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A Selection of Barrier Factors Affecting Reverse Logistics Performance of Thai Electronic Industry

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Abstract: The aim of research is to identify and select various significant barriers affecting Reverse Logistics (RL) performance in Thai Electronic Industry. The work utilizes Structure Equation Modeling (SEM) to empirically validate the relation of barrier to RL performance based on path analysis and Confirmation Factor Analysis (CFA) of SEM. The questionnaire to investigate barriers and RL performance are developed by using a literature review of international research works. The survey has been carried out on mostly large and medium size electronic companies with running operations more than 10 years and located in Thailand. The 67 responses can be obtained and formulate the SEM model for testing and analysis. The hypotheses were tested in which Barriers was directly, indirectly negatively associated with RL performance. After the modification of SEM model according to fit indices, it was shown that 29 barriers are found statistically significant in this empirically study. These barriers can be categorized into eight groups. Such barriers are Management barrier, Organization barrier, Product barrier, Technological barrier, Infrastructural barrier, Financial barrier, Involvement and Support barrier and Legal barrier. The research finding gives priority to enhancement in RL practices in electronic industry to establish effective RL projects as a crucial strategy to meet the environment awareness in global trends.

Keywords: Barriers, Reverse logistics, Electronic industries, Structure equation modeling.

1. Introduction

All In global awareness of environment due to the rapidly increasing of e-waste with responsibility to consumers, many countries and internal environmental organizations are in courage to decrease this problem to effect environment. A number of regulations are used to control by regularly reporting the quantity sold and to ensure that the products are disposed of in an environmentally friendly way. Some well-known regulations are WEEE (waste electronic and electrical equipment) to manage proper disposal and RoHS to ban some toxic substances like lead, cadmium, mercury, hexavalent chromium, PBB and PBDE used in electronics and electrical part and product. Thus, electronic manufacturing and government organization have to play attention to this trend in order to reduce the environmental problem, cost and increase competitiveness by using concept of Green supply chain (GSC). Therefore, Reverse Logistics (RL) is one of GSC management is really needed to perform effectively to deal with this work. Reverse logistics (RL) is an important process because of potentials of value recovery from the used products which RL focuses on waste management, material recovery, parts recovery or product recovery [1]. Many manufacturing companies use RL as one of key strategic activity because it can create value. The company can get more benefits from reverse logistics management such as rating additional revenue, reducing operating costs, and minimizing the opportunity costs of defective or out-of-date products [2]. The efficient management for collected waste is the development of all necessary infrastructures and also coordination of all relevant stakeholders in supply chain [3].

In Thailand, electronic industry plays an important role to Thailand's economic. In the year 2018, total value of exporting electronic products was about US$ 37 billion. The first rank of exporting product was computer parts that were about 56% of total exporting electronic products. The more manufacturing and export, the better economics for Thailand but it consequently causes a huge e-waste inside the country. Thus, the focusing on support electronic manufacturing to manage their environment matters though RL practices is an important issue in Thai electronic industry apart from only complying with law and environmental regulations. This research aims to investigate the impediment of implementing Reverse Logistics, although some woks have been done in these areas, but they are not specific especially in Thai electronic industry. This work employs empirical approach with Structure Equation Modeling (SEM), one of well-known and promising research techniques. In the early part of work, the literature review of these barriers on academic research and international journal are comprehensively explored and presented in the next section. For an empirically study in Thai electronic industry, manufacturing companies are widely surveyed with a well-construct questionnaire. The obtained data are analyzed by using SEM, an effective statistical technique to testing hypotheses about relation of variables. The selection of barrier to RL is variables found statistically significant in Thai electronic Industry.

2. Literature reviews

2.1 Barrier factors in reverse logistics

There are a number of studies done to facilitate implementation of reverse logistics due to the increasing of environmental awareness. However, the practice of RL is still difficult for an electronic company to perform with barriers in various aspects. The literature review of barriers for implementing RL on international database are carried out and summarized in the authors' works [4-5]. Barriers are categorized into eights groups and their 37 sub-criteria are shown in Table 1 associated with their references.

