Supplier Selection with Structure Equation Models

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Abstract— *Procurement and supplier selection pose as major tasks to companies. However, supplier selection is a complicated issue which requires total analysis. From product quality to product delivery, all factors must be taken into consideration. The research provides an insight to the task. The aim is to facilitate companies to select suppliers wisely. The research attempts to: (1) summarize the factors that involves in supplier selection, define dimensions and their hierarchy structure; (2) use Structural Equation Models (SEM) to analyze the weight of influential factors in supplier selection and discuss the significance of each factor; (3) use SEM to analyze each level within the supplier selection hierarchy first, then apply AHP to construct a selection model.*

***Keywords*—Supplier Selection, Structural Equation Models (SEM), Analytic Hierarchy Process (AHP)**

I. INTRODUCTION

The development and popularization of the Internet has triggered the prosperity of ecommerce. As selection widens, the number of options and the level of flexibility increases, the convenience of online purchase becomes more evident. In general, supplier selection is a price-driven process. Profit margin is squeezed to the minimal within the price comparison process. Suppliers that wish to maintain the profit margin at a certain level need to cut down the material cost, which may result in quality reduction. Otherwise the supplier must seek other ways to increase revenue.

For the company, reducing cost production may affect the quality of the goods, resulting in finding unqualified products during quality check process. Other possible effects include the supplier is financially-constrained and is unable to produce and deliver goods on time. A financially-constrained supplier is also more vulnerable to external market forces as well. Whatever the reason behind, the negative affect it poses on a company is profound. Business reputation and customer loyalty are expected to be affected.

This research reviews literatures on supplier selection and surveys professional opinion on the topic. The data serves as the input to create a Structural Equation Model (SEM) to analyze the reliability and validity of the research. The study continues to analyze the weight of each factorial dimension, which is combined to create a framework using Analytic Hierarchy Process (AHP). A pairwise comparison matrix is constructed at the end to test data consistency in order to determine the ideal supplier selection method.

The study starts with passing survey to experienced people that are familiar with the distribution channels in the computer and communication industry in order to filter the

criteria when selecting a supplier. Using SEM, the research analyzes the influential factors that distributors and resellers are concerned of. Supplier selection dimension can be constructed based on the criteria. Researchers will then use AHP to develop a selection hierarchy and a pairwise comparison matrix. A final check on the consistency aims to conclude an optimal supplier selection method for distribution channels in the computer and communication industry.

II. LITERATURE REVIEW

Huang [1] stated that the idea of supply chain management is influencing the relationship between suppliers and buyers. The relationship turned from the traditional adversary and opposite position to one that seek mutual interest and maximum benefit for both sides. Huang combined the 23 criteria that were applied for supplier evaluation by Diskson [2] with researches on local supplier and advice from experienced professional to form a supplier evaluation framework that can be closely applied to Taiwanese environment. The finding is put to test in a survey sent out to automobile, bike, computer, and communication industry. A total of 49 suppliers and experienced professional joined the survey. The result is analyzed using factor analysis. From the findings, researchers were able to summarize the 9 evaluation factors that each of the four industries focused on. This was further compared with recent research findings. On the other hand, M. Navid Kasirian et al. [3] proposed a 5-step principle to determine the selection criteria and the weight of each dimension.

Sonmez [4] summarized a total of 147 pieces of researches between 1985 and 2005. He concluded that for products that are ordered routinely, and that the good itself requires no learning curve, supplier selection tend to put more focus on logistic and cost. Sonmez also mentioned a 5-step supplier selection process:

1. Demand for a new supplier.
2. Confirm and establish on decision principle.
3. Initial filtering process to filter out unqualified candidates.
4. Continue the filtering process until a supplier is chosen.
5. During the initial cooperation period, the company should continue to observe the newly selected supplier to determine whether it meets the demand of the company.

