APLICATION OF INTERPRETIVE STRUCTURAL MODELING FOR CRITERIA SELECTION

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ABSTRACT

Criteria selection is a process used to determine appropriate candidates from among different criteria. This study uses Interpretive Structural Modeling (ISM) to evaluate and select suitable criteria for supplier selection process through analyzing the relationships among them. A case study in a Vietnamese company is used to illustrate the method. In which, a set of 23 criteria is suggested and analyzed. The result shows that among 23 criteria, the criterion called "after-sales service" is belongs to the Autonomous, so it is eliminated. Others are ranked in three areas called Dependent, Linked and Independent. This result will be used as an input for supplier selection process in the company.

Keywords: Interpretive Structural Modeling model, Criteria evaluation, Criteria selection, Supplier selection, Supply chain management

1. INTRODUCTION

Today, in the context of commercial production globalization, enterprises are actively promoting production and business as well as efforts to compete in the domestic and international markets. Business owners need to ensure that their business is operating as effectively as possible, by manage all capabilities across the entire supply chain. One of the first important tasks for supply chain management effectively is supplier selection process. Choosing the appropriate supplier will help enterprises reduce costs and improve competitiveness, meet the customer needs (Bevilacqua et al., 2006).

However, there are different criteria used for supplier selection and they can be independent or interactive. Selecting the appropriate criteria is also an interesting task. Many researchers suggest using Interpretive Structural Modeling (ISM) model to support this task through analyzing the relationship between criteria. Minhaj and Rakesh (2011) implemented a study to evaluate green suppliers. In this study, the ISM methodology was used to determine the relationship of the 13 criteria based on expert opinion. Then, based on the final matrix, Impact Matrix Cross-Reference Multiplication Applied to Classification (MICMAC analysis) was used to classify criteria into 4 Clusters, they are Autonomous, Dependent, Linked, and Driver. The result confirms that the levels of drivers are important in the Green supply chain management implementation process. The ISM model proposed in this paper can provide the decision maker a more realistic representation of the problem. Based on research by Minhaj and Rakesh (2011), Rachit (2014) proposed a method combine between ISM and TOPSIS methodology in order to select the best supplier. In this study, the ISM was used to examine the relationships among the criteria and use the MICMAC analysis method to find the criteria for the four clusters. The study also confirmed that the criteria having high driving power and low dependence power play the most important role in supplier selection in comparison to other criteria. According to Mandal and Deshmukh (1994), Dependent variables are very important for vendor selection whereas

independent variables are important for vendor development. On the other hand, the criteria in Autonomous cluster have both low "Driver Power" and "Dependent Power" may not influence the supplier selection. Linked Criteria with higher power and dependence power should be treated with utmost care since the action on such variable may affect other since they are unstable in nature (Firoz and Rajesh, 2014).

Due to the usefulness of ISM, this research aims at applying this method for criteria evaluation used in supplier selection process. The paper is divided into four sections. The first section introduces the background of the problem of the study. The methodology of ISM is then presented. A case study is given to illustrate the method in the third section. The last section includes the concluding remarks, suggestions, and limitations of the study.

2. Interpretive Structural Modeling (ISM)

The Interpretive Structural Modeling method (ISM) was developed as an effective way to comprehend complex problems and find solutions to problems (Warfield, 1973). ISM creates process to consider and solve problems, as well as perform pair comparisons of elements to transform a complex problem into a more understandable structural model.

In fact, each specific problem is always influenced by elements; these factors can be independent or interactive. ISM can be used for identifying and analyzing the relationships among specific variables, which define a problem or an issue. The ISM process consists of seven steps.

- Step 1: Identify and define elements

- Step 2: Define Contextual Relationship between criteria and develop a structural self-interaction matrix (SSIM).

A questionnaire was used to obtain expert opinion on the relationships between each criterion and the other criteria.

Four symbols have been used to denote the direction of relationship between two barriers *i* and *j* as follow:

V Barrier *i* will lead to barrier *j*, not in reverse direction

A Barrier *j* will lead to barrier *i*, not in reverse direction

X Barrier *i* and *j* will lead to each other, in both directions

O Barrier *i* and *j* are unrelated

- Step 3: Develop Initial Reachability Matrix base on SSIM

The SSIM has been converted in to a binary matrix, named Reachability Matrix by substituting V, A, X, O by 1 or 0 applying the following rules:

+ If (*i, j*) value in the SSIM is V, (*i, j*) value in the reachability matrix will be 1 and (*j, i*) value will be 0.

