World Academy of Science, Engineering and Technology
International Journal of Industrial and Manufacturing Engineering
Vol:5, No:11, 2011

The Relationship between Manufacturing System Performance and Green Practices in Supply Chain Management

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***Abstract*—**Green supply chain management is an increasingly recognized practice among companies that are seeking to improve environmental performance. Of particular concern is how to arouse organizational awareness and put green activities into practice in order to enhance manufacturing performances. This paper investigates the correlation of green supply chain practices and manufacturing performances in Malaysian certified MS ISO 14000 manufacturing firms. The findings shows that green supply chain practices which that can be denominated product recycling, environmental compliance and optimization have significant influence to some of the manufacturing performances.

***Keywords*—**Green supply chain practice, Manufacturing system performance, Malaysia

I. Introduction

SUPPLY chain management (SCM) is a concept that received great attention from industrialist as strategic planning in design, maintenance and operation of supply chain process satisfaction of end user needs. Although the improvements have been achieved through the successfully SCM practice, some of organizations are neglected to take care the environmental issues such as global energy, global warming, reverse logistic, etc. Environmental, ecological concerns in global competition attracted researchers in variety of disciplines.

The growing body of literature on the subject demonstrates a widespread appeal especially with regard to the application of ISO 14001 or Environmental Management System (EMS) standards. Simultaneously, the public's environmental awareness has increased through formal and informal environmental education channels. As a result, a systematic approach, Green Supply Chain Management (GSCM), has been increasingly accepted and practices by forward-thinking organizations [1]. For example, there are various streams of research that have made their focus the study of the dynamics and variables involved in the greening of business and supply chains, including reverse logistics, green purchasing, life cycle analysis, and design for environment.

Moreover, GSCM allows the information sharing of supplier, manufacturer, retrieving trader, law enforcement agency and user via user-friendly mechanism such Internet which mainly includes the data of choosing of the green material, product design, evaluation in supplier and selecting, green product, transported and distributed, packed, sold and wastes recovery. GSCM has become as an effective management tool for leading manufacturing organizations especially to enhance the environmental management system and manufacturing or operational performance [2]-[3]. However, GSCM is being adopted by industry, though not in a very apparent way, in different parts of the world. The extent and mode of implementation vary significantly [4]**.** As a result, it was captivated many researchers who have interested to identify the strategy and methodology to enhance the GSCM practice [5]-[6].

This paper is an empirical study on the relationship between manufacturing system performance and green supply chain practices in Malaysia. It aims to discover the green practices that existed in Malaysian certified MS (Malaysian Standard) ISO 14000 manufacturing firms and the significant result that influence the manufacturing system performances. The following sub-title will describe the research methodology, validation of the result, result, discussion, and conclusion which can be referred by other companies to define their green initiatives and other academician to explore what can be improved in green supply chain management and the sustainability.

II. Research Methodology

This study focused on sampling the perceptions and experience of MS ISO 14000 certified companies in the Malaysia manufacturing industry. The questionnaire designed in this study mainly comprised three parts: company profile, manufacturing system performance and green supply chain practices. The first part was designed to provide fundamental and background information, including industry type, employee (sizes) and EMS experience years; meanwhile, the next part focused on analysis of the manufacturing system performances and green supply chain practices. Respondents were asked to rate each item under 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 items was practiced in their respective organization.

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Data collection covered distributing questionnaires to various manufacturing companies that certified MS ISO 14000 in Malaysia. All target respondents were selected from SIRIM QAS (a Malaysian certification body) database which have more than 2 years experience in implementing certified environmental management system (EMS). Only single plant is preferred if the certified companies have more than one plant. In other words, from a total of 522 certified companies only 241 companies are considered as the population. The questionnaire, comprising 32 items, was addressed to the managing director and environment management representative.

A total of 241 questionnaires were mailed out and 61 were returned, of which 50 were valid, representing a response rate of 20.74 percent. Regarding to other studies related to green supply chain utilized a response rate of similar proportion to this study; Bowen et al [7] used a sample of 24 firms to indentify the supply management capabilities into corporate environmental approach. In addition, Rao [4], and Rao and Holt [5] produced significant finding of green supply chain with a sample only 52 firms. Simpson et al [8] used a sample of 55 firms to explore green supply chain practices in Australian automotive industry. More recently, Holt and Ghobadian [9] used a sample of 60 usable surveys without specific population to perform an empirical study of green supply chain practices amongst UK manufacturers.

