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Manufacturing Performance in Green Supply Chain Management

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Abstract: The purpose of the study is to examine the influence of manufacturing performance on green supply chain management amongst Malaysian companies. A conceptual model is proposed and is subjected to an empirical verification with the use of a survey of manufacturing companies in Malaysia. The AMOS structural equation modelling was used to measure the respondents' overall perceptions of the green supply chain management and current manufacturing performance. Results indicate that improving manufacturing performance leads to an integrated green supply chain, which ultimately leads to an enhancement of environmental compliance as well as an optimisation of the operational resources and product recycling activities. However, most practices have a very weak correlation with overall manufacturing system performance. Being the first ever empirical investigation of the link between manufacturing performance and green supply chain management practices amongst organisations in Malaysia, this study helps industrialist to enhance improvement in productivity. Future research should include different industrial sectors or countries, to enable comparative studies. A larger sample would also allow a detailed cross-sector comparison.

Key words: Green Supply Chain Management (GSCM) % Manufacturing Performance % Structural Equation Modelling (SEM)

INTRODUCTION

Green Supply Chain Management (henceforth GSCM) strategies refer to efforts to minimize the negative impact of organisations and their supply chains on the natural environment regarding climate change, pollution and non-renewable resource constraints. GSCM integrates the supply chain management in order to reduce environmental impact during the entire product life cycle, by the harmony and the common actions of the partners in the chain [1]. It requires working with suppliers and customers, analysing the internal operations and processes, considering environmental factors in the product development process and extending stewardship across the product's life cycle [2].

The aim of GSCM is to make the material flow value-added by harmonizing and controlling the flow of material, capital, information and work. In addition, the aim also includes providing high quality products and services to customers promptly, but with the lowest cost and environmental impact [3]. The development of research on products' life cycle shows that the actions of a single enterprise at a certain stage of a product's life cycle cannot effectively reduce the environmental impact

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over the entire cycle. Many researchers believe that the environmental sustainability and ecological performance of an organization may depend on the performance of its suppliers in these aspects [4-6].

GSCM features three issues that are important to the theory of ecological modernization and thus are important to the environmental management and sustainability in general: first, the inclusion of environmental aspects in an integrated chain management of industrial chains for the manufacturing of goods; second, the integration of technological innovations for environmentally beneficial outcomes throughout the industrial supply chain; and, last, the participation of a broader range of industrial actors for the environmental management of industrial production, to strengthen the capacity-building on environmental governance [7]. In addition, a review of the literature has shown the existence of an important link between GSC and supply chain decisions [8]. For some enterprises, a new green perspective will be transformative, leading to fresh thinking, new markets, profitability gains and increased values. For others, the environmental focus may emerge more gradually and modestly, as another critical element of corporate strategy [9]. With time, these companies may find long-term, sustained advantage from being green, but not dramatic immediate gains. For the large, heavy industries, the gains are closer to being assured, but smaller and "cleaner" organizations will find surprising benefits as well [10].

A measure of success in implementing any manufacturing system or supply chain management can be defined along a few performance parameters. In the literature, it is widely suggested that a prerequisite for the successful implementation of the corporate, business and operational strategies of an organisation and for any improvement initiative, is the use of a reliable performance measurement system [11,12]. Being such a fundamental issue of SCM, supplier performance measurement has been one of the main concerns for managers and academics. Some of the performance measurement systems were designed within the academic discipline of accounting, since for many decades the main strategies of organisations were price competition and cost reduction [13,14].

Performance measurement emphasises the link between internal (operations) and external (operations) performance, in terms of general operational dimensions as cost, speed, quality, dependability and flexibility, which customers value. The "customer perspective" in performance measurement, for example, which is reflected in the marketing and relationship marketing literature, has been adopted in the operational management and service management literature, with the realisation that the service provided to customers can be used to improve operational performance. Slack *et al.* [15] suggests that performance should always be measured against benchmarks, which could be historical standards, target performance standards, competitor performance standards and absolute performance standards. Moreover, Brun *et al.* [16] add that the performance measures must reflect a supply chain's requirements. This paper examines the influence of manufacturing performance on green supply chain management amongst companies in Malaysia. The study can be used by other companies to define their own green initiatives and other academics to explore what can be improved in green supply chain management and sustainability.

