opportunities are all examples of knowledge-related barriers. A lack of corporate social responsibility is a commitment-related barrier, whereas the complexity of designing to reuse/recycle used items is a product design-related obstacle.
E-waste management (Kumar & Dixit, 2018)	The DEMATEL-based methodology not only helps convert the unclear and poorly articulated models of systems into structural models, but also helps establish the interdependence among the barriers by categorising them into cause-and-effect group barriers. The study showed that the lack of public awareness of e-waste recycling and the lack of policies and regulations addressing e-waste problems were the most influential and causal barriers. Hence, there is a need for more focus on the successful implementation of e-waste management in the Indian context. The barriers under the cause or influential groups were vital and had a tendency to affect the overall system. On the contrary, the barriers under the effect or dependent groups tend to be easily affected by cause or influential barriers.
Business intelligence (Mavi & Standing, 2018)	The categorised business intelligence (BI) advantages of cause-and-effect benefits may be understood and studied for their complex interrelationships using DEMATEL. To deal with the uncertainty inherent in expert judgement, the authors used the DEMATEL method. The cause-and-effect advantages were determined to be “better coordination with business partners/suppliers” and “increased revenue”, respectively. The organisation’s strategic decision-making procedures were aided by ranking BI advantages.
Healthcare Supply Chain (HCSC) (Hossain & Thakur, 2020)	DEMATEL was applied to identify the cause-and-effect relationships among factors of implementing the Industry 4.0 in the healthcare supply chain (HCSC). The study found that HCSC management aspects had been assigned the highest priority, and, subsequently, followed by integrated HCSC and sustainable HCSC having approximately the same weightage, and preceded by HCSC innovation and technological aspects. Additionally, the four factors were classified into the cause group (integrated HCSC, management of HCSC, HCSC competitiveness and social aspects), and the other four were identified as effect group factors (HCSC innovation and technological aspects, sustainable HCSC, HCSC institutional perspective and economic factors). The categorisation of these factors would aid managers in the healthcare industry to control the causal group of factors, and reshape them to implement the Industry 4.0 in the HCSC successfully.
Constructions (Seker & Zavadskas, 2017)	According to the findings, several precautions against potential occupational hazards could be suggested. They focus on the cause group criteria because of their influences on the effect group criteria. The precautions against potential occupational hazards include safety culture, safety management, poor site management, poor education of labourers and the construction process.

Urban water and sewage company (Mousavizade & Shakibazad, 2018)	According to industry experts, the results of applying the DEMATEL technique showed that the strategy and goals were the main factors, and the infrastructure of the model should be prioritised for planning the first step. From the results, the priorities and causes factors were teamwork, management support and organisational culture.
Education (Sekhar, 2019)	Through extensive literature review and expert interviews, the study identified four primary barriers and 46 sub-barriers. Applying sustainability in the Indian Management Education Institution resulted in changes in behaviour involving increased respect for the environment, hence, leading to improved sustainable efficiency. To include sustainability in management education institutions curriculum, leadership should go beyond producing future managers that are "work-ready" to develop "future-ready" managers by using new knowledge and learning experiences that enhance their commitment and provide the ability to engage productively with the unfolding challenges of cultural, social, economic, and environmental sustainability in their chosen profession.

Expert comments were gathered using a comparison scale to compare the relative relevance degrees of the components. Table 4 provided the basis for the comparison scale.

The average matrix Z = [Zij] represents the matrices from m experts used to aggregate all of their judgments. This study was verified by ten experts from the Malaysian manufacturing industry.

$$Z\,ij = \frac{1}{m}\sum\nolimits_{i=1} m\; x_{ij}^{i} \qquad \textbf{(1)}$$

The worth of each element in matrix *D* is placed between [0,1] and the normalised initial direct-relation matrix *D* is denoted as d_{ij}

$$D = \lambda \times Z \qquad \textbf{(2)}$$

$$[d_{ij}\,]_{n\times n} = \lambda\big[Z_{ij}\big]_{n\times n} \qquad \textbf{(3)}$$

where:

$$\lambda = Min\left(\frac{1}{\max 1 \le i \le n \sum_{j=1}\left|Z_{ij}\right|}, \frac{1}{\max 1 \le i \le n \sum_{i=1}\left|Z_{ij}\right|}\right) \qquad \textbf{(4)}$$