Table 1. Summarized barrier factors of reverse logistics

Criteria	Sub-criteria	Code	References
Management Barriers (MB)	Lack of commitment by top management	MB1	[6-18]
	Lack of strategic planning for ensuring RL practices	MB2	
	Lack of awareness and understanding in RL adaptation	MB3	
	Lack of specific goals for environment and waste management	MB4	
	Lack of policies for RL practices	MB5	
	Company policies	MB6	
Organization Barriers (OB)	Lack of proper organizational structure & support for RL practices	OB1	[8-12], [14-15], [17-20]
	Lack of shared understanding of best practices	OB2	
	Lack of training & education about RL	OB3	
	Lack of organization personnel resources	OB4	
	Lack of appropriate performance management system	OB5	
Product Barriers (PB)	Uncertain quality and quantity of return products from point of consumption	PB1	[5], [8-10], [14-15], [17], [21]
	Less economic value recovered	PB2	
	Risk of storage of hazardous materials	PB3	
Legal barriers (LB)	Lack of enforced laws, legislation and directives for EoL products	LB1	[7-10], [11], [13-16]
	Lack of government supportive policies on RL practices	LB2	
	Lack of standard/green practices for recycling	LB3	
	Loopholes in Thai laws and regulations on waste management	LB4	
Technological barriers (TB)	Lack of information and technological systems for RL practices	TB1	[5-10], [12], [15], [20]
	Less development of recycling technologies	TB2	
	Lack of available technological infrastructure to adopt RL practices	TB3	
	Lack of technical expertise to support RL practices	TB4	
	Lack of flexibility to change from traditional system to new system	TB5	
Infrastructural barriers (IB)	Lack of infrastructure facility to support RL implementation	IB1	[8], [10], [16-17], [20]
	Lack of efficient and effective systems to monitor returns and recalls	IB2	
	Lack of investment in RL product storage	IB3	
	Increase of unstandardized waste management area	IB4	

Table 1. Summarized barrier factors of reverse logistics (cont.)

Financial barriers (FB)	Financial constraints	FB1	[6-12], [15-21]
	High investments and less return-on-investments	FB2	
	Expenditure in collection and storage of used products	FB3	
	Cost of environmentally friendly packaging	FB4	
	Cost of nonhazardous and hazardous waste disposal	FB5	
Involvement and support barriers (ISB)	Lack of coordination and collaboration with 3rd party logistics providers	ISB1	[5-21], [13], [15-17], [19], [21]
	Lack of support of supply chain partners	ISB2	
	Customer perception about reverse logistics	ISB3	
	No proper training/ consultancy/ reward for supply chain partner	ISB4	
	Lack of public focus on environmental issues	ISB5	

Table 2. Reverse logistics performance factors

Criteria	Sub-criteria	Code	References
Green Image (GI)	Percentage of reduction of consumption of rare material/non-renewable energy	GI1	[23-24]
	Percentage of reduction in the use of hazardous materials/ products / process	GI2	
	Number of environmental certifications/ awards achieved	GI3	
Flexibility (FL)	Feasibility in recycling/ repair options	FL1	[23-24]
	Reusability of parts/ products (product modularity/ durability)	FL2	
Quality (QA)	Percentage of defects	QA1	[23-25]
	Customer complaints resolved	QA2	
Responsiveness (RE)	Reduction of return rates	RE1	[23-25]
	Reduction of total lead time for customer complaints resolved	RE2	
Expense (EX)	Reverse distribution/ transportation cost	EX1	[23-26]
	Total cost for testing/ sorting/ repair/ refurbishment/ remarketing/ redistribution inventory/ land filling/ scrapping	EX2	
	Cost of information and communication technology (ICT) support installed	EX3	
Value Recovered (VE)	Revenue from reselling repaired products in value-recovery	VA1	[23-25], [27]
	Cost avoidance by reusing refurbished parts in the forward supply chain	VA2	
	Cost avoidance by recycling materials	VA3	

2.2 Reverse logistics performance

The reverse logistics performances are also reviewed and categorized in the work of Sirisawat and Kiatcharoenpol [22]. The criteria to evaluate the performance are set into six groups with details of sub-criteria as presented in the Table 2.

The criteria are Green Image, Flexibility, Quality, Responsiveness, Expense and Value Recovered and all fifteen sub-criteria as RL performance factors, which will be used for validating significant barriers factors or variables in Thai electronic industry by using Structure Equation Modeling methodology.