This implies that the sample proportion of response rate of this study is acceptable, and it reflects the virtue of novel issue of green supply chain practice in Malaysia manufacturing MS ISO 14000 certified companies.

III. Result And Discussion

A. Demography of Respondents

Table. I lists the distribution of respondents in terms of their manufacturing sectors, ownership, company size and EMS experience years. The highest percentage of respondents is from electric and electronic industries (42.0 percent), followed by chemical products and engineering (38.0 percent), automotive industry (12.0 percent), and mechanical engineering (8.0 percent). Regarding the size of respondents ranged from under 250 to over 750 employees which found that respondent's companies are mainly from less than 250 to more than 750 as shown in Table. I. Meanwhile, 64.0 percent of respondents have more than 8 years EMS experience.

TABLE I
DEMOGRAPHY OF RESPONDENTS

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

N= 50

B. Green Supply Chain Practice

Green supply chain practices are determined by factor analysis. Table. II show the factor analysis result. Factor analysis has performed to extract factors based upon the principal components analysis with varimax rotation. Besides, Barlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy were employed to test appropriateness of the data for factor analysis [10]**.** 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 [11].

Based on the tests, it is evident that all factors all suitable for applying factor analysis. The authors performed factor analysis to extract factors in accordance with the eigenvalues of discontinuity greater than 1 and factor loading exceeding 0.6 was principle in choosing factors. The seven variables were eliminated because their factor loadings were less than 0.6. The remaining 14 items, therefore, were re-analyzed and extracted into three dimensions, which represented at least 60.862 percent of variances that can be denominated product recycling, environmental compliance and optimization.

Reliability concerns the extent to which an experience, test or any measuring procedure yields the same results on 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 were recalculated without those seven items. Table. II lists the new Cronbach's alpha values, ranging 0.867 to 0.912, after the seven items were dropped. Generally, Cronbach's alpha values in this study are greater than 0.7, revealing the high internal consistency.

The various approaches of green supply chain practices proposed by different authors were extract into three dimensions and 14 items of practices by factor analysis, statistical tests showed that three dimensions were all valid as shown in Table. III. Each of the items were evaluated on a four point scale. From the data, for each items, the percentage of companies which said "agree" and the percentage of companies which said "strongly agree" were determined. Table. III provides the details of the exploratory analysis. Considering both "agree" and "strongly agree", the item which had the highest percentage (98 percent) is "taking environmental criteria into consideration". This implied that most respondents had said either "agree" or "strongly agree" to the item.

TABLE II
FACTOR ANALYSIS RESULT

Dimension	Green practices	Item loading range	Eigenvalues	Cumulative percentage	Cronbach's alpha
Product recycling	1. Helping suppliers to establish their own EMS	0.829	8.507	40.510	0.891
	2. Use of alternative sources of energy	0.810			
	3. Recovery of the company's end-of-life products	0.806			
	4. Use of waste of other companies	0.737			
	5. Taking back packaging	0.723			
	6. Eco-labeling	0.667			
Environmental compliance	1. Taking environmental criteria into consideration	0.761	2.465	52.247	0.867
	2. Choice of suppliers by environmental criteria	0.727			
	3. Substitution of environmental questionable materials	0.723			
	4. Environment-friendly raw materials	0.704			
	5. Use of cleaner technology processes to make savings (energy, water, wastes)	0.676			
	6. Urging/pressuring supplier(s) to take environmental actions	0.602			
Optimization	1. Optimization of processes to reduce water use	0.891	1.809	60.862	0.912
	2. Optimization of processes to reduce air emissions	0.856			

Next came to "environment-friendly raw materials" (96 percent) followed by "optimization of processes to reduce air emissions" (94 percent). Substitution of environmental questionable materials came next, with 92 percent of the companies agreeing or strongly agreeing. Optimization of processes to reduce water use and use of cleaner technology processes to make savings (energy, water, wastes) were also implemented in majority of cases (90 percent). Among the items which were least implemented were eco-labeling (34 percent), recovery of the company's end-of-life products (52 percent) and taking back packaging (56 percent).