Table 4: Scale of relative influence used in the pairwise comparison matrix

Scale	**Linguistic Variable**
0	No influence
1	Low influence
2	Medium influence
3	High influence
4	Very high influence

Equation 5 is used for the calculation and identification of the total impact matrix (T).

$$T = \lim_{m \to \infty} (D + D^2 + \cdots + D^m) \quad \textbf{(5)}$$

$$T = D\,(1 - D)^{-1} \quad \textbf{(6)}$$

Vector r and c are used to depict the sum of rows and columns in the total impact matrix (T).

$$r = [r_i]_{n \times i} = \left(\sum\nolimits_{j=1}^{n} t_{ij}\right)_{n \times 1} \quad \textbf{(7)}$$

$$c = [c_j]'_{1 \times n} = \left[\sum\nolimits_{j=1}^{n} t_{ij}\right]'_{1 \times n} \quad \textbf{(8)}$$

where $[c_{ij}]'$ was denoted as the transposition matrix. In order to determine the threshold value of α, the elemental average was calculated in matrix T.

$$\alpha = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} [t_{ij}]}{N} \quad \textbf{(9)}$$

The element average was computed in matrix T to produce the threshold value as calculated by Equation 9. This computation was focused on removing a few small affecting components from the matrix T. The determined threshold value aided in the formation of the causal connection structure (or interrelationship structure) and distinguished it (Sekhar, 2019).

In matrix T, the total elements were also represented by N. The coordinate sets of r_i+c_i and r_i-c_i were mapped together to create a cause-and-effect diagram, which aided in identifying the important link and facilitated information that was beneficial for determining the most crucial factors, as well as how the influence impacts the factors (Kumar & Dixit, 2018). The elements are depicted in a cause-and-effect diagram to indicate that *tij* is higher than (Yang, 2010).

Results and Discussion

The results from the DEMATEL analysis were recorded in Table 5. Using Equation 9, the threshold value (α) was 47.1764/25 = 1.8871. From the analysis, for the Recycling Commitment factor, SEP5 (taking back packaging) was identified as the most significant evaluation indicator with the largest $r+c$ value of 19.4073, and classified as the highest cause indicator with values of 1.0474 for $r-c$. According to Matthews (2004), the initial expenditures were incurred as a result of the time and effort spent creating, testing, and implementing the new packaging method.

Thus, the ability to recycle the use of packaging will extremely reduce packaging costs. This subsequently promoted recycling, reuse and other forms of waste prevention and recovery that are related to packaging. The action was further encouraged by the European Parliament and the Council of the European

Table 5: Average of elements in matrix T for recycling commitment in SEP

	SEP 1	**SEP 2**	**SEP 3**	**SEP 4**	**SEP 5**	**ri**
T	1.7721	1.8966	1.9245	1.9081	1.8775	9.3788
	1.8126	1.6279	1.7980	1.7704	1.7623	8.7712
	1.9156	1.8853	1.6982	1.8461	1.8045	9.1497
	2.0230	1.9778	1.9865	1.7614	1.9006	9.6493
	2.1382	2.1046	2.0937	2.0558	1.8350	10.2273
47.1764	9.6615	9.4922	9.5009	9.3418	9.1800	cj
α=1.8871	19.0403	18.2633	18.6507	18.9911	19.4073	ri+cj
	-0.2827	-0.7210	-0.3512	0.3075	1.0474	ri-cj
	effect	effect	effect	cause	cause	
	P 2	P 5	P 4	P 3	P 1	

Union, which have set targets of 55% for the requirement of reusing or recycling plastic packaging waste 2025 (Foschi & Bonoli, 2019).

Meanwhile, SEP2 (use of waste from other companies) was perceived to have the smallest $r+c$ value = 18.2633. This indicated that SEP2 was the least significant indicator and was assigned under effect elements with a value of -0.7210. This indicated that the use of waste from external parties was not advisable. The waste needs to be processed and needs to produce a significant impact, but mostly affects other elements (Bartolacci *et al*., 2019).

As shown in Figure 5, SEP5 (taking back packaging) and SEP4 (recovery of the company's end-life-product) were identified as cause indicators, while SEP1 (helping suppliers to establish their own EMS), SEP3 (use of alternative sources of energy), and SEP2 (use of waste from other companies) were grouped as effect indicators. The cause groups were vital due to their direct impact on the recycling commitment factors. Among these two causes, SEP5 had the higher $r-c$ value with 1.0474, which implied that SEP5 had more impact on the factor. This was in line with SEP5 as a prioritised element in this factor. The lowest $r-c$ value was SEP22, with a score of -0.7210. This means that the use of waste is not important in the factor as the value of the lowest $r+c$ and lowest $r-c$.

