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A Supplier Selection Model for Textile and Apparel Companies: An Analytic Network Process Approach

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Abstract - **The purpose of this study is to help textile and apparel (T&A) companies select their best suppliers by using a suitable Multicriteria Decision Making (MCDM) method. From then, a managerial and theoretical implications are made to adjust the set of criteria to make it more effective and the selection method for T&A companies. In order to do that, first, the literature on supplier selection criteria was reviewed to determine necessary criteria for T&A industry. Next, an appropriate methodology was proposed to build up a selection model. Then, the proposed approach was implemented in three particular companies in the industry. Finally, discussion on managerial and theoretical aspects of the MCDM and the set of supplier selection was made. The findings will be a good contribution to the selection process of T&A companies as they can utilize these criteria to select capable suppliers.**

Key words - *Sourcing activities, supplier selection criteria, supply chain management, textile and apparel.*

1. Introduction

Procurement is always a challenging task as the selection of right suppliers at the right price is a complex process involving a variety of criteria. These criteria differ depending on the purchasing circumstances [1] and numerous judgement factors [2]. Especially, textile and apparel (T&A) industry is characterized with unpredictable and uncertainty [3]. Therefore, proposing multiple criteria supplier selection model in which a set of supplier selection criteria with detailed weights is a critical interest of experts and practitioners [1]. Recently, there has been a related research on exploring supplier selection

criteria in 2019 [4]. This research provides a comprehensive set of selection criteria for T&A industry in general and Vietnamese T&A industry in particular, but not a supplier selection model or not applied their results into practice of selecting suppliers. In terms of supplier selection model, there have been some researches on proposing the selection models in T&A industry, but the same weakness of them is that no researches till date have solved the problem of interdependence among criteria and sub-criteria to select suppliers (Appendix 1). Therefore, an attempt to propose a supplier selection model which can solve the questioning problem has been made by the authors to help T&A companies easily choose the best suppliers.

2. Literature review

2.1 Supplier Selection Criteria

Supplier selection criteria have been studied for years resulting in different kinds of criteria ranging from micro and traditional factors such as costs, quality, delivery, trust … to macro ones as political and economic stability of sourcing countries, cultural differences, etc. [5]. Basing on that, in 2017, Guo et al. proposed a list of selection criteria to evaluate and select green suppliers in apparel manufacturing, but nothing new compared to other studies [6]. The list includes quality, cost, delivery, technology, service, environment competency. In 2018, Su & Wood conducted personal in-depth interviews with five apparel companies in the United States to explore key supplier selection criteria [7]. The results stated that all sourcing companies rely on certificates and standards to select suppliers so that they could purchase reliable materials and products. In addition, transparency and traceability in suppliers' textile and

apparel supply chain was also a key criterion when doing business with them. This is a one-sided result because firstly the interviews were conducted with only five apparel companies; secondly, sourcing activities depend on a comprehensive set of selection criteria [4]. Then, in 2019, Guarnieri & Trojan tried to balance social, environmental and economic criteria, along with related ethical issues, in the supplier selection process when outsourcing activities in the textile industry, in which the set of criteria comprised a list of environment impact/ costs/ management/, environmentally friendly packaging, diversity, projects for environment, managing the emission of dangerous gases, security, human rights, philanthropy, continuous improvement, certification, public disclosure, and reverse logistics [8]. The list focuses much on environment protection and social responsibilities rather than other criteria. However, in practice, there are a variety of criteria which need to be considered for purchasing companies to develop in the fiercely competitive market.

In summary, there are plenty of supplier selection criteria, but quite sporadical. Researchers only focus on one specific aspect of the industry or a particular case to propose selection criteria. A comprehensive and all-sided set of criteria for the T&A industry is currently lacking. Especially, no study has been made for Vietnamese T&A industry until 2019 by Nong and Ho [4]. Selection criteria for T&A industry, especially in Vietnam, were explored by Nong and Ho (2019) in a survey of 282 T&A companies in Vietnam. According to the results, there are 8 groups of criteria for T&A companies to select their supplier including Quality, Costs, Delivery, Service, Sourcing country, Relationship, Capability, and Company's Image. Their sub-criteria are presented in Figure 1
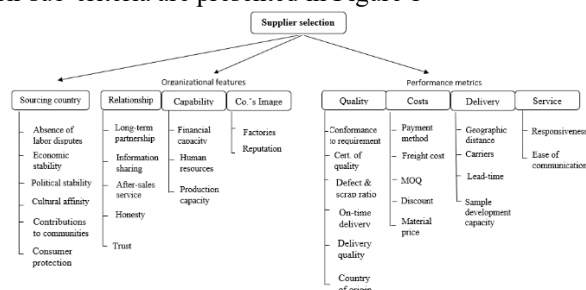

Figure 1. Supplier selection criteria in the hierarchy

Source: [4]

This set of criteria is critically useful for practitioners and researchers in the field.

2.2 Supplier Selection Method

To deal with supplier selection, many different methodologies have been proposed by authors. Gary Teng & Jaramillo proposed their own supplier evaluation method in which suppliers were ranked by their total scores [9]. The total supplier score would be the sum of delivery score, flexibility score, quality score and reliability score minus cost score. These five scores are from the five significant supplier performance clusters. In order to define scores of these clusters, purchasers are in need of construe the weights of clusters, the weights of factors which affect the cluster, the desired value, and a value which is calculated by dividing a purchaser given score by the factor's desired value. Unlike Gary Teng and Jaramillo, many authors applied MCDM method to select suppliers. Koprulu & Albayrakoglu in 2007; Shyjith, Ilangkumaran & Kumanan in 2008; Ünal and Güner in 2009; Chan & Chan in 2010; Vijayvagy in 2012; Wararkar, Patil & Wararkar in 2017 used the most popular method which is AHP to evaluate and choose the best suppliers [10] [11] [12] [13] [14] [15]. However, to overcome the uncertainty and linguistic assessment problem, a fuzzy-based approach is needed to translate the suppliers' linguistic attributes into fuzzy numbers. Therefore, Mızrak Özfirat, Tuna Taşoglu, &Tunçel Memiş in 2014 proposed fuzzy AHP method for the supplier selection problem of a textile enterprise [16]. However, in 2008 Shyjith, Ilangkumaran & Kumanan and in 2017 Mishra, Pundir & Ganapathy proposed TOPSIS to select the best alternative because it enables systematic and compatible criteria [11] [17]. Li, Wong & Kwong in 2013 with their aims of minimizing the total procurement costs and risks used a dynamic programming approach, contingent on supplier capacity and customer demand [18]. Also in 2013, Mokhtari et al. suggested to use a multi-criteria optimization and compromise solution - fuzzy VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) to rank and sort alternatives against numerous conflicting criteria [19]. In 2017, Fallahpour et al. proposed fuzzy TOPSIS to rank suppliers in an Iranian textile manufacturing company [20]. Until 2019, Guarnieri & Trojan re-used AHP because of its simplicity to define weights of criteria, but the authors integrated AHP with ELECTRE-TRI to classify suppliers [8]. Also in 2019 Charkha & Jaju proposed to apply Delphi method to build decision support framework, then use AHP to analyze the

