Factors Affecting Green Supply Chain Management of Lampang Ceramics Industry

Nattida Wannaruk, Wasawat Nakkiew

***Abstract*—**This research aims to study the factors that affect the performance of green supply chain management in the Lampang ceramics industry. The data investigation of this research was questionnaires which were gathered from 20 factories in the Lampang ceramics industry. The research factors are divided into five major groups which are green design, green purchasing, green manufacturing, green logistics and reverse logistics. The questionnaire has consisted of four parts that related to factors green supply chain management and general information of the Lampang ceramics industry. Then, the data were analyzed using descriptive statistic and priority of each factor by using the analytic hierarchy process (AHP). The understanding of factors affecting the green supply chain management of Lampang ceramics industry was indicated in the summary result along with each factor weight. The result of this research could be contributed to the development of indicators or performance evaluation in the future.

***Keywords*—**Lampang ceramics industry, green supply chain management, analytic hierarchy process, factors affecting.

I. INTRODUCTION

CERAMICS is one of the important industries of Thailand and the main ceramic products includes ceramic tiles, sanitary wares, tableware, gift decorations, and insulators [4]. In ceramic production, kaolin is the main component. When kaolin is used in the biscuit firing and gloss firing process it cannot be reused and some processes can cause pollution such as heat, dust, noise, and waste from the factory and waste water, etc. It is also difficult to degrade and can negatively affect the environment [8].

At present, environmental problems are one of the important problems and many firms have applied it is a way to demonstrate their sincere commitment to sustainability. Green supply chain management (GSCM) considers activities that impact on the environment: green design, green purchasing, green manufacturing, green logistics and reverse logistics [9]. If there is effective environment management along the supply chain, as a result, the impact on the environment may be reduced to the firms and helping them to achieve profit, market share, while raising their efficiency.

A study of past research found studies about green supply chain in a variety of industries, as well as the use of tools related to multiple criteria decision-making for environmental research such as the technique for order preference by similarity to ideal solution (TOPSIS), decision making trial and evaluation laboratory (DEMATEL) and AHP, etc. [15]. However, the study of factors affecting the GSCM of the Lampang ceramics industry was very limited. Therefore, this research aims to study the factors that affect the performance of GSCM in the Lampang ceramics industry and the results of this research can contribute to the development of indicators or the performance evaluation of GSCM in the future.

II. LITERATURE REVIEW

A. Green Supply Chain Management (GSCM)

GSCM have been beneficial that can lead to the achievement of environmental sustainability [6], [16]. According to the study of [3], GSCM comprises of 1. Green procurement, 2. Green manufacturing or materials management, 3. Green distribution or marketing and 4. Reverse logistics. It has also been stated that firms tend to implement GSCM to improve their competitive advantages and to achieve enhanced profit ratios [5], [14]. In addition, the research of [11], mentioned that GSCM is an important and effective principle for firms, as an initiative for environmental enhancement, economic performance, and competitiveness. Therefore, many researchers had made it evident in their work that GSCM implementation is very vital and result oriented, which keep in view of the environmental aspects of the firms as well.

B. Analytic Hierarchy Process (AHP)

The multiple criteria decision making is one of the most appropriate methods for environmental management. According to the study of [10], AHP was used to evaluate the vendor's environmental performance and applied in automotive case studies that there were five steps to assess a supplier. The highest rated suppliers were considered the most popular and recommended to use. This method will help to identify the environmental performance of suppliers and environmental strategies to helps the decision maker develop the ranking process. In addition, the research of [2] refers to the AHP approach as a support tool to help understand the difference between environmental factors that it can use to assess the relative importance of various environmental characteristics and gain access to supplier-specific performance with specific characteristics.

III. RESEARCH METHODOLOGY

The five steps in this research process are:

Step 1. Study on the supply chain of the ceramics industry, relevant information and theories related to collecting factors that affect the performance of GSCM in the

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Lampang ceramics industry.