MATERIALS AND METHODS

This study focuses on analysing the perceptions and experience of MS ISO 14001 certified companies in the Malaysian manufacturing industry. Nawrocka *et al.* [17] believe that ISO 14001 has a facilitating role in the environmental activities between a customer and a supplier. In addition, Rao and Holt [18] consider that certified organisations have a direct responsibility in greening the supply chain. According to Potoski and Prakash [19], the promise of ISO 14001 is that if a participating organisation adheres to the requirements of the standard, it will increase its chances of reducing its environmental impact relative to the non-participating organisations. The implementation of the ISO 14001 requires organisational structures, routines and a knowledge base to manage the company's direct environmental aspects. Such managerial capabilities can also be utilized to manage the indirect environmental aspects associated with the activities of the company's suppliers [20].

The questionnaire designed in this study comprises three main parts: company profile, GSC practices and manufacturing system performance. The first part is designed to provide fundamental and background information, including industry type, employees (size) and years of EMS experience; the next part focuses on an analysis of GSC practices and current manufacturing system performance. Respondents are asked to rate each item using a four-point Likert-type scale (e.g. 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree), to indicate the extent to which each item is practised in their organization.

The data collection involves distributing questionnaires to various manufacturing companies with MS ISO 14001 certifications in Malaysia. All target respondents are selected from the SIRIM QAS (a Malaysian certification body) database, which have over two years' experience in implementing the certified environmental management system (EMS). If the certified company has more than one plant, a single plant is preferred. In other words, from a total of 522 certified companies, just 241 companies are considered as the population. The questionnaire, comprising 29 items, is distributed to the managing directors and environment management representatives.

A total of 241 questionnaires were mailed out and 61 were returned, of which 50 were valid, representing a response rate of 20.74%. This sample size meets the absolute minimum requirement for the maximum likelihood estimation (MLE) procedure to provide a valid result, as prescribed by Hair *et al.* [21] although they recommend a number of 100 or higher. Other studies also utilize a response rate similar to this study. For example, Bowen *et al.* [22] use a sample of 24 firms to identify the supply management capabilities in a corporate environmental approach; Rao [3] and Rao and Holt [18] produce significant findings regarding a green supply chain with a sample of only 52 firms; Simpson *et al.* [23] use a sample of 55 firms to explore green supply chain practices in the Australian automotive industry; more recently, Holt and Ghobadian [24] used a sample of 60 usable surveys, without a specific population, to perform an empirical study of green supply chain practices amongst UK manufacturers. This implies that the sample response rate of this study is acceptable and it reflects the topical relevance of green supply chain management in Malaysian manufacturing MS ISO 14001 certified companies.

RESULTS AND DISCUSSION

Demography of Respondents: Table 1 lists the distribution of respondents in terms of their manufacturing sectors, ownership, company size and years' experience of EMS. The highest percentage of respondents is from the electrical and electronic industries (42%), followed by chemical products and engineering (38%), the automotive industry (12%) and mechanical engineering (8%). The majority of respondents were companies with fewer than 250 or more than 750 employees. Meanwhile, 64% of respondents have more than 8 years' experience of EMS.

GSC Practice: GSC practices were evaluated on a four point scale. For each item, the percentage of companies which state "agree" and "strongly agree" were determined from the data. Table 2 provides the details of the exploratory analysis. Considering both "agree" and "strongly agree", the item which has the highest percentage (98%) is "taking environmental criteria into consideration", implying that all respondents are either "agree" or "strongly agree" to the item followed by "environment-friendly raw materials" (96%). *Optimization of processes to reduce solid wastes, recycling of materials internal to the company, optimization of processes to reduce air emission* and *design considerations* are also implemented in the majority of cases (94%). For *substitution of environmentally questionable materials,* 92% of the companies indicate "agree" or "strongly agree". Among the items which are least implemented include eco-*labelling* (34%), *recovery of the company's end-of-life products* (52%) and *taking back packaging* (56%).