+ If (*i, j*) value in the SSIM is A, (*i, j*) value in the reachability matrix will be 0 and (*j, i*) value will be 1.

+ If (*i, j*) value in the SSIM is X, (*i, j*) value in the reachability matrix will be 1 and (*j, i*) value will also be 1.

+ If (*i, j*) value in the SSIM is O, (*i, j*) value in the reachability matrix will be 0 and (*j, i*) value will also be 0.

- Step 4: Develop Final Reachability Matrix

At this step, the Transitivity Checks will be performed to develop the final reachability matrix by inspect the relationships of the criteria. It states that: If criteria *i* is related to criteria *j* and criteria *j* related to criteria *k*, then criteria *i* will also be related to criteria *k*. Then, the value in cell (*i, k*) will be changed from 0 to 1.

- Step 5: Level Partition on Reachability Matrix

From final reachability matrix, reachability and antecedent sets are determined, which have a set of row relationships and the intersection of rows and columns will be selected as the highest order in the hierarchy. Once the level of a criterion has been determined, the criterion is removed and the decentralization process continues with the remaining criteria. The grades of the criteria will help to build the final ISM model. The top-level criteria for each hierarchy are the criteria, in which antecedent set and intersection set are same in the ISM hierarchy. Once the top level barrier is identified, it is removed from consideration and other top level barriers are found.

- Step 6: Formation of ISM based model.

In this step, a digraph will be constructed from the previous result.

- Step 7: Cluster Formation

Based on MICMAC analysis method, the elements will be divided into 4 clusters:

+ Autonomous Factor: Consist of criteria which have weak Driving Power (DP) and weak Dependent Power (DrP).

+ Dependent Factor: Consist of criteria which have strong DP and weak DrP.

+ Linked Factor: Consist of criteria which have strong DP and strong DrP.

+ Independent Factor/ Driver Factor: Consist of criteria which have weak DP and strong DrP.

After using the ISM method, the criteria will be classified into 4 clusters. Criteria in autonomous cluster will be removed; criteria of the other three groups will be used to select the suppliers.

3. CASE STUDY

In this study, Thanh Phu Plastic Packaging Company in Vietnam is choosen to collect nescessary data. Thanh Phu Plastic Packaging Company is one of the leading plastic packaging manufacturers in Vietnam. It has more than 500 employees, a system of modern machinery and equipment, closed production process. Its main products include: food packaging, seafood packaging, washing powder packaging, diaper packaging, sanitary pads, dry paper packaging, etc. With high quality products, diverse designs, its products meet the most demanding requirements in the domestic market and export markets.

Firstly, Based on previous studies, a set of 23 criteria is suggested for analysis and selection (Table 1).

Table 1. Criteria set for supplier selection

No.	Criterion	Evaluation manner
Cheraghi et al. (2004); Chang et al. (2011); Nielsen (2014)		
1	Price	Raw materials, transport costs, etc., of supplier compared to competitors?
2	Delivery	Efficiency in delivery: On time delivery, ensure production schedule, requirements in a short time.
3	Quality	The supplier's materials are clearly originated; get the company's standards, less defective products.
4	Ability/Capacity	Supplier meets a number of products as customer requirement.
5	After-sales service	Include after-sales activities such as manual, repair, ...
6	Facilities	Facility layout also have the ability to use, and equipped with the necessary equipment to meet