Step 2. Design a questionnaire about a factor that affects the performance of GSCM in five major groups which are 1. Green design, 2. Green purchasing, 3. Green manufacturing, 4. Green logistics and 5. Reverse logistics. The questionnaire consisted of four parts which are: part 1 is the details of each factor which are the definitions of those five major groups of factors, part 2 questions about the relevant factors with the total 29 questions, part 3 is a comparison between those factors according to the theory of AHP and part 4 is general information of company. Then, test the validity of the questionnaire and data validation by two professionals who are expert in supply chain logistics and ceramics to collect actual data.

Step 3. Data collected using a structured questionnaire mailed to a sample of 20 factories in Lampang ceramics industry.

Step 4. Perform statistical analysis using descriptive statistics and weight of each factor using AHP.

Step 5. Summarize the results of factors affecting GSCM of the Lampang ceramics industry, and the weight and priority of each factor.

IV. Results and Discussion

A. Green Supply Chain Management

The study the supply chain of the Lampang ceramics industry can be shown in Fig. 1. Started from upstream to downstream, it involves the supplier, the designer, the manufacturer, the distributor, the carrier, the retailer and the consumer. At each stage, resources such as energy, water, packaging materials, etc. were used. In addition, wastes and/or water wastes come out throughout the chain [13].

From the study of theory and related research in GSCM, the result can be obtained from five main factors:

1. Green design is to bring the eco-friendly concept into the product design phase such as a property of a product, materials selection for production, operation and use energy that is considered throughout the life cycle of a product.
2. Green purchasing is the procurement or services that are environmentally friendly by considered quality, price, and delivery of goods or services such that it can reduce the impact on the environment caused by production and service.
3. Green manufacturing are production processes which have low environmental impacts and are highly efficient: generate little or no waste or pollution. It also reduces raw material costs, increases profitability and safety.
4. Green logistics consists of distribution, moving and delivering raw materials and products at the lowest possible cost while maintaining the highest standards and minimizing the environmental impact in the process [7].
5. Reverse logistics is the process considered in the steps after a product was used. This includes recycling and the proper disposal processes that are environmentally friendly.

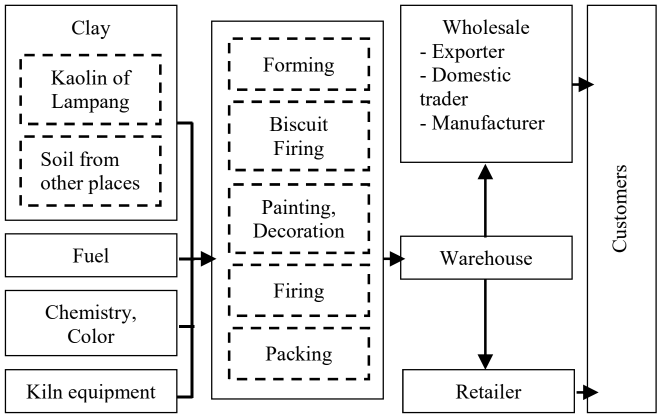

Fig. 1 Supply Chain of Lampang Ceramics Industry [1]