2.3 Structure equation modeling techniques

A structure equation modeling (SEM) is a comprehensive statistical approach to testing hypotheses about relations among observed and latent variables [28]. Rigdon [29] defines SEM as a methodology for representing, estimating, and testing a theoretical network of (mostly) linear relations between variables. SEM is also be the test of hypothesized patterns of directional and non-directional relationships among a set of observed (measured) and unobserved (latent) variables [30]. In the work Teo et al. [31] and Byrne [32], SEM is compared against other multivariate techniques and listed four unique features of SEM:

1) SEM takes a confirmatory approach to data analysis by specifying the relationships among variables *a priori*. By comparison, other multivariate techniques are descriptive by nature so that hypothesis testing is rather difficult to do.

2) SEM provides explicit estimates of error variance parameters. Other multivariate techniques are not capable of either assessing or correcting for measurement error. For example, a regression analysis ignores the potential error in all the independent (explanatory) variables included in a

model and this raises the possibility of incorrect conclusions due to misleading regression estimates.

3) SEM procedures incorporate both unobserved or latent and observed variables. Other multivariate techniques are based on observed measurements only.

4) SEM is capable of modeling multivariate relations, and estimating direct and indirect effects of variables under study.

As mentioned above, SEM has ability to evaluate, approximate, stipulate and portray models to demonstrate hypothesis interrelationships between variables through non rational path diagram. It has ability to deal with non- recursive models and has effective ability to solve the real-life complex problems, which a multiple linear regression cannot model because of certain problems and violations. SEM has played significant role of applications in wide areas such as strategy planning, supply chain, process control, industrial safety and ergonomics, industrial performance, decision making and environmental impacts of manufacturing organizations. A number of applications have proven the practical benefit of the techniques [33-36].

3. Research methodology

3.1 Methodology

The research has been conducted in situation of Thai electronic industries. Fig. 1 shows the methodology adopted for the study. Firstly, the investigation is focus on reviewing literature on international journals and database to identify barriers of RL implementation and its performance. Then the questionnaire has been developed and sent to target electronic manufacturing. The SEM is using in the phase three to evaluate statistically significant Barriers of empirical data. Lastly in the phase four, a group of specific barriers affecting RL performance of Thai electronic industry is selected.

The questionnaire is then utilized to seek information on the situation of RL of an electronic company in Thailand. A rationally extensive samples of companies were investigated and 67 valid responses were obtained. Finally, the data collected from the manufacturing has been compiled and analyzed through SEM technique using AMOS computer software for obtaining concrete validations. The demographic of responses which are manufacturing firms have been shown in Table 3.

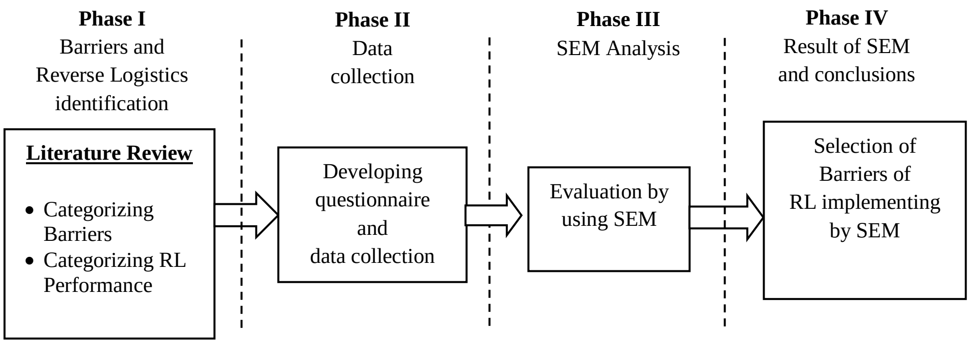

Figure. 1 Research methodology

Table 3. Demographic of respondents

Sample Characteristic		Percent (%)
Respondent's working experience	Lower than 5 years	13.43%
	Between 5 to 10 years	11.94%
	More than 10 years	74.63%
Company operating year	Lower than 5 years	2.99%
	Between 5 to 10 years	7.46%
	More than 10 years	89.55%
Number of employees	Lower than 50 persons	14.93%
	Between 50 to 150 persons	2.99%
	More than 150 persons	82.08%
Ownership	Thai	28.13%
	Foreign-owned	9.38%
	Joint venture	62.50%

For the characteristic of respondents in Table 3, the majority of companies have been operating more than 10 years (89.55% of all respondents). The survey was dominated by foreign-owned and joint-venture companies (71.88%). The responding companies varied in size, but a majority of the respondents employs more than 150 persons (82.08%). It is noted that most of respondents are large and medium size companies which are mostly foreign involved ownership.