		customer's requirements.
7	Attitude	The positive attitude of the staff brings the comfort.
8	Discount policy	Number of discount and discount rate compared to the others.
9	Origin of products	Information about materials must be clear, complete.
10	Communication system	Suppliers provide a variety of facilities for communication.
11	Long-term relationship	Recognize the possibility of long-term cooperation in the future.
12	Environment management system	Suppliers equipped environmental treatment systems, solve pollution problems effectively.
13	Green Image	Working environment qualify "Green-Clean-Nice"
14	Operating Controls	Supplier has a clear operational plan, professional management.
Fazil and Kesavan (2014), Govindan et al. (2015)		
15	Packaging ability	Goods are packaged to ensure safety, and protected from the impact of the environment.
16	Financial position	Evaluate financial problem, Stable Financial Sources is the best choice.
Kumar et al. (2006); Chen et al. (2006); Rachit (2014)		
17	Techical capability	Staff abilities are professional or not?
18	Technology level	Supplier is able to apply new methods and processes into business.
19	Flexibility	Quick change schedules when there are unintended problems.
20	Geographical location	The location of the supplier is convenient for delivery. The route and the distance from the supplier to customer have the lowest risk in transportation process.
21	Customer service	The level of customer's satisfaction.
22	Reliability	Supplier has to abide by legal and morality, create a nice working environment, commit to the quality of products and services, etc.
23	Reputation	Evaluations from previously collaborated customers.

A questionaire will be sent to three experts, who have experience in supplier selection process in the company. After evaluating, data will be aggregated as in Table 2.

Table 2. Structural Self-Interaction Matrix

Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	X	A	A	O	O	O	O	A	A	O	V	O	O	A	A	A	O	X	A	A	O	O	A
2		X	V	O	O	O	O	O	O	O	O	O	O	O	X	O	O	O	X	X	V	V	O
3			X	V	O	O	O	O	A	O	V	A	O	X	A	O	A	A	A	A	O	V	V
4				X	O	A	O	O	O	O	V	O	O	A	A	A	A	A	A	A	V	V	V
5					X	O	O	O	O	A	V	O	O	O	O	A	O	O	O	O	V	V	V

6						X	O	O	O	O	V	V	V	V	V	V	O	X	O	O	O	X	X
7							X	O	O	O	V	O	O	O	O	O	O	O	O	O	O	X	X	X
8								X	X	O	X	O	O	O	O	O	O	O	O	O	O	X	O	V
9									X	X	V	O	O	O	O	O	O	O	O	O	O	V	V	V
10										X	O	O	O	O	O	A	O	A	O	O	X	O	V
11											X	O	O	A	A	A	A	A	A	A	A	A	A
12												X	X	X	O	A	A	A	A	A	O	O	V
13													X	X	O	A	A	A	A	A	O	O	V
14														X	X	O	X	A	X	O	V	V	V
15															X	O	X	A	X	O	V	V	V
16																X	X	X	A	X	O	V	V
17																	X	O	V	O	V	V	V
18																		X	O	O	V	V	V
19																			X	O	X	V	V
20																				X	V	V	O
21																					X	V	V
22																						X	X
23																							X

Table 3 presents the initial reachability matrix of the criteria.

Table 3. Initial Reachability Matrix

Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1	0
3	1	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	1
4	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1
5	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1
6	0	0	0	1	0	1	0	0	0	0	1	1	1	1	1	1	0	1	0	0	0	1	1
7	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1
8	1	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
9	1	0	1	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1
10	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1
11	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1
13	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1
14	1	0	1	1	0	0	0	0	0	0	1	1	1	1	1	0	1	0	1	0	1	1	1
15	1	1	1	1	0	0	0	0	0	0	1	0	0	1	1	0	1	0	1	0	1	1	1
16	1	0	0	1	1	0	0	0	0	1	1	1	1	0	0	1	1	1	0	1	0	1	1
17	0	0	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	0	1	0	1	1	1
18	1	0	1	1	0	1	0	0	0	1	1	1	1	1	1	1	0	1	0	0	1	1	1
19	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	1	0	1	1	1
20	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0	1	1	1	0
21	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	1	0	1	1	1
22	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
23	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1

Next step, the Final Reachability Matrix is developed (Table 4).

For example: Price criterion (1) influences delivery criterion (2). On the other hand, criterion (2) related to quality (3), packing ability (15), flexibility (19), geographical location (20),

customer service (21) and Reliability (22), so it can be inferred that criterion (1) will relate to criterion (3), (15), (19), (20), (21) and (22). Then, the values in cells (1, 3), (1, 15), (1, 19), (1, 20), (1, 21) and (1, 22) will change from 0 to 1.