Based on the findings, all certified MS ISO 14001 organisations consider environmental criteria. Many organizations have participated in the development of the green management programmes in Malaysia. They are government agencies, industry organizations, research and development organizations, environmental service organizations, non-governmental organizations and public and finance sectors. The Department of the Environment (DOE), under the Ministry of Natural Resources and Environment, is empowered under the Environmental Quality Act (EQA) of 1974 to control and prevent pollution and to protect and enhance the quality of the environment. The DOE has a stake in Cleaner Production (CP) implementation, since the adoption of CP by Small and Medium Industries (SMIs) will reduce pollution in a significant way. Effective from 9th April 2009, a new ministerial portfolio was introduced to strengthen the green management programme in Malaysia. The establishment of the Ministry of Energy, Green Technology and Water (KeTTHA) reflects the nation's determination to drive home the message that 'clean and green' is the way forward towards creating an economy that is based on sustainable solutions [25]. The National Green Technology Policy (NGTP) was formulated to provide guidance and to create opportunities for businesses and industries to bring a positive impact to economic growth.

Table 3 shows the factor analysis results. Factor analysis was performed to extract factors based upon the principal components analysis with varimax rotation.

Table 1: Demography of respondents

	Size (employees)			EMS experience (certified years)	
Type of industry	*Items*	*%*	*Items*	*%*	*Items*
Mechanical engineering	8.0	> 750	30.4	> 15	10.0
Automotive engineering	12.0	501 - 750	10.9	8 - 12	54.0
Electrical & electronic engineering	42.0	250 - 500	23.9	4 - 7	24.0
Chemical products & engineering	38.0	< 250	34.8	< 3	12.0

Table 2: Green Supply Chain Practices

Green Practices	Agree (%)	Strongly Agree (%)	Total (%)
1.Taking environmental criteria into consideration	58	40	98
2.Environment-friendly raw materials	44	52	96
3.Optimization of processes to reduce solid wastes	56	38	94
4.Recycling of materials internal to the company	56	38	94
5.Optimization of processes to reduce air emissions	62	32	94
6.Design considerations	68	26	94
7.Substitution of environmentally questionable materials	46	46	92
8.Optimization of processes to reduce water use	56	34	90
9.Optimization of processes to reduce noise	58	32	90
10.Use of cleaner technology processes to make savings (energy, water, wastes)	58	32	90
11.Choice of suppliers by environmental criteria	52	32	84
12.Environment-friendly improvement of packaging	58	24	82
13.Urging/pressuring supplier(s) to take environmental actions	62	18	80
14.Providing consumers with information on environmentally friendly products and/or production methods	52	22	74
15.Change to more environment-friendly transportation	50	14	64
16.Eco-labelling	46	16	62
17.Taking back packaging	44	18	62
18.Use of alternative sources of energy	50	10	60
19.Recovery of the company's end-of-life products	40	16	56
20.Helping suppliers to establish their own EMS	46	6	52
21.Use of other companies' waste	26	8	34

Table 3: Factor analysis of green practices

Dimension	GSC practices	Item loading range	Eigenvalues	Cumulative percent	Cronbach's alpha
Product recycling (PR)	Helping suppliers to establish their own EMS (PR1)	0.829	8.507	40.510	0.891
	Use of alternative sources of energy (PR2)	0.810			
	Recovery of the company's end-of-life products (PR3)	0.806			
	Use of other companies' waste (PR4)	0.737			
	Taking back packaging (PR5)	0.723			
	Eco-labelling (PR6)	0.667			
Environmental compliance (EC)	Taking environmental criteria into consideration (EC1)	0.761	2.465	52.247	0.867
	Choice of suppliers by environmental criteria (EC2)	0.727			
	Substitution of environmentally questionable materials (EC3)	0.723			
	Environment-friendly raw materials (EC4)	0.704			
	Use of cleaner technology processes to make savings (energy, water, wastes) (EC5)	0.676			
	Urging/pressuring supplier(s) to take environmental actions (EC6)	0.602			
Optimization (OPT)	Optimization of processes to reduce air emissions (OPT2)	0.891	0.809	60.862	0.912
	Optimization of processes to reduce air emissions (OPT2)	0.856			