TABLE I
FACTORS AND SUB-FACTORS OF GSCM FOR THE LAMPANG CERAMICS INDUSTRY

Factors	Sub-factors
1. Green design (A)	1.1 The use of environmentally friendly raw materials. (A1)
	1.2 The use of easily recyclable raw materials (A2)
	1.3 The environmentally harmful products are avoided. (A3)
	1.4 The environmental regulations. (A4)
	1.5 Environmental labeling of products such as the green label. (A5)
2. Green purchasing (B)	2.1 Quality Inspection of Raw Materials. (B1)
	2.2 Choosing a vendor location, such as the distance between the vendor and the. (B2)
	2.3 The packaging from the vendor is environmentally friendly. (B3)
	2.4 The vendor environmental certification such as ISO14000. (B4)
	2.5 Communication technology with the vendor. (B5)
	2.6 Cooperation with suppliers for environmental objectives. (B6)
3. Green manufacturing (C)	3.1 Toxins control in the production process. (C1)
	3.2 Waste-reducing system. (C2)
	3.3 The use pollution control system. (C3)
	3.4 Manufacturing technologies are applied such as lean manufacturing, 3R manufacturing. (C4)
	3.5 The manufacturing machines frequently undergo maintenance procedures. (C5)
	3.6 The quality of the final product. (C6)
	3.7 Skillful of the employee. (C7)
4. Green logistics (D)	4.1 The delivery routes are determined. (D1)
	4.2 The use of assisted transportation technologies such as GPS, RFID (D2)
	4.3 The delivery vehicles are well checked, and maintenance plans are available. (D3)
	4.4 Appropriate for the model. (D4)
	4.5 Appropriate for transport fuel. (D5)
	4.6 Cooperation with the customer for environmentally friendly. (D6)
5. Reverse logistics (E)	5.1 The wastewater treatment. (E1)
	5.2 The waste disposal (E2)
	5.3 The management of used or recycled packaging (E3)
	5.4 The returned product management (E4)
	5.5 Having a wastes collection agent (E5)

All 29 sub-factors were collected from the supply chain study of the Lampang ceramics industry, as shown in Table I.

TABLE II
GENERAL INFORMATION ON FACTORIES IN THE LAMPANG CERAMICS INDUSTRY

General information		Percent (%)
1.Type of ceramics	Tableware	65
	Gift and Decorations	20
	Gift and Decorations, Tableware	10
	Ceramic Tiles	5
2. Founding of business	More than 9 years	95
	7-9 years	5
3. Number of employees	Less than 100 people	95
	201-500 people	5
4. Concept of GSCM applied in the factory	There is no implementation but there are ways to apply it in the future.	45
	There is no implementation.	35
	There is implementation.	20
5. Type of production	Both made to order customer and made to stock	80
	Made to order customer	20
6. Channel of distribution	Both domestic market and international market	55
	Domestic market	40
	International market	5

TABLE III
AVERAGE IMPORTANT AND STANDARD DEVIATION OF FACTORS

Factors	Sub-factors	$\overline{X}$	S.D.	Level important
1. Green design (A)	1.1 The use of environmentally friendly raw materials. (A1)	4.05	0.83	Very important
	1.2 The use of easily recyclable raw materials (A2)	3.80	0.95	Very important
	1.3 The environmentally harmful products are avoided. (A3)	4.35	0.88	Very important
	1.4 The environmental regulations. (A4)	3.85	0.81	Very important
	1.5 Environmental labeling of products such as the green label. (A5)	3.35	1.09	Moderately important
2. Green purchasing (B)	2.1 Quality Inspection of Raw Materials. (B1)	4.20	0.77	Very important
	2.2 Choosing a vendor location, such as the distance between the vendor and the factory. (B2)	3.40	1.35	Moderately important
	2.3 The packaging from the vendor is environmentally friendly. (B3)	3.60	0.88	Very important
	2.4 The vendor environmental certification such as ISO14000. (B4)	3.65	0.81	Very important
	2.5 Communication technology with the vendor. (B5)	4.00	0.92	Very important
	2.6 Cooperation with suppliers for environmental objectives. (B6)	3.60	0.75	Very important
3. Green manufacturing (C)	3.1 Toxins control in the production process. (C1)	4.35	0.59	Very important
	3.2 Waste-reducing system. (C2)	4.10	0.79	Very important
	3.3 The use pollution control system. (C3)	3.95	0.76	Very important
	3.4 Manufacturing technologies are applied such as lean manufacturing, 3R (C4)	3.40	0.82	Moderately important
	3.5 The manufacturing machines frequently undergo maintenance procedures. (C5)	4.40	0.60	Very important
	3.6 The quality of the final product. (C6)	4.40	0.68	Very important
	3.7 Skillful of the employee. (C7)	4.30	0.80	Very important
4. Green logistics (D)	4.1 The delivery routes are determined. (D1)	3.60	1.00	Very important
	4.2 The use of assisted transportation technologies such as GPS, RFID (D2)	3.15	1.04	Moderately important
	4.3 The delivery vehicles are well checked, and maintenance plans are available. (D3)	3.90	0.85	Very important
	4.4 Appropriate for transport model. (D4)	3.65	0.93	Very important
	4.5 Appropriate for transport fuel. (D5)	3.65	0.93	Very important
	4.6 Cooperation with the customer for environmentally friendly. (D6)	3.45	0.95	Moderately important
5. Reverse logistics (E)	5.1 The wastewater treatment. (E1)	3.80	1.11	Very important
	5.2 The waste Disposal (E2)	4.05	0.95	Very important
	5.3 The management of used or recycled packaging (E3)	3.45	1.15	Moderately important
	5.4 The returned product management (E4)	3.35	1.09	Moderately important
	5.5 Having a wastes collection agent (E5)	3.50	1.10	Very important