Sonmez [4] further explained the filtering process, which can be summarized into the following flowchart, and more related research also can found in [5, 6, 7, 8, and 9].:

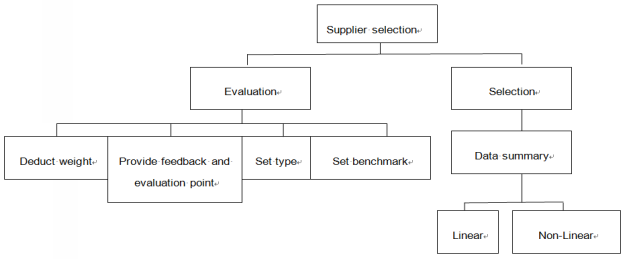


Figure 1: Flowchart of supplier selection process and practices(Source: Mahmut Sonmez , 2006.[4])

Sonmez [4] also mentioned several key factors during the supplier selection process, which is illustrated in Figure 2.

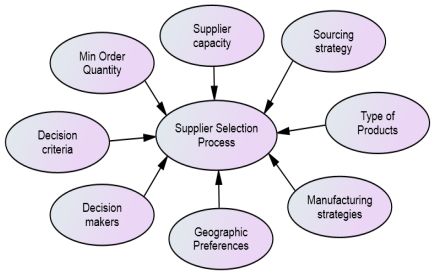


Figure 2: Key factors on supplier selection (Source:

Mahmut Sonmez, 2006.[4])

The above figures explain the following:

1. Supplier capacity: This indicates a supplier's capability in price negotiation, the quality and quantity of goods delivery.
2. Sourcing strategy: Procurement process must be stable to secure supply of goods and services. In order to achieve this, supplier must have a sourcing strategy.
3. Type of products: The goods should be products that are ordered regularly, products that are assembled or operated, or those that offers efficiency.
4. Manufacturing strategies: This indicates a business' long term strategy and how it approaches the goal, including action plan and resource allocation. Such can be discussed in different aspects like cost, quality, delivery, and the company's flexibility. Skinner (1969) suggested to approach through the following: (1) Hardware infrastructure; (2) Production planning management; (3) Human Resources; (4) Production design and manufacturing; (5) General management.
5. Geographic preference: Location of the supplier and its production plant.
6. Decision makers: The role that holds the final decision on the supplier selection.
7. Decision criteria: The selection criteria on supplier selection.
8. Minimum order quantity: The smallest order quantity that the supplier is able to provide.

2.1 Structural Equation Models

Structural Equation Models (SEM) is a statistical technique for systematic analysis. The model includes combining numerous linear models and their variables. A SEM estimates the relationship between measured variables and latent variables to evaluate the direct and the indirect effect. To give a clearer description on the complex equation, Hoyle et al (1995) proposed a SEM thesis should be discussed from two aspects: a structural model and a measurement model. The structural model indicates what the researcher wish to understand, such as the relationship between two different dimensions. The measurement model can be presented as an image to effectively deliver the approach and its goal. The measurement model is obtained after computer analysis. In other words, the measurement model can't be obtained through theoretical inference. Structural equation model analyzes the weight of each dimension through the following steps as Figure 3 shown:

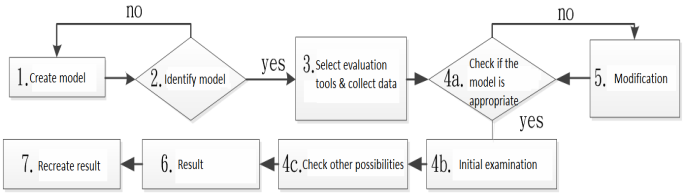


Figure 3: SEM analysis flowchart (Source: http://www.semsoeasy.com.tw/[10])

2.2.1 Reliability and Validity

Reliability and validity are the two important criteria in any kind of experiment. When reviewing the relationship between the evaluation criteria and the construct of these criteria. A construct is a concept that's formed by bringing together concepts, reality, and impression through a systematic way. A questionnaire should be tested on its reliability and validity before carrying out the official survey. Based on the analysis, questionnaire structure is adjusted to improve the reliability and validity. Figure 4 illustrates how reliability is determined. A latent variable is reflected in three manifest variables. λx11 to λx31 serve as

standardized factor loading (SFL). The purpose of which is similar to the factor loadings in factor analysis. SFL ranges between 0 and 1. δ1 to δ3 are the residual of the manifest variables. Residual are parts that can't be explained by latent variable.