Table 4: Performance of manufacturing systems

MP		Relative Performance (%) 1	2	3	4	Mean	sd
MP1.	Product quality improvement	-	10	58	32	3.22	0.616
MP2.	Work-in-progress reduction	-	6	80	14	3.08	0.444
MP3.	Throughput time reduction	-	8	80	12	3.04	0.450
MP4.	Lead time reduction	2	10	70	18	3.04	0.605
MP5.	Machine utilization improvement	-	14	70	16	3.02	0.553
MP6.	Manufacturing cost reduction	-	12	76	12	3.00	0.495
MP7.	Flexibility improvement	-	16	74	10	2.94	0.512

N= 50, Cronbach's Alpha = 0.843

In addition, Barlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy were employed to test the appropriateness of the data for factor analysis. The results of KMO show that the compared value is 0.627, significantly exceeding the suggested minimum standard of 0.5 required for conducting factor analysis [26]. Based on the tests, it is evident that all factors are suitable for applying factor analysis. Factor analysis is performed to extract factors in accordance with the eigenvalues of discontinuity greater than 1 and factor loading exceeding 0.5 is the principle in choosing factors. Seven variables are eliminated because their factor loadings are less than 0.5. Therefore, the remaining 14 items are re-analyzed and extracted into three dimensions, representing at least 60.862% of variance namely *product recycling*, *environmental compliance* and *optimization.* Reliability concerns the extent to which an experience, test or any measuring procedure yields the same results in repeated trials. The reliability of the factors needs to be determined to support any measures of validity that may be employed. Both reliability tests and item analysis are recalculated without those seven items. Table 3 lists the new Cronbach's alpha values, ranging from 0.867 to 0.912, after the seven items are dropped. Generally, Cronbach's alpha values in this study are greater than 0.6, revealing a high internal consistency.

Performance of the Manufacturing System: The companies are requested to indicate the performance of their manufacturing system. The measures used are 1 (very poor) up to 4 (very good). The results are summarized in Table 4.

It can be deduced that the respondents are satisfied with most features of the manufacturing systems. On average, over half of the respondents considered the performance of their systems to be good or very good. Product quality improvement is the performance measure considered to be most satisfactory, whereas flexibility improvement is rated poorly. Cronbach's alpha values (0.843) of the manufacturing performances are greater than 0.7, revealing a high internal consistency. Factor analysis as shown in Table 5 is performed for measuring the manufacturing performance.

The results of KMO show that the compared value is 0.774, which significantly exceeds the suggested minimum standard of 0.5 required for conducting factor analysis. Three variables have been eliminated because their factor loadings were lower than 0.5. The remaining 4 items were re-analyzed, representing at least 66.935% of variance, which could be denominated into two different factors. However, the correlation value (0.57) between the two groups is considered a strong relationship and the 4 items have been extracted into one factor. The new Cronbach's alpha value of 0.747 reveals a high internal consistency.

Structural Equation Modelling: The model is run using AMOS graphics for Windows Version 5.0, estimating the regression weight of each link and the associated significance. Figure 1 shows the regression weights between the latent constructs. As indicated by the statistics detailed in Table 6, the overall convergence of the SEM model is significant after some items, such as PR6, EC5 and EC6 are dropped as their factor loadings are lower than 0.7. The convergence of the model is given by the Chi square value, the degrees of freedom and the associated probability level, the *p*-value.