importance of criteria, sub-criteria and alternatives [21]. This paper will be published in 2020.

In summary, to evaluate and select suppliers in the T&A industry, some commonly used methods encompass Delphi, AHP, fuzzy AHP, TOPSIS, fuzzy TOPSIS, VIKOR, ELECTRE not to mention ANP (Appendix 1) although there exist the interrelations among criteria and sub-criteria in T&A industry [4]. Thus, it is impossible for those currently used decision-making methods to solve that problem. This confirms the necessity to propose a supplier selection model in which a suitable multiple criteria decision making is used.

2.3 Supplier Selection

T&A companies have sought dependable suppliers to manage some of their current production operations either domestically or internationally [9]. The inherent features of the T&A industry and the increased pressure from erratic consumers and an uncertain business environment [22] as well as the uncertainties of international sourcing activities result in complexity and risk [18] in the supply chain's operation. Therefore, the process of supplier selection garners much focus from purchasers. This process is divided into three procedures: preselection, selection, and post-selection [23]. During preselection, it is necessary for enterprises to set the strategic goals for sourcing. Then, the selection stage begins with numerous prospective suppliers and ends with the most favourable supplier. A set of criteria is established to evaluate and select a satisfactory supplier during this process. After the selection process, the purchaser begins collaborating with the selected supplier. These three phases are overly complicated for decision makers to perform, particularly the selection stage, as suppliers affect a company's performance [24].

However, the selection of suppliers can be easily solved by applying the multi-criteria decision-making (MCDM) method, which considers the decision under multiple conflicting criteria. The MCDM method consists of four components: alternatives; criteria; weight of each criterion; and the measured performance of each alternative in terms of the criteria [25]. The selection framework is suggested as in Figure 2.
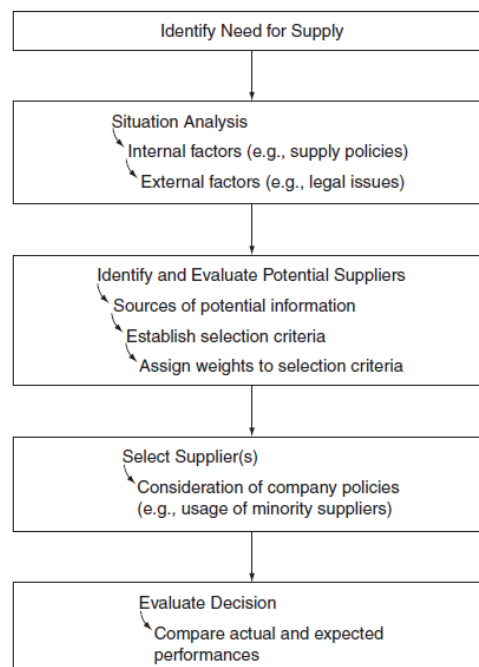

Figure 2. Supplier selection framework
Source: [26]

3. The Proposed Supplier Selection Model

3.1 The Proposed Model

As stated earlier, the overall goal of this research is to develop a supplier selection model. Therefore, the research model includes different steps (Figure 3)

- Firstly, define the selection problem (goal/ requirements)
- Secondly, collect candidate suppliers (alternatives)
- Thirdly, define supplier selection criteria
- Fourthly, perform ANP analysis into choosing suppliers,.

ANP was chosen because firstly T&A industry is characterized with uncertainty, this issue has been already solved by being added into the set of selection criteria; secondly, trade-offs among criteria are existed in decision making under T&A industry; thirdly, ANP is a multicriteria decision making technique which can solve the problem of interdependence among clusters of criteria under T&A industry.
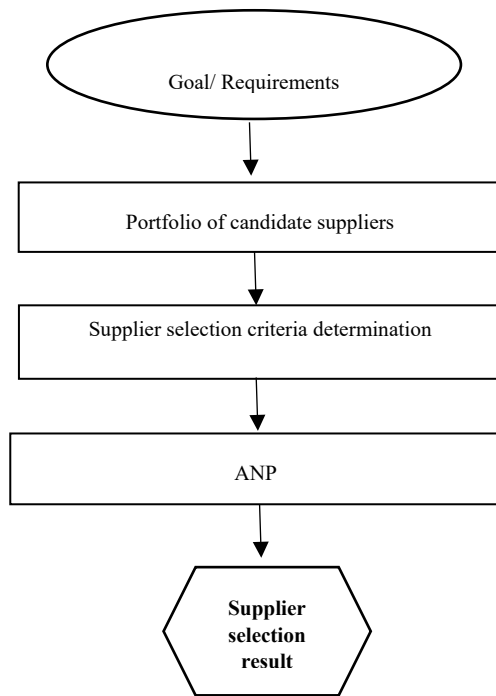
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Figure 3. Supplier selection model for the research

3.2 Analytic Network Process

This method, proposed by Saaty in 1996, is the extension of the AHP to extricate the limitation of the hierarchical structure, which specifies that the criteria are independent from each other.