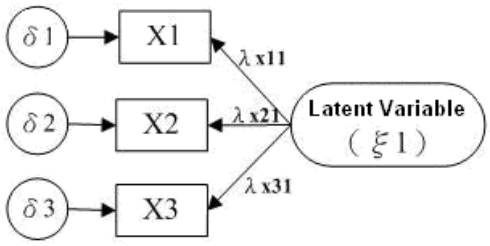


Figure 4. Latent variable (ξ1)Source: http://tw.myblog.yahoo.com/da_sanlin/article?mid=2585[11]

The reliability of latent variable can be examined by construct reliability (CR), which can also be written as component reliability or composite reliability. The formula is as follows:

Standardized factor loading represents the correlation coefficient of the latent variable and a manifest variable. In this formula, SFL is presented as λx11 to λx31. The square of SFL is called the square multiple correlation (SMC, or R^2). SMC describes how well the latent variable explains the manifest variable. In SEM, the manifest variable is often represented as number 1. The difference between 1 and SMC is the residual. In short, $\delta 1+(\lambda x11)^2=1$

$$CR=(\lambda_{x11}+\lambda_{x21}+\lambda_{x31})^2/$$

$$(\lambda_{x11}+\lambda_{x21}+\lambda_{x31})^2+(\delta_1+\delta_2+\delta_3) \qquad (1)$$

The concept of SEM CR is to take the self-variance as the numerator and the total variance, which is the sum of self-variance and residual, as the denominator. CR is a number between 0 and 1. The larger the number is indicates that true variance is more significant in the total variance, which means a higher consistency level. Fornell et (1981) suggests CR value should be above 0.60.

When discussing the convergent validity of latent variable, the average variance extracted (AVE) is the most significant. The formula is as follows:

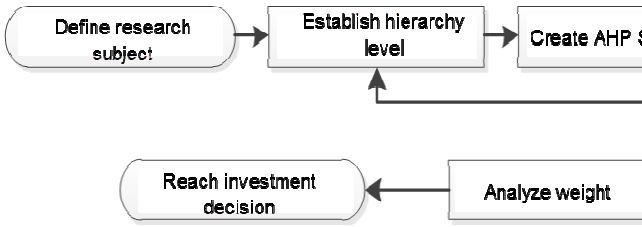
$$AVE=[(\lambda_{x11}+\lambda_{x21}+\lambda_{x31})^2]/$$

$$[(\lambda_{x11}+\lambda_{x21}+\lambda_{x31})^2]+(\delta_1+\delta_2+\delta_3) \qquad (2)$$

The formula of AVE and CR is very similar. But CR is the square of the sum of all SFL value. But AVE is the sum of all squared SFL value.

The definition of AVE is easy to understand. Since the variance of each manifest variable is standardized as 1 and that $\delta + \lambda 2 = 1$, therefore the numerator indicates the sum of how well the latent variable explains each manifest variable. The denominator is the total variance of manifest variables, which is the number of all manifest variables. Therefore AVE is to take the sum of factor loading and divide it by the number of all manifest variables. AVE can be concluded as "the average of SMC or R^2".

Fornell and Larcker [12] and Bagozzic and Phillips [13] suggest that the AVE of latent variable should be above 0.50. A figure above 0.50 indicates the latent variable has



more effective factors than error factors. However, to acquire an AVE value that's above 0.50 means the average

of all factor loadings must be above 0.71, which is difficult to obtain in reality. Therefore if there are 5 latent variables, there will be 5 AVE values. If 3 or 4 of the AVE values can reach 0.50 while the others are above 0.30 or 0.40, the value is deemed as acceptable. According to Hair et al. [14], SFL must reach the 0.50 threshold. This means AVE should be 0.50^2, which is 0.25.