The model is acceptable at a 5% level of significance given a *p*-value > 0.05. The Chi square values and associated *p*-value are highly acceptable, indicating a good fit for the model. However, the covariance between latent constructs in GSC practices is not significant, so the model suggests that there is a significant link between manufacturing performance and GSC practices. This is expected, as excellent manufacturing performance encourages GSC practices. On the other hand, baseline comparisons such as NFI, RFI, IFI, TLI and CFI, ranging from 0.645 to 0.918 represent an overall degree of fit (squared residuals from predictions compared to the actual data) on the moderate side. In general, models with overall fit indices of less than 0.9 can usually be improved substantially. These indices and the general hierarchical comparisons described previously, are best understood by examples [26].

The typical range for TLI and CFI lies between 0 and 1, but it is not limited to that range. TLI and CFI values close to 1 indicate a very good fit. Similar to this condition, an RMSEA value of 0.05 or less would indicate a close fit of the model in relation to the degrees of freedom. This figure is based on subjective judgment. It cannot be regarded as infallible or correct, but it is more reasonable than the requirement of exact fit with an RMSEA of 0.0. Browne and Cudeck [27] suggest that an RMSEA value of around 0.08 or less would indicate a reasonable error of approximation and would not wish to employ a model with a RMSEA greater than 0.1.

The Spearman correlation test was performed to identify the relationship between green supply chain practices and manufacturing system performance.

Table 5: Factor analysis of manufacturing performance

MP	Item loading range	Eigenvalue	Cumulative percentage	Cronbach's alpha
MP2	0.883	3.676	52.518	0.747
MP3	0.789			
MP4	0.754			
MP7	0.910	1.009	66.935	

Table 6: Regression weights

Regression weights	Estimate	Critical ratio
The maximum likelihood estimates		
MP - PR	0.202	1.229
MP - EC	0.414	3.409
MP - OPT	0.221	1.243

Notes: Chi-square =117.059; Degrees of freedom = 87; Probability level =0.17; NFI = 0.743;
RFI = 0.645; IFI = 0.918; TLI = 0.876; CFI = 0.910; RMSEA = 0.084

Table 7: Correlation Spearman Coefficient

	Product Recycling				Environmental Compliance					Optimization	
MP	PR1	PR2	PR3	PR4	EC1	EC2	EC3	EC4	EC5	OPT1	OPT2
MP2	.293*	.171	.151	.116	.514**	.385*	.427**	.470**	.385**	.179	.231
MP3	.128	.031	.218	.111	.391**	.405**	.265	.352*	.293*	.170	.124
MP4	.106	.091	.069	.083	.322*	.303*	.144	.348*	.192	.317*	.187
MP7	.146	.116	.052	.098	.180	.241	.398**	.277	.317*	.122	.150

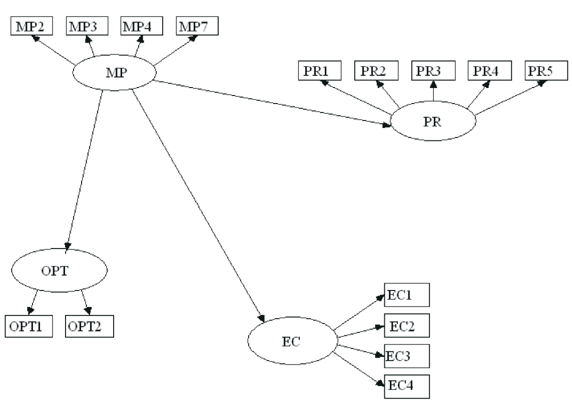

Fig 1: Structural equation modelling of the relationship between manufacturing performance and GSC practices

Table 7 shows the correlation coefficients results. The results show, Dimension 2- Environmental Compliance has several significant results at the level 0.05 and 0.01. This suggests that some of the green practices are significant with manufacturing system performance at a confidence level of at least 95%. Among the listed green practices, taking environmental criteria into consideration is most significantly correlated with manufacturing system performance, while lead time reduction (r = 0.514) has the lowest significance level of 0.01. In other words, consideration of the environmental criteria is positively influenced by lead time reduction with a probability of 0.514.