Table 4. Final Reachability Matrix

Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Dr
1	1	0	1*	1*	0	1*	0	1*	0	1*	1	1*	1*	1*	1*	1*	0	1	0	0	1*	1*	1*	16
2	1	1	1	1*	0	1*	1*	1*	0	1*	1*	1*	1*	1*	1	1*	1*	1*	1	1	1	1	1*	21
3	1	0	1	1	0	1*	1*	1*	0	0	1	1*	1*	1	1*	0	1*	1*	1*	0	1*	1	1	17
4	1*	0	0	1	0	1*	1*	1*	0	1*	1	0	0	0	0	0	0	0	1*	0	1	1	1	11
5	1*	0	0	0	1	1*	1*	1*	0	1*	1	0	0	0	0	0	0	0	1*	0	1	1	1	11
6	1*	1*	1*	1	1*	1	1*	1*	0	1*	1	1	1	1	1	1	1*	1	1*	1*	1*	1	1	22
7	1*	0	0	0	0	1*	1	1*	0	1*	1	0	0	0	0	0	0	0	1*	0	1	1	1	10
8	1	0	1*	1*	0	1*	1*	1	1	1*	1	0	0	0	0	0	0	1*	1*	0	1	1*	1	14
9	1	0	1	1	1*	1*	1*	1	1	1	1	0	0	1*	0	0	0	1*	1*	0	1	1	1	16
10	1*	0	1*	1*	1	1*	1*	1*	1	1	1*	0	0	0	0	0	0	0	1*	0	1	1*	1	14
11	1*	0	0	0	0	0	0	1	1*	0	1	0	0	0	0	0	0	0	0	0	1*	0	1*	6
12	1*	0	1	1*	0	1*	1*	0	0	0	1*	1	1	1	1*	0	1*	0	1*	0	1*	1*	1	15
13	1*	0	1*	1*	0	1*	1*	0	0	0	1*	1	1	1	1*	0	1*	0	1*	0	1*	1*	1	15
14	1	1*	1	1	0	1*	1*	1*	0	1*	1	1	1	1	1	1*	1	1*	1	0	1	1	1	20
15	1	1	1	1	0	1*	1*	1*	0	1*	1	1*	1*	1	1	1*	1	1*	1	1*	1	1	1	21
16	1	1*	1*	1	1	1*	1*	1*	1*	1	1	1	1	1*	1*	1	1	1	1*	1	1*	1	1	23
17	1*	1*	1	1	1*	1*	1*	1*	0	1*	1	1	1	1	1	1	1	1*	1	1*	1	1	1	22
18	1	1*	1	1	1*	1	1*	1*	1*	1	1	1	1	1	1	1	1*	1	1*	1*	1	1	1	23
19	1	1	1	1	1*	1*	1*	1*	0	1*	1	1	1	1	1	1	1*	1*	1	1*	1	1	1	22
20	1	1	1	1	1*	1*	1*	1*	0	1*	1	1	1	1*	1*	1	1*	1*	1*	1	1	1	1*	22
21	1*	1*	1*	1*	1*	1*	1	1	1*	1	1	1*	1*	1*	1*	1*	0	0	1	0	1	1	1	20
22	1*	0	0	1*	0	1	1	1*	0	0	1	1*	1*	1*	1*	1*	0	1*	0	0	1*	1	1	15
23	1	0	0	1*	0	1	1	1*	0	0	1	1*	1*	1*	1*	1*	0	1*	0	0	1*	1	1	15
Dep.	23	10	17	20	10	22	21	21	7	17	23	16	16	17	16	13	12	15	19	8	23	22	23	
"*" sign express the conversion from value 0 in initial reachability matrix to value 1 in final reachability matrix																								

From the final reachability matrix, the reachability set and antecedent set for each criterion are defined. After that, the intersection of these sets will be listed. If elements of reachability set and intersection set of one criterion are similar, then that criterion is in level I. Once the level I is determined, it is removed and next same process is conducted to discover the next level elements. The result is shown in Table 5.

Table 5. Level partitions process of the criteria.