3.2 Structure equation modeling to validate RL barriers

As per literature review and analysis of multiple regression analysis, eight independent constructs and one dependent construct namely, RL Performance (RLP) have been deployed to construct the SEM model. Fig. 2 depicts a systematic nomenclature of SEM Model deployed in present study indicating various predictors and outcome variable. It illustrates the conceptual model constructed in this research work to examine the relationships between eight barriers; Management Barrier (MB), Organization barrier (OB), Product Barrier (PB), Technological Barrier (TB), Infrastructural Barrier (IB), Financial Barrier (FB), Involvement and Support Barrier (ISB) and Legal Barrier (LB) by conducting an empirical analysis of manufacturing enterprises.

Thus, the following nine hypotheses (H1, H2, H3,.., and H9) are also proposed to examine the level of association between various barriers factors and RL performance in electronic companies. Hypothesis testings are consisted of two groups which are direct and indirect relation to RL performance.

The direct relation is :

H_a1: Reverse logistics barriers are directly negatively associated with the RL performance

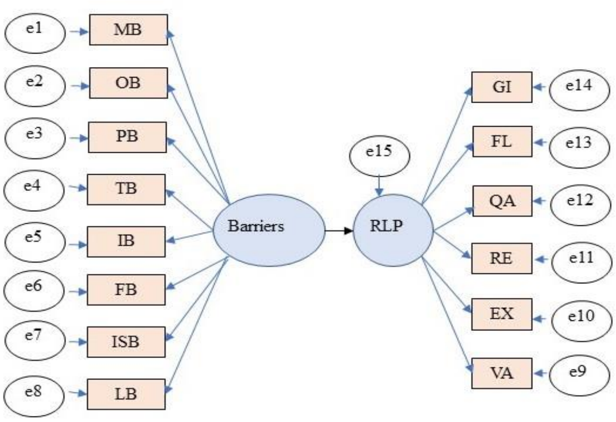

Figure. 2 SEM model for reverse logistics barriers

The indirect relations are :

H_a2: Management Barrier is indirectly negatively associated with the RL performance.

H_a3: Organization Barrier is indirectly negatively associated with the RL performance

H_a4: Product Barrier is indirectly negatively associated with the RL performance

H_a5: Technological Barrier is indirectly negatively associated with the RL performance.

H_a6: Infrastructural Barrier is indirectly negatively associated with the RL performance.

H_a7: Financial Barrier is indirectly negatively associated with the RL performance.

H_a8: Involvement and Support Barrier is indirectly negatively associated with the RL performance.

H_a9: Legal Barrier is indirectly negatively associated with the RL performance.

4. Analysis and results

4.1 Reliability of collected data

The data obtained from various manufacturing organizations through a questionnaire was tested to certain necessary techniques for testing like 'Cronbach's α' to evaluate data reliability before SEM has been employed. Based on the higher value suggest the higher internal consistent, all values are recommended more than 0.70 to indicate enough reliability [37]. The Cronbach's α'of Barrier factors and RL performance are presented in Table 4 and 5, respectively. It should be noted that all data obtained in this study have adequate reliability.

Table 4. Reliability test of barriers data

Barrier Factors	Cronbach's alpha (α)
MB	0.937
OB	0.877
PB	0.901
LB	0.862
TB	0.957
IB	0.891
FB	0.931
ISB	0.859

Table 5. Reliability test of RL performance data

RL Performance	Cronbach's alpha (α)
GI	0.861
FL	0.932
QA	0.757
RE	0.895
EX	0.750
VA	0.929

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4.2 Analysis of SEM model

A complete SEM Model exhibited in Fig. 3 has been developed by utilizing the AMOS software for evaluating the relationships amongst various attributes involved in the research. The study presents the linkage of independent constructs with regression coefficients in an unstandardized SEM model. The path analysis diagram for the constructs and refined variables with regression coefficients in the model as depicted in Fig. 3, demonstrates relation between Barriers and RL performance in the empirical study of Thai electronic industry.