As for the Natural Usage (NU) factor, the threshold value (α) was 83.4759/16 = 5.2172. By referring to Table 6, SEP6 (optimisation of processes to reduce solid wastes) was identified as the most significant evaluation indicator with the largest $r+c$ value of 42.7074, and is classified as the effect in this factor with $r-c$ values of -0.5774.

Solid waste is a term that refers to undesired or worthless solid materials produced by a combination of household, industrial, and commercial operations. Solid waste increases similarly with population expansion and economic development. Improper management of solid waste will produce an impact on greenhouse gas emissions. Therefore, proper planning and implementation of a comprehensive programme for waste management should be well defined. Optimisation of processes focuses on the use of all elements effectively by selecting the activity from the possible solutions of a problem, the best one, which is assessed after a predefined criterion (Afteni & Frumuşanu, 2017). To reduce solid waste, all optimisation process should be considered, as suggested by Effendi *et al.* (2019), in which optimisation could be one of the factors in reducing solid waste.

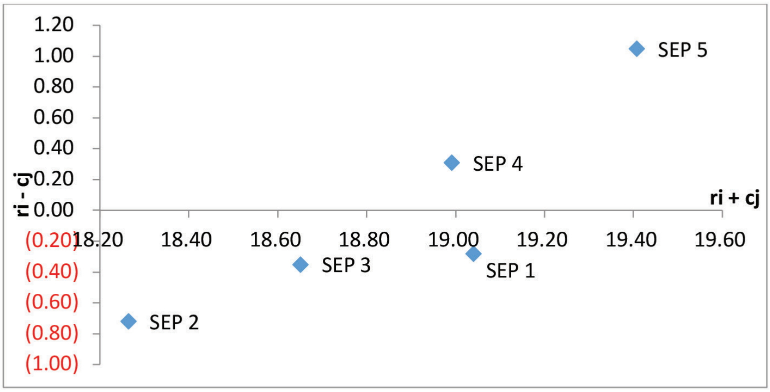

Figure 5: Visualisation of the causal relationship by recycling commitment in SEP

Table 6: Average of elements in matrix T for natural usage in SEP

	SEP 6	SEP 7	SEP 8	SEP 9	ri
T	5.2725	5.3832	5.3878	5.0214	21.0650
	5.3284	4.9446	5.1732	4.8449	20.2911
	5.6295	5.4685	5.2235	5.1205	21.4420
	5.4120	5.2755	5.2805	4.7099	20.6778
83.4759	21.6424	21.0718	21.0650	19.6967	cj
α=5.2172	42.7074	41.3628	42.5070	40.3745	ri+cj
	-0.5774	-0.7807	0.3770	0.9811	ri-cj
	effect	effect	cause	cause	
	P 1	P 3	P 2	P 4	

As shown in Figure 6, SEP9 (optimisation of processes to reduce air emissions), was recognised as the least significant indicator with the smallest $r+c$ value = 40.3745, and classified as the cause with the highest $r-c$ value of 0.9811. By referring to the results, although SEP9 is the lowest indicator in prioritised rank, it was identified as the highest cause that produced a direct impact on other indicators.

Meanwhile, for the Optimisation of Usage (OU) factor, the threshold value (α) was 48.3647/9 = 5.3786. As shown in Table 7, SEP11 (use of environmentally friendly raw materials) was identified as a significant evaluation indicator with the largest $r+c$ value of 32.7479, and was classified in the cause group with $r-c$ values of 0.0095. The cause group factors were vital due to their direct impact on the systems. This suggested that the use of environmental-friendly raw materials in manufacturing companies would produce a positive direct impact on GSCM systems. The results showed that the element was ranked based on the prioritised environmentally friendly raw materials, which were categorised into three types, plant/tree-based, animal-based, and mining-based. Different physical chemical parameters between the raw materials (direct and indirect raw materials) provided different growth environments, which affected the composition of materials used in production (X. Wang *et al*., 2015).