The analysis shows that green practices with a significance level of 0.01 have a better correlation coefficient with manufacturing system performance. However in general, most of the practices have a very weak correlation with overall manufacturing system performance. Green practices such as helping suppliers to establish their own EMS, use of alternative sources of energy, use of other companies' waste, taking back packaging, eco-labelling and optimization of processes to reduce air emissions are not significantly linked with any manufacturing system performances.

This study shows that manufacturing performance (MP) as the main thrust of research has influenced the greening supply chain practices. Although prior research has reported a positive impact of GSC practices on environment performance, little attention has been paid to the essential roles that MP plays in overall green practice.

This research model has a theoretical support and its empirical results suggest that MP matches GSC practices to business performance.

This paper demonstrates the link between manufacturing performance and GSC as an agent for product recycling, environmental compliance and optimisation of resources amongst a sample of companies in Malaysia. Buehlmann *et al.* [28] state that some governments have imposed new recycling requirements on manufacturing organisations, such as electronic product take-back or packaging waste reduction targets. In addition, higher landfill fees have also forced organisations to reconsider the costs of reuse against the costs of offsite transfer and disposal. More and more supply chains too have sought to introduce recycled products, which, in turn, expose an industry to recycling innovation. Optimizing the value added is recommended to secure economic efficiency and sustainability, thus green product design, of course, has a real impact on adding values in recycling activities, resulting in economic and environmental benefits. In addition, recycling of a product or material, as an industrial process, commences on completion of its primary purpose use, i.e. at its (economic) end-of-life. The product is somehow transferred to an intermediary - the first step in separation of products and materials - and then the part-products or materials are transferred to further re-use or recovery in a number of different ways [34].

Environmental compliance may be defined as the state of being in accordance with a set of guidelines, specifications or legislative mandates designed to protect or manage targeted environmental resources or amenities [35]. Achieving compliance and identifying situations where actions or activities fail to agree with established standards, remain a vital aspect of environmental protection [36]. Therefore, an effective environmental compliance program is an essential ingredient for organisations whose activities imposed on the environment. Hence, environmental regulations present significant challenges to manufacturing companies. The manufacturing environmental regulations may impact on the entire value chains, from inbound logistics (i.e. receiving, storing, material handling, warehousing and inventory control) through the transformation process to outbound logistics (collecting, storing and physical distribution of product) [20].

Optimisation of resources is a key concept and tool for an industry to use to move towards an enhanced sustainability of practice [37]. The principles include avoiding and/or reducing waste generation, replacing hazardous substances and at least maintaining the quality of the external natural environment. In industry, resource efficiency aims to reduce material, water and energy consumption; the combined savings from the bottom line will create economic benefits for the company and hence for the community. Furthermore, avoiding any loss in the process itself is essential for an efficient use of resources. Optimisation of resource opportunities must be considered when designing products - design needs to consider the long term waste management strategy for the product to enhance its lifetime and to increase its ease of disassembly for recycling.

CONCLUSION

In a nutshell, improvements in manufacturing performances such as work-in-progress reduction, throughput time reduction, lead time reduction and flexibility improvement can potentially lead to greening supply chain management in Malaysia. The respondents are satisfied with the results of the implementation of most of the green supply chain practices and current manufacturing systems. The GSC practices can be denominated into three dimensions, positively influencing some manufacturing system performances, especially with environmental compliance. However, the results show that most of the significant correlation coefficients are below 0.6, suggesting only a weak influence on performance. In addition, the results do not provide enough evidence to conclude that green supply chain practices can influence overall manufacturing system performances. Nevertheless, the results of this research are useful in helping manufacturing firms to identify an effective approach towards successful green supply chain practices. Future research should empirically test the relationships of GSC practices in this study for different criteria, such as type of industry, company size, organisational behaviour to enable a comparative study. A larger sample would also allow a detailed cross-sector comparison.

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