The ANP is unstructured network dealing with sources, sinks, and cycles. It describes the outer and inner dependence. When the elements within a cluster have effects on its own, there exists the inner dependence. When a cluster with elements affects another cluster, the outer dependence happens. ANP may handle the interdependence among criteria by calculating the composite weight through supermatrix, from then the best alternatives would be selected by their priorities.

The ANP is illustrated through the following steps [27]:

Step 1: The first step of the ANP is to compare the criteria in the whole system to form supermatrix, which is done through pairwise comparisons by asking "How much importance does a criterion have compared to another criterion, with respect to our interests or preferences?"

The relative importance value can be determined using a scale from 1 to 9 for representing equal importance to extreme importance.

Table 1. The fundamental scale of the ANP

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak	
3	Moderate importance	Experience and judgment slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another, its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity i has one of the above nonzero number assigned to it when compared with activity j, then j has the reciprocal value when compared with i	

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Figure 4. General form of supermatrix

Where, C_m denotes the mth cluster, e_{mn} denotes the nth element in the mth cluster, and Wij is the main eigenvector of the influence of the elements compared in the jth cluster to the ith cluster. In addition, if the jth cluster has no influence on the ith cluster, then $Wij = 0$. Therefore, the form of the supermatrix depends heavily on the variety of the structure.

Step 2: The next step is to calculate the influence (i.e., calculate the principal eigenvector) of the elements (criteria) in each component (matrix).

Step 3: Form the supermatrix based on the above eigenvectors and structure.

Step 4: Transforming all column sums to unity exactly to derive the weighted supermatrix.

Step 5: Raise the weighted supermatrix to limiting powers such as Equation below to get the global priority vectors

$$\lim_{k \to \infty} W^k.$$

If the supermatrix has the effect of cyclicity, the limiting supermatrix is not the only one. The Cesaro sum would be calculated to get the priority. The Cesaro sum is formulated as

$$\lim_{k \to \infty} \left(\frac{1}{N} \right) \sum_{r=1}^{N} W_r^k ,$$

To calculate the average effect of the limiting supermatrix where W_r denotes the rth limiting supermatrix. Otherwise, the supermatrix would be raised to large powers to get the priority weights.

All these mathematical issues can be solved by Super Decision Software designed by Saaty in 2004, in which the methodology can be summarized into steps:

(1) the pairwise comparison matrices to compare among criteria and alternatives
(2) examine the inconsistency ratio,
(3) compute the priorities of criteria and alternatives, and then examine the inconsistency ratio,
(4) determine the best alternative.

For the results of decision model analysis, the ranking of alternatives will be presented in Normal and Ideal. The normal column shows the priorities for the alternatives normalized by adding the elements of the total column and dividing each element by the sum to get the normalized vector. The total value of the elements in the normalized vector is 1. The ideal column is taken by dividing each element of the total column by the largest one, so the best alternative will get a priority of 1.

The results of criteria priorities will be shown in Normalized by Cluster and Limiting. The limiting column represents the importance weights for every element in the whole model in which interdependence among criteria is considered whilst the results in Normalized by Cluster present the priorities of criteria within that cluster only.

One more result needs to be considered is sensitivity analysis. Whether the final result is stable to changes in the inputs, either judgements or priorities. Of important interest is to see if those changes affect the order of the alternatives and the weights of criteria through sensitivity graph. The priorities of alternatives are plotted on the y axis whilst different experiments of the element are on the x-axis.

4. Application of Supplier Selection Model

The proposed approach was implemented in three T&A companies.

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The first case is a T&A company that was established in 2004, named A. There are more than 200 employees at different positions. At present, it is specializing on producing garment under CMT method. Its main export markets include Japan, EU, and USA. Company A has frequent demand on thread, button, or label for its exported products under some main supplier selection criteria such as price, quality, and delivery, which causes difficulties for it in case its suppliers have various characteristics. At this time, the company would apply the set of supplier selection criteria recommended by the author and ANP method to select the best supplier for their present purchasing order – 10,000 skeins of thread. Table 2 is the brief description of three suppliers that Company A takes into consideration in selecting the best one. These three suppliers are to be evaluated as sources for a new product that Company A is working on with a customer.

Table 2. Description of three supplier candidates (alternatives) of Company A

	Alternative 1	Alternative 2	Alternative 3
Production capital	10 million metres of fabric/ year	1 million metres of fabric/ year	1 million metres of fabric/ year
Payment method requirement	Deferred remittance	Deferred remittance	Deferred remittance
Country of origin	Vietnam	Vietnam	Vietnam

Source: Company A

The second case is a T&A company specializing on producing garment under FOB method, named B. It was established in 2010 and has more than 200 employees. Company B has frequent demand on fabric, thread, button, label …for its exported products to EU. The company has already had its own supplier selection criteria such as quality, price, or relationship to evaluate the candidate suppliers. This often causes a bias selection result. However, under this case, the company would apply the set of supplier selection criteria recommended by the author and ANP method to select the best supplier for their present purchasing order – 20,000 metres of fabric. Table 3 is the brief description of three suppliers that the company takes into consideration in selecting the best one.

Table 3. Description of three supplier candidates (alternatives) of Company B

	Alternative 1	Alternative 2	Alternative 3
Production capital	120,000 pcs/ year	100,000 pcs/year	50,000 pcs/ year
Payment method requirement	Cash against documents	Deferred remittance	Deferred remittance
Country of origin	China	Taiwan	Taiwan

Source: Company B

The third case is a large company with more than 25,000 employees and has been in T&A industry for more than 40 years, called C. Its main export markets are Europe, USA and Japan. Its production methods cover from CMT, FOB, OBM to ODM. Although it is large and has long life in T&A industry, it has not had an official set of supplier selection criteria. Each department will have different set of criteria. When the company has orders, it will consider minimum order quantity, production capacity, price, delivery time, payment method. Payment method is put on the top because it affects other remaining criteria such as finance, capacity … Especially, these criteria are not assigned weights. The final supplier selection decision will be made by the manager. Therefore, the supplier selection results are sometimes dictated intuitively. The manager often bases on how candidate suppliers build trust through their action and responsibility in conversations to determine the ones the company can select. Under this situation, Company C is really in need of an official and standard supplier selection criteria as well as a selection model for it to select the most efficient and rational suppliers. Therefore, Company C would apply the set of supplier selection criteria recommended by the author and ANP method to select the best supplier for their present purchasing order – 50,000 metres of fabric. Table 4 is the brief description of three suppliers that the company takes into consideration in selecting the best one. The first candidate supplier was established in 1975 and specializes in manufacturing and researching various fabric and garment. As an international textile and garment supplier, it is trying to maintain the highest level of honesty and sincerity. It has integrated all resources to provide its customers the most innovative products and becomes the main supplier of the major brands in the world. The second and third candidate suppliers are also textile companies in China.