Criterion	Reachability	Antecedent	Intersection	Level
1	1, 3, 4, 6, 8, 10, 11, 12, 13, 14, 15, 16, 18, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 3, 4, 6, 8, 10, 11, 12, 13, 14, 15, 16, 18, 21, 22, 23	I
8	1, 3, 4, 6, 7, 8, 9, 10, 11, 18, 19, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 18, 19, 20, 21,	1, 3, 4, 6, 7, 8, 9, 10, 11, 18, 19, 21, 22, 23	I

Criterion	Reachability	Antecedent	Intersection	Level
		22, 23		
11	1, 8, 9, 11, 21, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 8, 9, 11, 21, 23	I
21	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 19, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 19, 21, 22, 23	I
23	1, 4, 6, 7, 8, 11, 12, 13, 14, 15, 16, 18, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 4, 6, 7, 8, 11, 12, 13, 14, 15, 16, 18, 21, 22, 23	1
6	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	II
7	1, 6, 7, 8, 10, 11, 19, 21, 22, 23	2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	6, 7, 8, 10, 19, 21, 22, 23	II
22	1, 4, 6, 7, 8, 11, 12, 13, 14, 15, 16, 18, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 4, 6, 7, 8, 12, 13, 14, 15, 16, 18, 21, 22, 23	II
4	1, 4, 6, 7, 8, 10, 11, 19, 21, 22, 23	1, 2, 3, 4, 6, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 4, 6, 8, 10, 19, 21, 22, 23	III
5	1, 5, 6, 7, 8, 10, 11, 19, 21, 22, 23	5, 6, 9, 10, 16, 17, 18, 19, 20, 21	5, 6, 10, 19, 21	III
19	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21	2, 3, 4, 5, 6, 7, 8, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21	III
3	1, 3, 4, 6, 7, 8, 11, 12, 13, 14, 15, 17, 18, 19, 21, 22, 23	1, 2, 3, 6, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21	1, 3, 6, 8, 12, 13, 14, 15, 17, 18, 19, 21	IV
12	1, 3, 4, 6, 7, 11, 12, 13, 14, 15, 17, 19, 21, 22, 23	1, 2, 3, 6, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 3, 6, 12, 13, 14, 15, 17, 19, 21, 22, 23	IV
13	1, 3, 4, 6, 7, 11, 12, 13, 14, 15, 17, 19, 21, 22, 23	1, 2, 3, 6, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 3, 6, 12, 13, 14, 15, 17, 19, 21, 22, 23	IV
10	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 19, 21, 22, 23	1, 2, 4, 5, 6, 7, 8, 9, 10, 14, 15, 16, 17, 18, 19, 20, 21	1, 4, 5, 6, 7, 8, 9, 10, 19, 21	V
2	1, 2, 3, 4, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	2, 6, 14, 15, 16, 17, 18, 19, 20, 21	2, 6, 14, 15, 16, 17, 18, 19, 20, 21	VI
14	1, 2, 3, 4, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23	1, 2, 3, 6, 9, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 2, 3, 6, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23	VI
15	1, 2, 3, 4, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 2, 3, 6, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 2, 3, 6, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	VI
17	2, 3, 4, 5, 6, 7, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22	2, 3, 6, 12, 13, 14, 15, 16, 17, 18, 19, 20	2, 3, 6, 12, 13, 14, 15, 16, 17, 18, 19, 20	VI
18	2, 3, 4, 5, 6, 7, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22	2, 3, 6, 9, 14, 15, 16, 17, 18, 19, 20, 22	2, 3, 6, 9, 14, 15, 16, 17, 18, 19, 20, 22	VI
9	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 18, 19, 21, 22, 23	8, 9, 10, 11, 16, 18, 21	8, 9, 10, 11, 18, 21	VII
20	1, 2, 3, 4, 5, 6, 7, 8, 10, 11,	2, 6, 15, 16, 17, 18, 19, 20	2, 6, 15, 16, 17, 18, 19, 20	VII

Criterion	Reachability	Antecedent	Intersection	Level
	12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23			
16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 2, 6, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	1, 2, 6, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	VIII