B. Factors Affecting the GSCM of the Lampang Ceramics Industry

In this study, data were collected from 20 factories in the Lampang ceramics industry. The highest percentage of respondents is from tableware ceramic (65%). Regarding the founding business of respondents, from the factories formed for more than 9 years and employ less than 100 people (95%) about 45% of these know about GSCM but have not applied it yet. With regard to the type of production, the highest percentage of respondents is made to order customer and made to stock (80%), and for channel distribution, the highest percentage of respondents is the domestic and international market (55%), as shown in Table II.

TABLE IV
THE RESULT OF ANALYSIS AVERAGE IMPORTANCE (SELECTED ONLY MOST IMPORTANT SUB-FACTORS)

Factors	Sub-factors	$\overline{X}$
Green design (A)	The use of environmentally friendly raw materials. (A1)	4.05
	The use of easily recyclable raw materials. (A2)	3.80
	The environmentally harmful products are avoided. (A3)	4.35
	The environmental regulations. (A4)	3.85
Green purchasing (B)	Quality Inspection of Raw Materials. (B1)	4.20
	The packaging from the vendor is environmentally friendly. (B3)	3.60
	The vendor environmental certification such as ISO14000. (B4)	3.65
	Communication technology with the vendor. (B5)	4.00
Green manufacturing (C)	Toxins control in the production process. (C1)	4.35
	Waste-reducing system. (C2)	4.10
	The use pollution control system. (C3)	3.95
	The manufacturing machines frequently undergo maintenance procedures. (C5)	4.40
	The quality of the final product. (C6)	4.40
	Skillful of the employee. (C7)	4.30
Green logistics (D)	The delivery routes are determined. (D1)	3.60
	The delivery vehicles are well checked, and maintenance plans are available. (D3)	3.90
	Appropriate for transport model. (D4)	3.65
	Appropriate for transport fuel. (D5)	3.65
Reverse logistics (E)	The wastewater treatment. (E1)	3.80
	The waste disposal. (E2)	4.05
	Having a wastes collection agent. (E5)	3.50

C. Score for Importance Factor

The second part of the questionnaire focused on the analysis of the factors for GSCM. Respondents were asked to rate each item under a five-point Liker-type scale (e.g. 1 = not important, 2 = least important, 3 = moderately important, 4 = very important, 5 = most important), to indicate the extent to which each item was practiced in their respective organization. The average and standard deviation is shown in Table III. In addition, the interpretation of average is 1.00-1.49 = least important, average 2.50-3.49 = moderately important, average 3.50-4.49 = very important and 4.50-5.00 = most important.

Table IV shows the rated levels of most importance for each of the sub-factors for GSCM in the Lampang ceramics industry. It is observational from analysis result of this investigation (Table IV) that the average of all sub-factor in the factors of Green design, Green purchasing, Green manufacturing, Green logistics and Reverse logistics are 3.50-4.49 (very importance).