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Table 4. Description of three supplier candidates (alternatives) of Company C

	Alternative 1	**Alternative 2**	**Alternative 3**
Production capital	2,500 tons of knitted fabric, up to 1,000 tons of dyeing capacity, and up to 2.5 million of garments manufacturing/month	500,000 metres of fabric/year	200,000 metres of fabric/year
Payment method requirement	Documentary credit (L/C)	L/C	L/C
Country of origin	China	Taiwan	Taiwan

Source: Company C

5. Research Findings

The demonstration of each criteria subnet in terms of the pairwise comparison matrices, inconsistency ratio, and criteria prioritization is presented. It should be noted that the weights of criteria are different for each purchaser. Therefore, pairwise comparisons between criteria are needed to determine the weights of each criterion in the case of interdependence among them and pairwise comparisons between supplier alternatives with the goal of finding the best supplier. Figure 5 illustrates the structure of the ANP model under Super Decision Software.
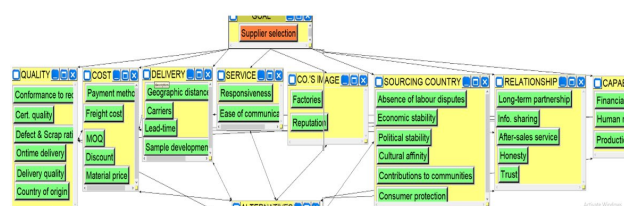

Figure 5. Structure of the ANP model in SuperDecision software

Case 1:

Basing on the above model, a meeting between the author and the purchasing manager of the first case company took place. The manager was asked to respond a series of pairwise comparisons between criteria and alternatives. SuperDecision software was used at the same time to calculate the inconsistency ratio which can ensure the most consistent value for the entries. The inconsistency ratio should be less than 0.1 [28].

Table 5 illustrates the synthesized results of decision model analysis. As can be seen from the results, Supplier 1 is the best supplier. Supplier 3 following Supplier 1 and 2 is the less suitable supplier among the alternatives.

Table 5. Priorities of alternatives of Company A

Alternatives	Normal	Ideal	Ranking
Supplier 1	0.52461	1	1
Supplier 2	0.25455	0.4852	2
Supplier 3	0.22084	0.4210	3

In addition, the priorities of criteria are illustrated in Appendix 2

It can be observed from Appendix 2 that in Quality cluster, defect & scrap ratio (22.116%), conformance to requirements (24.815%) and on-time delivery (20.424%) are the primary focus when the company assesses the quality since the percentages are up to nearly 70% in total. However, country of origin is not much considered. In terms of Cost, the price of material accounts for approximately 40%, which shows its importance in the set of criteria. For Delivery, although lead-time has the highest percentage (54.195%), other sub-criteria in the cluster also have approximate importance. In terms of Service, responsiveness is superior to ease of communication. Considered as sub-criteria of Company's Image, factories tend to be more attentive than Reputation. Honesty under Relationship cluster and Production capacity of Capability cluster dominate the weights, 34.326% and 54.994% respectively, which mean this purchasing company focuses much on the honesty and production ability of suppliers. Other sub-criteria of the remaining criteria have nearly equal percentages, but not outstanding.

Also, in Appendix 2, the results of the limiting column show that Material price is the most attentive (0.113219), following by Long-term partnership (0.100779). These two criteria accounts for slightly over 20% of the whole set of criteria. Other four important criteria include Factories, Production capacity, Ease of communication, Responsiveness, and Defect & scrap ratio. Totally, these seven criteria get the total weight of 50% out of 33 sub-criteria.

The concern for the above results is whether the final result is stable to changes in the inputs, either judgements or priorities. Therefore, sensitivity analysis is considered and shown through Figure 6 - the sensitivity graph. The graph shows that no matter

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what the values of supplier are, Supplier 1 still remains the best alternative. The tests led to conclusion that the outcome is very stable and does not change the overall results.
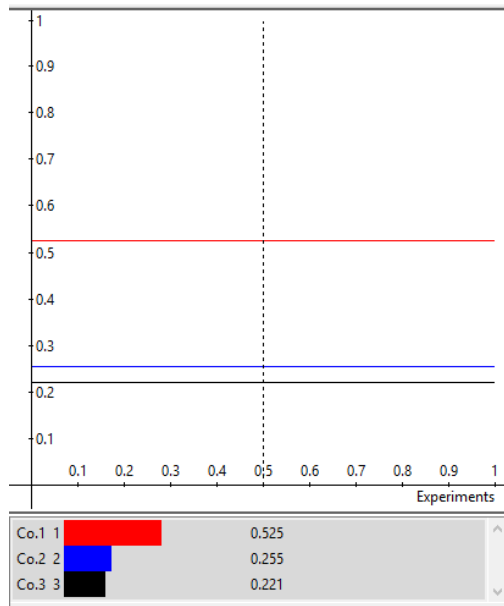

Figure 6. The sensitivity graph for supplier selection of Company A

Case 2:

Table 6 illustrates the synthesized results of decision model analysis. As can be seen from the results, Supplier 1 is the best supplier among the alternatives, followed Supplier 3 and 2.