For model testing, the fit indices are calculated as displayed in Table 6. It shows that values of CMIN/DF (3.361) > 2, Goodness of Fit Index (GFI = .641) < 0.95, Root Mean Square Error Approximation (RMSEA =.189) > 0.05 and P-value < 0.05.

These indices point out that the first trial of SEM model is not consistency. An improvement can be made by applying the modification index (MI) values for covariance and regression weight for some factors including reduction of a few of barrier factors to increase correlation of observed data that make model acceptable.

4.3 Modification of SEM model and results

Fig. 4 depicts the modification of the original SEM model. MI describes changes in structure of the model and demonstrates improvements in fit, presented by incorporating specific additional relationships in SEM model.

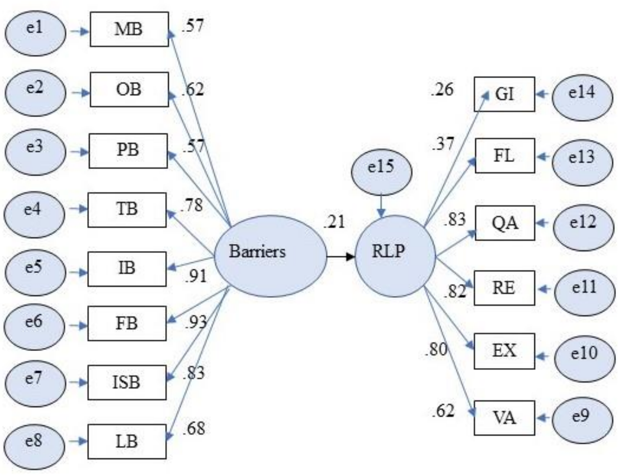

Figure. 3 Path diagram for relation between barrier and RL performance

Table 6. Fit indices of SEM model

Model	CMIN	DF	P
Default	255.434	76	.000
Model	CMIN/DF	GFI	RMSEA
	3.361	.641	.189

The selection of MI should be made based on threshold values to reduce the display of MI to a smaller set. The fit indices of modified SEM model and its values have been presented in Table 7.

The CMIN/DF (1.306) < 2, Goodness of Fit Index (GFI = .898) < 0.95 and Root Mean Square Error Approximation (RMSEA =.068) > 0.05 are in the range of acceptable criteria. Therefore, these all fit indices associated with P-value > 0.05 indicate the modified model is sound and applicable for this work. The analysis of hypothesis testing of the modified SEM model can be reliably obtained. The results from AMOS demonstrated in Table 8 show that relations of barriers to RL performance are statistically significant at alpha 0.10 both in direct and indirect relations.

4.4 Selection of barriers to RL performance

Using SEM technique to identify significant barriers to RL performance of Thai electronic Industry, the selections are listed in Table 9 comprising of 29 barriers in similar eight groups.

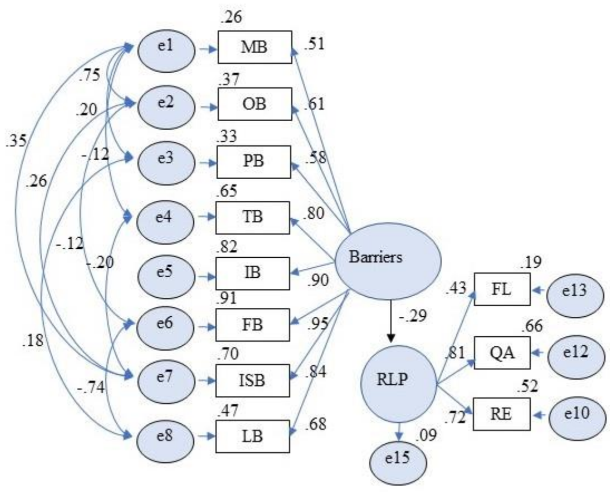

Figure. 4 Modified of SEM model

Table 7. Fit indices of the modified SEM model

Model	CMIN	DF	P
Modified	44.418	34	.109
Model	CMIN/DF	GFI	RMSEA
	1.306	.898	.068

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Table 8. Results of hypothesis testing