Determine the weight factor by using the data from the questionnaire in part 3 is pairwise comparison according to the AHP method. The evaluation scales used in the example are those recommended by [12]. Evaluated on a nine-point intensity scale, where 1 is equally important, 3 is moderately more important, 5 is strongly more important, 7 is very strongly more important and 9 is extremely more important. For example, the weight factor score of 1 factory is shown in Table V.

Where W^t is the weight of each factor, AW^t is calculated from a value of each factor in each row multiplied with a weight of each factor and then AW^t/W^t is the ratio between AW^t with W^t. In addition, the calculated value of each factor, both the main factor and sub-factor, is conducted according to the AHP method, as shown in Table VI.

TABLE V
EXAMPLE THE FACTOR SCORE OF 1 FACTORY

Factor	A	B	C	D	E	W^T	AW^T	AW^T/W^t
A	1	5/7	5/3	5/3	5/7	0.21	1.07	5.19
B	1	1	1	7/3	1	0.24	1.22	5.03
C	3/5	1	1	7/3	1	0.20	1.06	5.16
D	3/5	3/7	3/7	1	3/7	0.10	0.52	5.03
E	7/5	1	1	3/7	1	0.24	1.22	5.03
Total	5.00	4.14	5.10	9.67	4.14	1.00		

TABLE VI
EXAMPLE CALCULATED WEIGHT FACTOR OF 1 FACTORY

Factor	Geometric mean		Weight	
A	$(1\times5/7\times5/3\times5/3\times5/7)^{1/5}$	= 1.07	1.07/5.22	= 0.21
B	$(1\times1\times1\times7/3\times1)^{1/5}$	= 1.27	1.27/5.22	= 0.24
C	$(3/5\times1\times1\times7/3\times1)^{1/5}$	= 1.07	1.07/5.22	= 0.20
D	$(3/5\times3/7\times3/7\times1\times3/7)^{1/5}$	= 0.54	0.54/5.22	= 0.10
E	$(7/5\times1\times1\times3/7\times1)^{1/5}$	= 1.27	1.27/5.22	= 0.24
	Total	5.22	**Total**	1.00

D. Consistency Ratio (CR)

Consistency index (CI) can be formulated as:

$$CI = \frac{(\lambda_{\max} - n)}{(n - 1)}$$

where $\lambda_{\max}$ the maximum eigenvalue of the judgment *matrix.*

1) Random index values (RI) are shown in Table VII.
2) Consistency ratio (CR) can be formula is CR = CI/RI and CR should be less than 0.1.

TABLE VII
RANDOM INDEX VALUES

n	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

E. Example of the Calculated Consistency Ratio (CR) Main Factor of the Factory

$$\lambda_{max} = (5.19+5.03+5.16+5.03+5.03)/5 = 5.09$$

$$CI = (5.09-5)/4 = 0.02$$

$$RI = 1.12\ (n = 5)$$

$$CR = 0.02/1.12 = 0.02$$

The calculating consistency ratio of the major factor from 1 factory it was found that CR = 0.02, which less than 0.1 indicating that the data was consistent.

The weight scores average from 20 factories were calculated before the calculation of consistency ratio. The consistency ratio of the five main factors is 0.039, sub-factor of green design is 0.007, sub-factor of green purchasing is 0.022, sub-factor of green manufacturing is 0.017, sub-factor of green logistics is 0.008, and sub-factor of reverse logistics is 0.022, which less than 0.1, indicating that the data were consistent and can be used to calculate the weight importance.

The calculation of the weight factor and sub-factor by AHP method are shown in Table V. In addition, the result of calculating the weight and rank of all important factors from the Lampang ceramics industry is shown in Fig 2. It is found that green manufacturing has the highest weight of 0.238, followed by green design of 0.233, green purchasing of 0.199, reverse logistics of 0.170 and last green logistic of 0.160, respectively.