Table 6. Priorities of alternatives of Company B

Alternatives	Normal	Ideal	Ranking
Supplier 1	0.472351	1	1
Supplier 2	0.230759	0.488532	3
Supplier 3	0.29689	0.628536	2

In addition, the priorities of criteria are illustrated in Appendix 2

It can be observed from Appendix 2 that in Quality cluster, Certificate of quality (29.584%) is the primary focus, then followed by On-time delivery, Delivery quality, Conformance to requirements, Defect & scrap ratio. These three sub-criteria have the approximate weights. Country of origin is not much considered. In terms of Cost, the price of material accounts for nearly 50%, which shows its importance in the set of criteria. The second important criterion is Payment method and MOQ. The other criteria in this cluster are not much attentive. For Delivery, Company B pays much attention to Lead-time since it has the highest

percentage (55.929%), other sub-criteria in the cluster have approximate importance, except Carriers (only 7.439%). Considered as sub-criteria of Company's Image, Factories tends to be more attentive more Reputation. Honesty, Long-term partnership and Trust under Relationship cluster and Financial capacity of Capability cluster dominate the weights, 38.635%, 21.901%, 21.354% and 44.342% respectively, which mean this purchasing company focuses much on honesty, trust, long-term relationship and suppliers' financial situation. In terms of Service cluster, Responsiveness is the primary focus of Company B. Other sub-criteria of the remaining criteria have nearly equal percentages.

Also, in Appendix 2, the results show that Material price is the most attentive (0.13370), following by Long-term partnership (0.11617). These two criteria accounts for over 20% of the whole set of criteria. Other four important criteria include Responsiveness, Defect & scrap ratio, Factories, Lead-time, and Payment method. Totally, these seven criteria get the total weight of more than 50% out of 33 sub-criteria.

Figure 7 shows the sensitivity graph. The priorities of alternatives are plotted on the y axis whilst different experiments of the element are on the x-axis. The graph shows that no matter what the values of supplier are, Supplier 1 is the best alternative. The tests led to conclusion that the outcome is very stable and does not change the overall results.
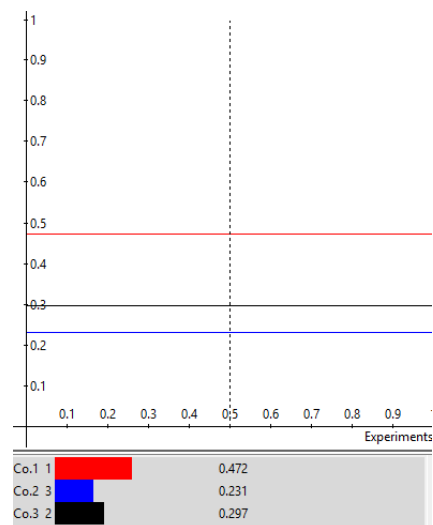

Figure 7. The sensitivity graph for supplier selection of Company B

Case 3:

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Table 7 illustrates the synthesized results of decision model analysis. As can be seen from the results, Supplier 1 is the best supplier among the alternatives, followed Supplier 2 and 3.

Table 7. Priorities of alternatives of Company C

Alternatives	Normal	Ideal	Ranking
Supplier 1	0.588735	1	1
Supplier 2	0.264529	0.449317	2
Supplier 3	0.146737	0.249241	3

In addition, the priorities of criteria are illustrated in Appendix 2

It can be observed from Appendix 2that in Quality cluster, On-time delivery (32.399%) and Delivery quality (23.884%) are the primary focus when the company assesses the quality since the percentages are up to more than 50% in total, then followed by Certificate of quality, Conformance to requirements, and Defect & scrap ratio. Country of origin is not much considered. In terms of Cost, the price of material and Payment method account for over 70%, which shows their importance in the set of criteria. The other criteria in this cluster are not much attentive. For Delivery, Company C pays much attention to Sample development capacity since it has the highest percentage, the followed by Geographic distance. Other sub-criteria in the cluster have approximate importance. Carriers receives the least focus in this cluster. Considered as sub-criteria of Company's Image, Reputation tends to be more attentive more Factories. Trust under Relationship cluster and Financial capacity of Capability cluster dominate the weights, 59.022% and 48.144% respectively, which mean this purchasing company focuses much on trust and suppliers' financial situation. In terms of Service cluster, ease of communication is the primary focus of Company C. Other sub-criteria of the remaining criteria have nearly equal percentages, but not outstanding.

Also, in Appendix 2, the results show that Long-term partnership is the most attentive (0.115221), following by Material price (00.11075). These two criteria accounts for over 20% of the whole set of criteria. Other four important criteria include Payment method, Reputation, Financial capacity, Ease of communication, and Sample development capacity. Totally, these seven criteria get the total weight of nearly 60% out of 33 sub-criteria.

Figure 8 shows the sensitivity graph. The graph shows that no matter what the values of supplier are, Supplier 1 still remains the best alternative. The tests led to conclusion that the outcome is very stable and does not change the overall results.
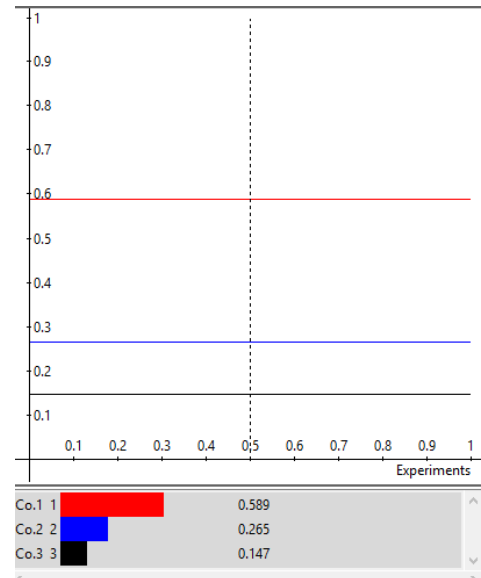

Figure 8. The sensitivity graph for supplier selection of Company C

6. Discussion

6.1 In terms of supplier selection criteria:

+ In comparison among three illustrative cases:

The supplier selection results of three illustrative cases reveal that all criteria are necessary for three companies in the case studies. The set of criteria covers all concerns of suppliers from micro and macro issues, from internal problems to external ones, from tangible to intangible, from quantifiable to non-quantifiable. This is illustrated by the priority results in table 6, table 8, and table 10. No criterion gets the weight of 0 per cent. In the set of criteria, there are some fundamental criteria that are necessary for all purchasers regardless of their scope or production methods. These criteria include Material price, Payment method, Long-term partnership, Responsiveness, and Ease of communication, in which Payment method and Material price are the two most concerned criteria. These criteria always receive higher weights in comparison with other criteria. Towards the end of the discussion between the author and Company's representative, Company B lays their emphasis on Payment method because it affects the

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price. It often selects suppliers who offer deferred payment. Also, at the discussions with Company C's sourcing manager, he explained that since the company's contract values were often high, so it laid its primary focus on the method of payment to protect itself against non-delivery and financial capacity to ensure the suppliers' delivery ability. In addition, Long-term partnership also draws the attention of the company since suppliers with good and long relationship often offer good payment method and good price, along with many other preferences. In terms of Responsiveness and Ease of communication, since apparel industry has short-life cycle, it prefers the suppliers' fast reaction and easy-to-contact suppliers in all situations.

However, there also exist some differences among purchasers in weighting the importance of those supplier selection criteria.

❖ Company A representing small companies tends to have more preferences on some more other criteria such as Factories, Production capacity, Defect & scrap ratio. According to this company's representative, T&A sector requires the fast reaction to the customers' requirements, so his company pays much attention to their suppliers 'capability, particularly in the number of factories or production capacity, and of course responsiveness and ease of communication is a must in business today. In addition, defect & scrap ratio is also a criterion for the company to base on to evaluate the suppliers' product quality.

❖ Company B is now producing its garment under FOB1 and FOB2 method. In addition to Material price and Long-term partnership, it also focuses much on Defect & scrap ratio, Factories, and Lead-time. As explained above, since apparel industry has short-life cycle, it requires the fast reaction of suppliers and short lead-time. In addition, in terms of Factories, the larger the factory is, the higher capacity the supplier has, so it is also a criterion used to evaluate candidate suppliers.

❖ Company C represents large companies with high level of production methods. In addition to its preferences on Material price and long-term partnership, the company also favours much on Reputation, Financial capacity, Sample development capacity and Certificate of quality. For Reputation, the company interests in high reputed suppliers to ensure

the quality and quantity. Besides, to be reputed suppliers, they already pass the harsh standards of severe clients … In terms of Sample development capacity, since Company C is practicing ODM and OBM production methods, it pays special attention to the suppliers' capacity in developing samples to be able to keep pace with the trend, then provide those samples for its ODM and OBM collection. For Financial capacity, because of always having high-valued contracts, Company C pays much attention to financial situation of suppliers. For Certificates of quality, they are often required by clients in foreign countries, so Company C also requires these certificates from its suppliers. Further, they are the proof of suppliers' quality in the first evaluation. In summary, all criteria and sub-criteria are crucial to T&A companies. They can adjust the importance of each criterion basing on the type, characteristics, or purchasing policy of their companies.

+ In comparison with previous studies:
Firstly, there is an emergence of one new criterion that is Company's Image including two sub-criteria: factories and reputation, which can reflect one company's business operation and capability. Although these two sub-criteria are not really novel and likely different in nature, they are arranged in the same group, showing the company's image. This may be the typical characteristics of T&A industry in general and Vietnamese T&A industry in particular.

Rather, there are also an emergence of some new sub-criteria which only exist in the T&A industry such as Payment method, MOQ and Discount in Costs cluster, Carriers and Sample development capacity in Delivery cluster, and the new re-arrangement of sub-criteria of CSR into Sourcing country or After-sales service sub-criteria into Relationship cluster. This emergence makes the research more meaningful not only in practical but also academic aspects.

Secondly, the set of supplier selection criteria covers full and comprehensive criteria and sub-criteria including from micro (such as Relationship, Capability, Company's Image, Quality, Costs, Delivery, and Service) to macro criteria (Sourcing country); both organizational features (Relationship, Capability, and Company's Image) and performance metrics (Quality, Costs, Delivery, and Service), both tangibles (Quality, Costs, Delivery, Service, Capability, Sourcing country) and intangibles

(Company's Image, Relationship), both short-term (criteria in performance metrics group) and long-term (criteria in organizational features group), both internal (Relationship, Capability, Company's Image, Quality, Costs, Delivery, and Service) and external (Sourcing country) criteria. Therefore, the findings overcome the gap of lacking a comprehensive set of supplier selection criteria for theories on supply chain management.

Thirdly, both qualitative and quantitative methods of the research were conducted not only in apparel industry but also in spinning, dying, and weaving; covering from CMT to FOB1, FOB2, ODM and OBM. Thus, the results can be practically applied into the whole T&A industry.

6.2   In terms of supplier selection model:

According to the sourcing managers who are also decision makers, the most advantage of this approach is that it considers the interdependence among criteria and uncertain situation of suppliers, while still allowing them to apply various criteria into evaluating candidate suppliers That is what they have not been able to handle over years. That is also the reason they often utilize some main criteria to evaluate and select suppliers because of its simplicity. In addition, the model proposed can help those companies select suppliers faster. Last but not the least, now the model arrives at a synthetic score, which can be useful for decision makers to assess and choose the most suitable suppliers rationally. The ANP method is a powerful multiple criteria method for dealing with human thinking with internal inconsistency and defining the weights of the criteria (Saaty, 2005). As compared to other methods like AHP, SAW, or TOPSIS, the analysis using the ANP is relatively burdensome because of the construction of a series of pairwise comparison matrices, but the most advantage of the ANP method is to solve interdependences among criteria and sub-criteria. That means the ANP is a more reliable resolution than other methods. This finding removes the gap of no study in T&A industry solving the problem of interrelations among criteria as presented in Appendix 1.

7.   Conclusion:

The proposed supplier selection model with full set of criteria can help decision makers select their

suppliers rationally, no longer depend on their subjective will.