Based on the result depicted in Figure 7, SEP3 (selection of suppliers by environmental

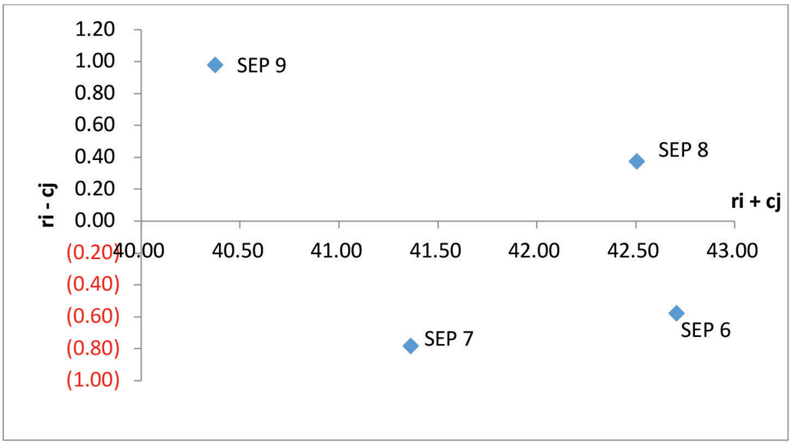

Figure 6: Visualisation of the causal relationship by natural usage in SEP

consideration) was classified as the least significant indicator with the smallest $r+c$ value = 31.5769, and assigned under the effect group, with $r-c$ values of -1.2369. SEP12 was easily influenced by other indicators. The selection of suppliers based on environmental elements highly influenced the competitiveness of the entire supply chain network. By considering environmental requirements, the selection of suppliers has a vital impact on the sustainability of the GSCM cycle, as well as the supply chain's performance. Therefore, this indicator should be integrated into the GSCM system to improve the level of competitiveness (Gurel *et al*., 2015).

Conclusion

The awareness of implementing green supply chain initiatives will provide a direct impact on a firm's performance outcomes. This signifies that GSCM initiatives can be of value to organisations, as well as to the external environment. In SEP, the prioritised elements were taking back packaging, optimisation of processes to reduce solid wastes and use of environmentally friendly raw materials. For the cause group factor, the elements identified were taking back packaging, optimisation of processes to reduce air emissions, and substitution of environmentally questionable materials. Designing strategic environmentally friendly practices, recycling used packaging, optimisation of processes to reduce solid wastes and using environmentally friendly raw materials were the prioritised elements that should be highlighted by manufacturing firms. Green supply chain projects play a significant role in reaching the "triple bottom line" of social, environmental, and economic advantages, and, hence, contribute to society's long-term sustainability. The of this study offer some basis to approaches that can be used in

Table 7: Average of elements in matrix T for optimisation of usage in SEP

	SEP 10	**SEP 11**	**SEP 12**	**ri**
T	5.2052	5.8148	5.7960	16.8160
	5.3869	5.3227	5.6691	16.3787
	4.9965	5.2316	4.9418	15.1700
48.3647	15.5886	16.3692	16.4069	cj
α=5.3739	32.4046	32.7479	31.5769	ri+cj
	1.2274	0.0095	-1.2369	ri-cj
	cause	cause	effect	
	P 2	P 1	P 3	

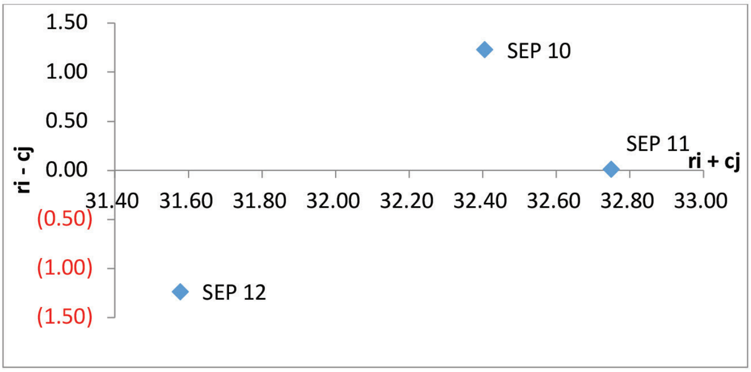

Figure 7: Visualisation of the causal relationship by optimisation usage in SEP

the development of theories, as well as for translating strategies and policies into action to achieve better manufacturing sustainability performance. The implementation of GSCM allowed manufacturing firms to respond more swiftly to the COVID-19 pandemic by modifying their supply chains, avoiding costly production halts, and assuring the supply of imported raw materials. These allowed manufacturing firms to optimise their practices, while expecting the best results in decision-making from the implementation of GSCM.

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