TABLE III
GREEN SUPPLY CHAIN PRACTICES

Green practices	Agree (%)	Strongly agree (%)	Total (%)	Rank
Dimension 1- Product recycling				
1. Helping suppliers to establish their own EMS	46	16	62	10
2. Use of alternative sources of energy	44	18	62	9
3. Recovery of the company's end-of-life products	46	6	52	13
4. Use of waste of other companies	50	10	60	11
5. Taking back packaging	40	16	56	12
6. Eco-labeling	26	8	34	14
Dimension 2 – Environmental Compliance				
1. Taking environmental criteria into consideration	60	40	98	1
2. Choice of suppliers by environmental criteria	52	32	84	7
3. Substitution of environmental questionable materials	46	46	92	4
4. Environment-friendly raw materials	44	52	96	2
5. Use of cleaner technology processes to make savings (energy, water, wastes)	58	32	90	6
6. Urging/pressuring supplier(s) to take environmental actions	62	18	80	8
Dimension 3 – Optimization				
1. Optimization of processes to reduce water use	56	34	90	5
2. Optimization of processes to reduce air emissions	62	32	94	3

N= 50

Commenting on the results, it was not surprising that all certified MS ISO 14000 organizations were considered environmental criteria. Mainly, many organizations had participated in the development of green management programme in Malaysia. They are government agencies, industry organizations, research and development organizations, environmental service organizations, non-governmental organizations, the public and funding, financial organizations and communities demanding such initiatives. Besides, Department of Environment (DOE) under Ministry of Natural Resources and Environment is empowered under the Environmental Quality Act (EQA), 1974 to control and prevent pollution and to protect and enhance the quality of the environment. DOE has a stake in Cleaner Production (CP) implementation since the adoption of CP by Small Medium Industries (SMIs) will reduce pollution in a significant way.

Effective on 9th April 2009, new ministerial portfolio was introduced to strengthen green management programme in Malaysia. The establishment of the Ministry of Energy, Green Technology and Water (also known as KeTTHA) reflects Malaysia's seriousness in driving the message that 'clean and green' is the way forward towards creating an economy that is based on sustainable solutions [12]. National Green Technology Policy (NGTP) was formulated to provide guidance and to create opportunities for business and industries to bring a positive impact to economic growth. The NGTP is built on four pillars: (1) Energy – seek to attain energy independence and promote efficient; (2) Environment – conserve and minimize the impact on the environment; (3) Economy – enhance the national economic development through the use of technology; and (4) Social – improve the quality of life for all.

In contrast, individual industries may not be fully aware about the green management programme. However, the industrial organization such as Business Council for Sustainable Development (BCSDM), the Malaysia International Chamber of Commerce and Industries (MICCI), the Federation of Malaysian Manufacturers (FMM) and the

SMI association (SMIA) are aware about the benefits of green management programme particularly for SMIs. The difficulties faced by the industry organizations are SMI's unwillingness to adopt green initiatives due to financial, technical, as well as manpower constraints. Research organizations such as Palm Oil Research Institute Malaysia (PORIM), Forest Institute of Malaysia (FRIM) and RRI assist the industries registered under them in improving environmental performance. Standard and Industrial research Institute of Malaysia (SIRIM) provides consultancy services to SMIs to help them conduct environmental audits and adopt EMS certification. Participation in ISO 14000 is becoming one of the most sought-after statues in the more general move towards globalization of environmental management. In recent years, there has been heightened international interest in and commitment to improve environmental management practices by both the public and private sectors [13].

C. Performance of the Manufacturing System

A measure of success in implementing any manufacturing systems or supply chain management can be defined along a few performance parameters. The companies were requested to indicate the performance of their manufacturing system. The measures used were: 1= very poor, and 4 = very good. The results are summarized in Table. IV. It can be deduced from the table that, in general, the respondents were satisfied with the achievement of most of the objectives of the manufacturing systems implementation. On average above half of the respondents considered the performance of their systems to be good or very good. Product quality improvement is the performance measures that were considered to be most satisfactory, whereas flexibility improvement was considered poor. Cronbach's alpha values (0.843) of the manufacturing performances are greater than 0.7, revealing the high internal consistency.

TABLE IV
PERFORMANCE OF MANUFACTURING SYSTEM

	Relative Performance (%)				Mean	sd
	1	2	3	4		
1. Product quality improvement	-	10.0	58.0	32.0	3.22	0.616
2. Work-in-progress reduction	-	6.0	80.0	14.0	3.08	0.444
3. Throughput time reduction	-	8.0	80.0	12.0	3.04	0.450
4. Lead time reduction	2.0	10.0	70.0	18.0	3.04	0.605
5. Machine utilization improvement	-	14.0	70.0	16.0	3.02	0.553
6. Manufacturing cost reduction	-	12.0	76.0	12.0	3.00	0.495
7. Flexibility improvement	-	16.0	74.0	10.0	2.94	0.512