Although the dissertation provides a helpful and robust decision-making model for purchasing managers, it cannot avoid its limitations either, which can be solved in future researches.

Firstly, the selection of suppliers for T&A sector is a complicated process. Thus, it cannot be solved by a single model as developed in the research. It may be a very interesting research to create additional models as variation tools for the proposed model.

Secondly, although the case studies used in this paper concern the T&A industry, it would be an impressive research to apply the model into other industries.

Thirdly, the sample size for illustrative cases were relatively low. Therefore, later studies can increase the number of the illustrative cases to make the results much more reliable comprehensive.

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APPENDIX 1

Methods applied in evaluating and selecting suppliers in the textile and apparel industry

No.	Articles	Research subjects	Methods applied	Review	
				Strengths	Weaknesses
1	A model for evaluation and selection of suppliers in global textile and apparel supply chains [9].	The United State	Multi-attribute approach: Step 1: Literature review --> Criteria Step 2: Set up Formula for supplier selection Delivery score = Cd[(Kgl * Vgl) + (Kft * Vft) - (Ktr * Vtr) + (Klt * Vlt) Total supplier score = delivery score + flexibility score + quality score + reliability score - cost score Step 3: Case study (buyers assign weight according to their needs)	Set up own formula to select suppliers	- Only base on literature review to explore criteria - Criteria may not be from the company's needs - Do not solve the problem of interrelations among criteria
2	Supply chain management in the textile industry: A supplier selection model with the analytical hierarchy process [10]	General	Build up a selection model by introducing all steps (AHP) and implications of the model for implementation		- Only present theories - Base on literature review to explore criteria - Do not solve the problem of interrelations among
3	Multi-criteria decision-making approach to evaluate optimum maintenance strategy in textile industry [11]	General	AHP		Do not solve the problem of interrelations among criteria
4	Selection of maintenance policy for textile industry using hybrid multi-criteria decision making approach [30]	India	Use FAHP to define weights of criteria & TOPSIS to rank suppliers	Linguistic issue	Do not solve the problem of interrelations among criteria
5	Selection of ERP suppliers using AHP tools in the clothing industry [12]	General	AHP		Do not solve the problem of interrelations among criteria
6	An AHP model for selection of suppliers in the fast changing fashion market [13]	General	AHP		Do not solve the problem of interrelations among criteria

7	Decision Framework for Supplier Selection through Multi Criteria Evaluation Models in Supply Chain [14]	General	Step 1: Literature review (not presented in details) Step 2: Questionnaire to 50 companies (not presented in details) Step 3: Case study --> Use AHP and TOPSIS to select suppliers and then compare the results of 2 methods	Present a selection framework	- Only focus on how to use AHP and TOPSIS - Criteria may not be from the company's needs - Do not solve the problem of interrelations among criteria
8	Indian textile suppliers' sustainability evaluation using the grey approach [31]	India	Grey		Do not solve the problem of interrelations among criteria
9	An integrated model of material supplier selection and order allocation using fuzzy extended AHP and Multiobjective programming [18]	Hongkong	FEAHP & dynamic programming: Step 1: Literature Step 2: 3 experts select important criteria Step 3: Define sub-criteria Step 4: Pairwise comparison --> weights Step 5: Empirical case to select suppliers (FEAHP)	- The study presented 04 scenarios - Linguistic issue	Do not solve the problem of interrelations among criteria
10	Supplier Selection in Textile Industry Using Fuzzy MADM [19]	Iran	Step 1: Use Fuzzy Delphi to explore criteria Step 2: Use FAHP to define weight Step 3: Use VIKOR to select suppliers	Combine three methods into select suppliers to make the result more precise. - Linguistic issue	Do not solve the problem of interrelations among criteria
11	A fuzzy analytic hierarchy process methodology for the supplier selection problem [16]	General	Use FAHP to select suppliers for 01 company Step 1: Define criteria based on the company's objective Step 2: Pairwise comparisons Step 3: Select suppliers	- Linguistic issue	Do not solve the problem of interrelations among criteria
12	Supplier Selection Problems in Fashion Business Operations with Sustainability Considerations [32]	General	Step 1: review literature to define supplier selection criteria Step 2: use FTOPSIS to rank and select supplier	- Linguistic issue	Do not solve the problem of interrelations among criteria
13	The Integrated Approach for Sustainable Performance Evaluation in Value Chain of Vietnam Textile and Apparel Industry [33]	Vietnam	Grey theory & DEA	Evaluate the whole Vietnam T&A industry	- Evaluate the performance of value chain of Vietnam T&A industry by basing on the input and output of data - Do not mention supplier selection criteria The topic is related to Vietnam, but not in supplier selection

14	A decision support model for sustainable supplier selection in sustainable supply chain management [20]	General	Fuzzy preference programming & FTOPSIS: Step 1: Determine criteria 1.1: Literature review --> criteria 1.2: Interview 5 experts to redefine criteria 1.3: Questionnaire to show importance and applicability of criteria + sub-criteria (Cronbach alpha) --> 23 out of 150 companies replied 1.4: Mann-Whitney U-test (p value > 0.05 --> no difference) Step 2: Case study (1 case) 2.1 Fuzzy preference programming --> Weight 2.2 FTOPSIS --> Select suppliers 2.3 Validation + Consistency index + Comparing with TOPSIS + Sensitivity analysis	Combine qualitative and quantitative approaches to make the result more precise.	Do not solve the problem of interrelations among criteria
15	Strategic Management Planning for Textile Industry in India in Accordance with Indian Textile Market [15]	India	AHP		Do not solve the problem of interrelations among criteria
16	Evaluation and Prioritisation of Manufacturing Flexibility Alternatives using Integrated AHP and TOPSIS Method: Evidence from a Fashion Apparel Firm [17]	General	Step 1: Literature review + Focus group to explore Criteria (4-tier hierarchy) Step 2: use AHP to define Weight Step 3: use TOPSIS to rank Alternatives Case study: Apply 3 above steps into one case	Combine many methods to make the result more precise	- The criteria may not represent for the whole industry - Do not solve the problem of interrelations among criteria
17	Green Supplier Evaluation and Selection in Apparel Manufacturing Using a Fuzzy Multi-Criteria Decision-Making Approach [6]	General	Step 1: Review literature Step 2: Use Fuzzy axiomatic design (AD) technique to evaluate and select suppliers.	Linguistic issue	Do not solve the problem of interrelations among criteria
18	Responsible Sourcing: A Perspective from Small Apparel Business Owners [7]	The USA	Qualitative method (In-depth)		Do not solve the problem of interrelations among criteria
19	Decision making on supplier selection based on social, ethical, and environmental criteria: A study in the textile industry [8]	General	• Propose model as follows: Step 1: Review literature to define criteria Step 2: Use AHP method to define weights of criteria Step 3: Use ELECTRE-TRI to classify suppliers • Apply the model into practice	- Combine many methods to make the result more precise - Practical significance	Do not solve the problem of interrelations among criteria