Null Hypothesis	*R^2*	*Estimate*	*P-value*	*Accept/Reject*
$H_0$1 Reverse logistics barriers are not directly negatively associated with RL performance.	0.086	-0.293	0.057*	Rejected
$H_0$2 Management barrier is not indirectly negatively associated with RL performance.	0.264	0.514	***	Rejected
$H_0$3 Organization barrier is not indirectly negatively associated with RL performance.	0.369	0.608	***	Rejected
$H_0$4 Product barrier is not indirectly negatively associated with RL performance.	0.334	0.578	***	Rejected
$H_0$5 Legal barrier is not indirectly negatively associated with RL performance.	0.469	0.685	***	Rejected
$H_0$6 Technological barrier is not indirectly negatively associated with RL performance.	0.647	0.805	***	Rejected
$H_0$7 Infrastructural barrier is not indirectly negatively associated with RL performance.	0.816	0.903	***	Rejected
$H_0$8 Financial barrier is not indirectly negatively associated with RL performance.	0.909	0.954	***	Rejected
$H_0$9 Involvement and support barrier is not indirectly negatively associated with RL performance.	0.698	0.836	***	Rejected

* P-value ≤ 0.10, *** The P-value ≤ 0.001

Table 9. Selection of RL barriers

Groups	**Barriers**
Management Barriers	1. Lack of commitment by top management
	2. Lack of strategic planning for ensuring RL practices
	3. Lack of awareness and understanding in RL adaptation
	4. Lack of specific goals for environment and waste management
	5. Lack of policies for RL practices
Organization Barriers	6. Lack of proper organizational structure & support for RL practices
	7. Lack of training & education about RL
	8. Lack of organization personnel resources
Product Barriers	9. Uncertain quality and quantity of return products from point of consumption
	10. Less economic value recovered
	11. Risk of storage of hazardous materials
Legal barriers	12. Lack of enforced laws, legislation and directives for EoL products
	13. Lack of government supportive policies on RL practices
	14. Loopholes in Thai laws and regulations on waste management
Technological barriers	15. Lack of information and technological systems for RL practices
	16. Lack of available technological infrastructure to adopt RL practices
	17. Lack of technical expertise to support RL practices
	18. Lack of flexibility to change from traditional system to new system
Infrastructural barriers	19. Lack of infrastructure facility to support RL implementation
	20. Lack of efficient and effective systems to monitor returns and recalls
	21. Increase of unstandardized waste management area
Financial barriers	22. Financial constraints
	23. High investments and less return-on-investments
	24. Expenditure in collection and storage of used products
	25. Cost of environmentally friendly packaging
	26. Cost of nonhazardous and hazardous waste disposal
Involvement and support barriers	27. Lack of coordination and collaboration with 3rd party logistics providers
	28. Lack of support of supply chain partners
	29. Lack of public focus on environmental issues

5. Conclusion

In the study, the aim is to identify essential barriers to implementing reverse logistics in Thai electronic industry. Firstly, based on the research works on the international journal and academic database, barriers for RL have been comprehensively investigated. Then the empirical study is applied in the electronic companies in Thailand with using Structure Equation Modeling Technique as a sophisticate tool to validate statistically significant of the Barriers. The SEM model has been fabricated using AMOS software to validate 37 barrier factors in the eight groups. For the first trial model, it was shown that the model cannot be fit with the empirical data. The modification is needed to adjusting the values of Modification Index for covariance and regression weight including cut off some of barriers.

After adjustment until the proposed model is fit, the analysis result presents the significant barriers of Thai electronic industry to implementing RL in this empirical work. They comprise 29 barriers within the same eight groups, which are Management Barrier (MB), Organization barrier (OB), Product Barrier (PB), Technological Barrier (TB), Infrastructural Barrier (IB), Financial Barrier (FB), Involvement and Support Barrier (ISB) and Legal Barrier (LB). The detail and explanation of barriers are described in the Section 4, Analysis and Results. However, manufacturings have to understand the situation of RL practices and barriers of their own and the findings of this research as mentioned above can be a guideline for creating suitable policies and strategies for improving efficiency of RL performance.

For further study, a set of practices to solve these significant barriers are needed to be precisely investigated. The effect of solutions to barriers studied specifically in the field work of Thai electronic industry would be the benefices of manufacturing firms to promote their Green supply chain.

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