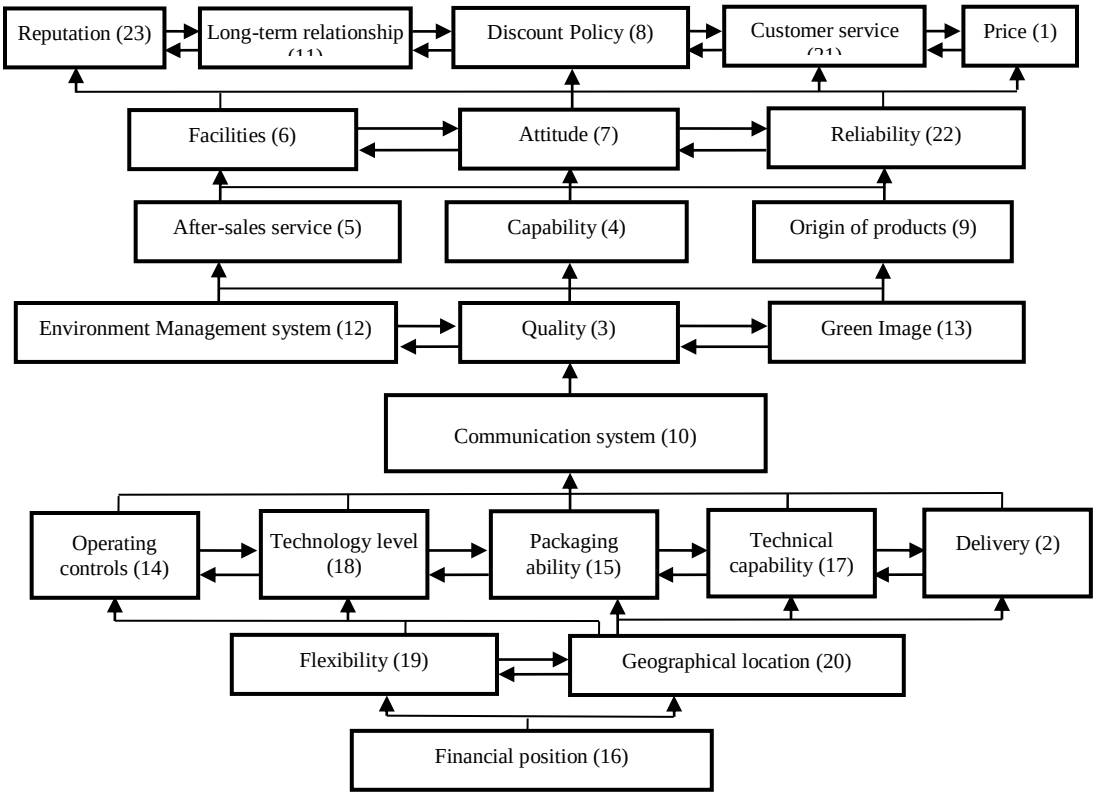

Figure 1. ISM Based model

Bases on Figure 1, "Financial position" is at the bottom level of ISM based model. The criteria on the top of hierarchy (Price, customer service, discount policy, long-term relationship and reputation) are criteria with higher Dependent power, these criteria need to be concerned in supplier selection process. ISM based model shows a fairly comprehensive relationships between criteria, thereby supporting supplier evaluation at the next stage.

To allocate criteria into clusters, rows and columns values on the final reachability matrix are defined. In which, total rows values are Driving power and columns values are Dependent power. Based on these values, criteria are located on the graph with the vertical axis represents Driving power and horizontal axis represents Dependent power.

Finally, the result of classsification criteria is obtained as in Table 6.

Table 6. Cluster formation of criteria

No.	Cluster	Criterion
1	Autonomous	After-sales service (5)
2	Dependent	Attitude (7)
		Long-term relationship (11)

		Ability/Capability (4)
3	Linked	Price(1)
		Quality (3)
		Facilities(6)
		Discount policy(8)
		Communication system(10)
		Environment management system (12)
		Green Image (13)
		Operating Controls(14)
		Packaging ability (15)
		Financial position (16)
		Technical capability (17)
		Technology level (18)
		Flexibility (19)
		Customer service (21)
		Reliability (22)
		Reputation (23)
4	Independent	Delivery (2)
		Origin of products (9)
		Geographical location (20)

Arcording to previous studies, Autonomous criteria have weak driving power and weak dependent power, so these criteria have less influence and less dependence on the others (Arvind & Mohd, 2014; Rahul et al., 2018). In other words, these criteria are called "Disconnected variables" or "secondary level". Indeed, After-sales service plays very important role in the business (especially for machinery and electronics), while this criterion is not concerned in raw material supplier selection process (typically for the company applying this model). When using materials, manufacturers often understand the materials clearly, after-sales service manuals are no longer need. In addition, for the company that uses raw materials in production, the term "mainternance" or "repair" does not exist, the factor they may consider is "qualified" or "not qualified". Therefore, after-sales service will be removed in this case. The remaining criteria will be used to evaluate and select suppliers in the company.