| 20 | Decision Support System for Supply Chain Performance Measurement: Case of Textile Industry [21] | General | Use Delphi method to propose decision support framework. Use AHP to analyze the importance of criteria, sub-criteria and alternatives. | Combine many methods to make the result more precise | Do not solve the problem of interrelations among criteria |

APPENDIX 2
Priorities of criteria of Company A – B – C

Company A			Company B			Company C		
Criteria	Normalized by cluster	Limiting	Criteria	Normalized by cluster	Limiting	Criteria	Normalized by cluster	Limiting
Quality cluster			**Quality cluster**			**Quality cluster**		
Conformance to requirements	0.24815	0.050631	Cert. of Quality	0.29584	0.02805	On-time delivery	0.32399	0.03339
Defect & Scrap ratio	0.22116	0.043936	On-time delivery	0.17829	0.01567	Delivery quality	0.23884	0.016429
On-time delivery	0.20424	0.019341	Delivery quality	0.17829	0.016429	Cert. of Quality	0.15080	0.041949
Delivery quality	0.18659	0.015831	Conformance to requirements	0.16428	0.02449	Conformance to requirements	0.13433	0.017785
Cert. of Quality	0.08056	0.022413	Defect & Scrap ratio	0.14661	0.01372	Defect & Scrap ratio	0.11988	0.015788
Country of origin	0.05927	0.007206	Country of origin	0.03665	0.00607	Country of origin	0.02488	0.00408
Cost cluster			**Cost cluster**			**Cost cluster**		
Material price	0.38863	0.113219	Material price	0.45474	0.13370	Payment method	0.36976	0.078178
MOQ	0.23857	0.030091	Payment method	0.29905	0.03522	Material price	0.36310	0.110750
Payment method	0.15271	0.031134	MOQ	0.10969	0.03434	Freight cost	0.15240	0.014293
Freight cost	0.11975	0.021183	Discount	0.06939	0.01727	Discount	0.08083	0.010639
Discount	0.10032	0.02744	Freight cost	0.06712	0.01627	MOQ	0.03391	0.018005
Delivery cluster			**Delivery cluster**			**Delivery cluster**		
Lead-time	0.54195	0.036044	Lead-time	0.55929	0.04448	Sample development capacity	0.47181	0.051282
Geographic distance	0.22605	0.019456	Sample development capacity	0.23634	0.01545	Geographic distance	0.38386	0.018597

Carriers	0.12278	0.021749	Geographic distance	0.12996	0.01443	Carriers	0.09432	0.004167
Sample development capacity	0.10921	0.018764	Carriers	0.07439	0.01735	Lead-time	0.05001	0.017834
Service cluster			**Service cluster**			**Service cluster**		
Responsiveness	0.75000	0.046098	Responsiveness	0.80000	0.06662	Ease of communication	0.50000	0.063998
Ease of communication	0.24999	0.046098	Ease of communication	0.20000	0.02221	Responsiveness	0.50000	0.027304
Company's Image cluster			**Company's Image cluster**			**Company's Image cluster**		
Factories	0.75000	0.057554	Factories	0.75000	0.05922	Reputation	0.88889	0.069872
Reputation	0.25000	0.034644	Reputation	0.25000	0.02961	Factories	0.11111	0.021429
Sourcing country cluster			**Sourcing country cluster**			**Sourcing country cluster**		
Absence of labour disputes	0.25486	0.015913	Contributions to communities	0.28769	0.02015	Consumer protection	0.24487	0.02099
Economic stability	0.19680	0.013256	Consumer protection	0.27721	0.02347	Political stability	0.23896	0.020831
Political stability	0.19680	0.012641	Political stability	0.15618	0.00817	Economic stability	0.23071	0.022314
Consumer protection	0.15993	0.019953	Economic stability	0.14135	0.00814	Contributions to communities	0.13197	0.016254
Contributions to communities	0.09579	0.016182	Cultural affinity	0.08952	0.01880	Absence of labour disputes	0.11694	0.006411
Cultural affinity	0.09579	0.014255	Absence of labour disputes	0.04802	0.01010	Cultural affinity	0.03655	0.004501
Relationship cluster			**Relationship cluster**			**Relationship cluster**		
Honesty	0.34326	0.019412	Honesty	0.38635	0.01327	Trust	0.59022	0.033084
Trust	0.18729	0.020378	Long-term partnership	0.21901	0.11617	Long-term partnership	0.16161	0.115221
Information sharing	0.18729	0.019412	Trust	0.21354	0.01650	Information sharing	0.14281	0.022244
After-sales services	0.14852	0.014286	Information sharing	0.11782	0.02224	After-sales services	0.07062	0.004108
Long-term partnership	0.13361	0.100779	After-sales services	0.06326	0.00862	Honesty	0.03474	0.006972
Capability cluster			**Capability cluster**			**Capability cluster**		
Production capacity	0.54994	0.046098	Financial capacity	0.44342	0.03768	Financial capacity	0.48144	0.069146
Human resources	0.24021	0.023049	Production capacity	0.38737	0.03495	Human resources	0.46291	0.015165
Financial capacity	0.20984	0.023049	Human resources	0.16919	0.01620	Production capacity	0.05563	0.006993