N= 50

D. Spearman Correlation Test

Spearman correlation test is performed to identify the relationship between green supply chain practices and manufacturing system performance. Table. V shows the correlation coefficients result. According to the Table. V, dimension 2- Environmental Compliance have several significant result at the level 0.05 and 0.01. It's mean that some of the green practices are significant with manufacturing system performances at confident level at least 95 percent. Among the listed green practices, taking environmental criteria into consideration is the most higher significantly correlated with manufacturing system performance, lead time reduction (r= 0.514) at the significance level 0.01. In other words, the consideration on the environmental criteria is positively influenced by lead time reduction with 0.514 chances.

TABLE V
SPEARMAN CORRELATION COEFFICIENT

Green practices \ Manufacturing System Performances	Product quality improvement	Work-in-progress reduction	Throughput time reduction	Lead time reduction	Machine utilization improvement	Manufacturing cost reduction	Flexibility improvement
Dimension 1- Product recycling							
1. Helping suppliers to establish their own EMS	0.093	0.047	0.071	-0.076	-0.079	0.073	0.068
2. Use of alternative sources of energy	0.174	0.098	0.128	0.110	0.077	0.042	0.110
3. Recovery of the company's end-of-life products	0.184	0.106	0.128	0.293(*)	-0.006	0.005	0.146
4. Use of waste of other companies	0.055	-0.091	-0.031	0.171	-0.144	0.060	0.116
5. Taking back packaging	0.222	0.069	0.218	0.151	-0.068	0.062	0.052
6. Eco-labeling	0.170	-0.083	0.111	0.116	-0.051	0.027	0.098
Dimension 2 – Environmental Compliance							
1. Taking environmental criteria into consideration	0.311(*)	0.322(*)	0.391(**)	0.514(**)	0.194	0.420(**)	0.180
2. Choice of suppliers by environmental criteria	0.144	0.303(*)	0.405(**)	0.385(**)	0.217	0.407(**)	0.241
3. Substitution of environmental questionable materials	0.274	0.144	0.265	0.427(**)	0.346(*)	0.419(**)	0.398(**)
4. Environment-friendly raw materials	0.289(*)	0.348(*)	0.352(*)	0.470(**)	0.105	0.401(**)	0.277
5. Use of cleaner technology processes to make savings (energy, water, wastes)	0.081	0.192	0.293(*)	0.385(**)	0.049	0.226	0.317(*)
6. Urging/pressuring supplier(s) to take environmental actions	0.282(*)	0.305(*)	0.378(**)	0.370(**)	0.241	0.136	0.072
Dimension 3 – Optimization							
1. Optimization of processes to reduce water use	0.099	0.317(*)	0.170	0.179	0.085	0.150	0.122
2. Optimization of processes to reduce air emissions	0.080	0.187	0.124	0.231	0.044	0.104	0.150

Note:
**. significance at the level 0.01
*. significance at the level 0.05

The analysis shows that only substitution of environmental questionable materials has significant result with machine utilization improvement performance. On the other hands, the green practices with significant at the level 0.01 have better correlation coefficient result with manufacturing system performances. However, in general, most of the practices have very weak correlation results with overall manufacturing system performances. Green practices such as helping suppliers to establish their own EMS, use of alternative sources of energy, use of waste of other companies, taking back packaging, eco-labeling, and optimization of processes to reduce air emissions are not significant with any manufacturing system performances.

IV. Conclusion

In the nutshell, the authors found that the respondents were satisfied with the achievement of most the green supply chain practices and current manufacturing systems implementation. The green supply chain practices can be denominated into three dimensions positively have significant influence result to some of the manufacturing system performances especially with environmental compliance. However, the current result shows that most of the significant correlation coefficient are below than 0.6 to prove strong influence results. In addition, the results have not enough evidence to conclude that green supply chain practices can influence the overall manufacturing system performances. On the other hands, the study only focused on the Malaysian certified MS ISO 14000 manufacturing firms which represent small pieces of supply chain groups. Nevertheless, the authors believe that the research results may prove useful in helping manufacturing firms to identify an effective approach towards the successful of green supply chain practices.

Acknowledgment

This research was co-funded by the Ministry of Higher Education Malaysia (MOHE) with partially Universiti Teknikal Malaysia Melaka (UTeM) under the program "Skim Latihan Akademik IPTA (SLAI)" and Universiti Kebangsaan Malaysia (UKM) under FRGS Grant.

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