4. CONCLUSION

This study was conducted to apply ISM model for criteria selection used in supplier selection process. From the literature review, a set of 23 criteria is suggested. The relationships between these criteria are then analyzed. The result shows that among 23 criteria, criterion "after-sales service" was eliminated because it belonged to Autonomous cluster. Others are ranked into three areas including Dependent, Linked and Independent. From the results, it is clearly that almost criteria are divided into Linked cluster, which should be evaluated carefully since they may affect others. In addition, Dependent criteria can be seen as important criteria for the supplier selection process. ISM model could help decision maker evaluate alternatives at the next stage of the supplier selection process based on the fairly comprehensive relationship showed in the model. For further research, the methodology for supplier evaluation and selection should be developed.

5. REFERENCES

Arvind, J. & Mohd, A. (2014). Analysis of the barriers for implementing green supply chain management (GSCM) Pratices: An Interpretive Structural Modeling (ISM) Approach. *Procedia Engineering* 97, 2157-2166.

Bevilacqua, M., Ciarapica, F., & Giacchetta, G. (2006). A Fuzzy-QFD approach to supplier selection. *Journal of Purchasing & Supply Management* 12(1), 14-27.

Chang, B., Chang, C.-W., & Wu, C.-H. (2011). Fuzzy DEMATEL method for developing supplier selection criteria. *Expert Systems with Applications* 38(3), 1850-1858.

Chen, C., Lin, C., & Huang, S. (2006). A fuzzy approach for supplier evaluation and selection in supply chain management. *International Journal of Production Economics* 102(2), 289-301.

Cheraghi, S., Dadashzadeh, M., & Subramanian, M. (2004). Critical success factors for supplier selection: An update. *Journal of Applied Business Research* 20(2), 91-108.

Fazil, B., & Kesava, R. (2014). Selection in Supply Chain Management Using ISM and ANP. *IOSR Journal of Mechanical and Civil Engineering* 3, 81-89.

Firoz, N., & Rajesh, R. (2014). Relationships among Supplier Selection Criteria using Interpretive Structural Modeling for Manufacturing Organization in Kerala. *International Journal of Engineering Science Invention* 3(8), 60-70.

Govindan, K., Rajendran, S., Sarkis, J., & Murugesan, P. (2015). Multi criteria decision making approaches for green supplier evaluation and selection: A literature review. *Journal of Cleaner Production* 98, 66-83.

Kumar, M., Vrat, P., & Shankar, R. (2006). A fuzzy programming approach for vendor selection problem in a supply chain. *International Journal of Production Economics* 101(2), 273-285.

Mandal, A., & Deshmuk, S. (1994). Vendor Selection Using Interpretive Structural Modelling (ISM). *International Journal of Operations & Production Management* 14(6), 52-59.

Minhaj, A., & Rakesh, L. (2011). An Innovative Approach to Evaluate Green Supply Chain Management (GSCM) Drivers by Using Interpretive Structural Modeling (ISM). *International Journal of Innovation and Technology Management* 8(2), 315-336.

Nielsen, I., Banaeian, N., Golińska, P., Mobli, H., & M., O. (2014). Green Supplier Selection Criteria: From a Literature Review to a Flexible Framework for Determination of Suitable Criteria. *Logistics Operations, Supply Chain Management and Sustainability*, 79-99.

Rachit, K. V. (2014). Implementation of Interpretive Structural Model and Topsis in Manufacturing Industries for Supplier Selection. *Industrial Engineering Letters* 4(5), 1-8.

Rahul, V., D., Shankar, S., M., Santosh, B., R. & Vanita, B. (2018). Analysis of interactions among barriers in project risk management. *Journal of Industrial Engineering International* 14, 153-169.

Warfield, J. (1973). Binary Matrices in System Modeling. *Transactions on Systems* 3, 441-449.