V. CONCLUSION

The results suggest the factors affecting in GSCM for 20 Lampang ceramics industry was investigated and presented in this paper. The significance levels of 29 sub-factors were identified. Firstly, green manufacturing is considered most important because it is produced to provide quality products according to customer requirements and the highest efficiency in production, including loss management during production and focused on the manufacturing machines frequently undergo maintenance procedures. Then, green design was focused on the environmentally harmful products are avoided. Next, green purchasing focused on the quality inspection of raw materials. After that, reverse logistics focused on waste disposal because waste can have a negative and harmful impact on the environment without proper management. Finally, green logistics focused on the delivery vehicles to ensure they are well checked and that maintenance plans are available.

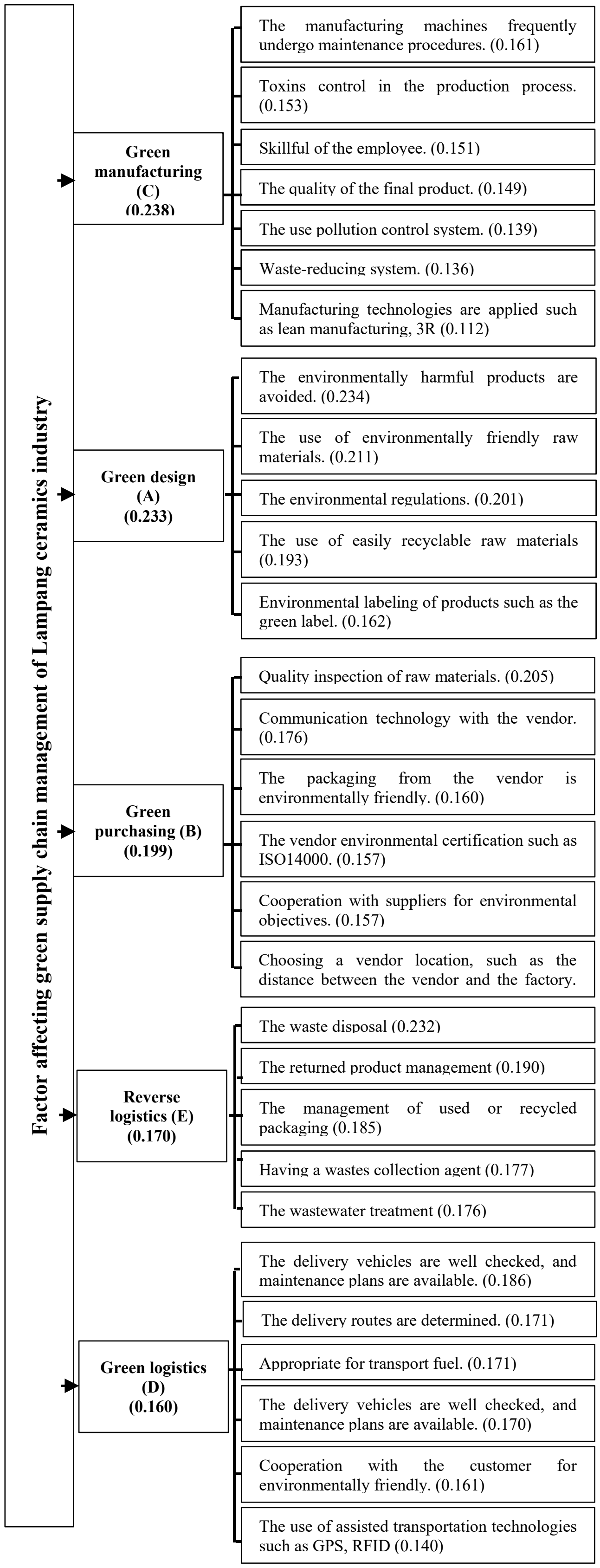

Fig. 2 The rank important and weight of factor affecting GSCM of Lampang ceramics industry

The concept and result of this research can be applied in the development of indicators or evaluation models of GSCM in the ceramics industry. It should be focused on the level of importance of factors, ranking, and the weight value to determining the indicators for evaluated GSCM in Lampang ceramics industry. The research is a preliminary study that improvement should be adopted and applied to other industries to operations will certainly improve their performance and profitability.

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