2.2 Analytic Hierarchy Process; AHP

Thomas L. Saaty at University of Pittsburgh introduces Analytic Hierarchy Process (AHP) in 1971. AHP is a decision method that's used under situations that are uncertain and involve multiple evaluation criteria. There has always been continuous research on supplier selection. The most common analysis methods include product analysis, structural analysis, and correlation analysis. AHP is a structured technique for organizing and analyzing decision behavior and the process which involves.

When applying AHP in a study, the process involves creating the hierarchy and evaluating each hierarchical layer. The basis of AHP analysis is to prioritize the elements involved in a complicated decision making model. The elements are placed as a hierarchy, which is compared in pairs to create a matrix and deduce the eigenvector. The matrix is also checked on its consistency to ensure the finding is eligible for use. Figure 5 is a flowchart on the process. An AHP structures includes three different kinds of layers: the goal, the objective, and the criteria. Researcher should consider the following points when constructing a hierarchy structure:

Figure 5: Flowchart on hierarchy analysis

(1) The top layer should represent the evaluation goal.

(2) The hierarchy should be defined based on the priority of each element. Elements that have similar level of importance should be placed at the same layer.

(3) The amount of elements in each layer should be limited to seven or less. Miller (1956) points out that human brain is only able to make comparison to less than seven items at the same time. Therefore, Saaty suggests that each layer should hold no more than seven elements in an AHP structure. If elements exceed the number, it's suggested to redefine the criteria and re-categorize elements into more than one layer. This is to ensure the result consistency.

(4) The elements in each layer should be independent against one another. If two or more elements are inter-dependent, it's suggested to analyze such elements separately from the independent ones first. The results are then combined to make a final analysis.

When making pairwise comparison, the evaluation may not be consistent throughout the survey. Therefore consistency should be checked to determine whether the difference is acceptable. A consistent result is important to the outcome of the result. To determine whether a pairwise comparison chart is consistent, Saaty suggests the Consistency Index (C.I.) should be kept at 0.1. The Consistency Index is the absolute deviation of the maximum eigenvalue (λmax) and n. The formula is

$$C.I. = (\lambda max - n)/(n-1) \quad (3)$$

The above formula is ideal for processing a single questionnaire. When the research involves multiple interviewees, the pairwise comparison matrix should be constructed based on the sum of questionnaire results and the geometric mean.

III. RESEARCH METHOD AND RESULT

The research focuses on the common factors that affect distributor and reseller's supplier selection within the communication and computing industry. The research methods include interviewing with experienced experts in the industry and literature discussion.

The interview target includes reseller and distributor of the communication and computing industry in Taiwan. Source of information includes literature and interview with relevant experts in the industry.

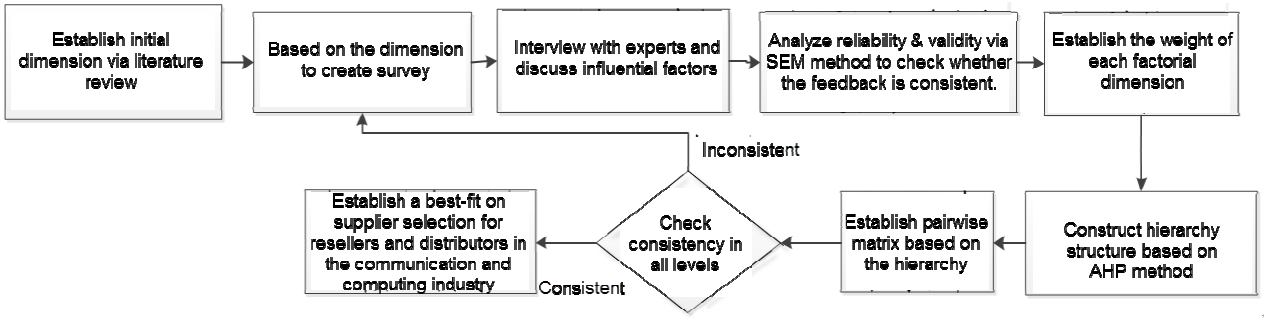


Figure 6: Research Flowchart

The goal of the research is to create a selection principle to determine the selection within communication and computing industry. The detailed process can be illustrated as the following flowchart (Figure 6). The following is an in-depth explanation on the steps shown in Figure 6:

1. Step 1: Organize literatures on the supplier selection in communication and computing industry. Determine the selection criteria mentioned in the literature.
2. Step 2: Perform initial evaluation on the possible reasons that affect reseller and distributor's supplier selection in the industry. Create a questionnaire based on the finding. List out experienced experts in the industry and arrange in-depth interview.
3. Step 3: Distribute questionnaire among experts in the industry and arrange selected follow-up interview based on the questionnaire. The feedback is later used to construct selection dimension. Since there may be unreturned or invalid questionnaires, 250 copies of questionnaires are distributed in this study.
4. Step 4: Analyze the reliability and the validity of the selection dimensions. The selection dimension determined by reseller and distributors are compared against the factorial dimension by experts. The goal is to check whether both sides have similar concern on supplier evaluation.
5. Step 5: Deduct the weight of each factorial dimension using the 5-step SEM analysis.

   (1) Create a structural model on reseller and distributor's supplier selection in the communication and computing industry. The model should be based on literatures and survey result. The model assumes that every two variables share either a cause-and-effect or a covariant relationship.

(2) Evaluate whether the structural model has enough data to obtain the model fit.

(3) Apply SEM to analyze the weight of each dimension that's involved in the supplier selection in the communication and computing industry.

(4) Following Step 3, the analysis result should generate multiple model fits for supplier selection.

(5) Select a best model fit for the situation. In this case, it's the reseller and distributor's supplier selection in the communication and computing industry. Analyze the result based on the model fit. If the index is under benchmark, the model should be modified and re-evaluated until an appropriate model fit and the weight of each dimension can be obtained.

6. Step 6: Obtain the weight of supplier selection dimension by construct a hierarchy structure on the supplier selection using AHP analysis.
7. Step 7: Once the weight of supplier selection dimension is deducted, apply Formula (3) to obtain a pairwise matrix based on each factor's importance level. Use Formula (4) to deduct the average row vector. Formula (5) is used to calculate the average column value. Use Fomula (6) to calculate column vector and reciprocal. Follow formula (7) to deduct the geometric mean of the rows. The data is used to construct a pairwise comparison matrix on reseller and distributer's supplier selection in the communication and computing industry.
8. Step 8: Once the pairwise comparison matrix is constructed, the research moves on to check the consistency of each level in the hierarchy. Formula (8) is used to examine if there is inconsistency in the matrix. The result derived from formula (8) is the Consistency Index (C.I.) The absolute deviation of maximum eignvalue is used as the benchmark. If C.I. is lesser or equal to 0.1, it indicates the result is consistent. The research can proceed to Step 9. However, if the result is inconsistent, the research must return to Step 3.
9. Step 9: If the research result is proven to be consistent, the result can be used to create a best fit model for the supplier selection in the communication and computing industry.

3.1 Determine the Factors Affecting Supplier Selection

The goal of the research focuses on resellers and distributors' supplier selection in Taiwan's communication and computing industry. The following is a list on the factors that affect supplier selection within the industry. The source comes from the study of this research.

Table 1: Factors affecting supplier selection in Taiwan's communication and computing industry.

Factor	Influential elements
Quality	System stability, operation time, usability, life expectancy, scalability
Price	Unit cost, discount, minimum order amount, profitability
Functionality	Visual device, USB 3.0, CD-ROM, numeric keypad, cost/performance value
Design	Exterior look, fashion brand, style
Flexibility	Purchase flexibility, lead time length
Location	Risky location, transportation risk and cost.
Delivery	Lead time, delivery precision, delivery ratio (the ratio between delivered goods

	and order amount), defective goods ratio
Service	Post-sales service, warranty, repair capability, technical support (professional level, Q&A)
Branding	Brand popularity, market share, company image
Cooperation	Contract liability, premium and authorized fund, reward and returns (include monetary offering or purchase priority), support and services, payment terms

3.2 Create an SEM Structure

By leveraging information in Table 1, an SEM structure on supplier selection for resellers and distributor in communications and computing industry is created. The SEM structure is illustrated as Figure 7:

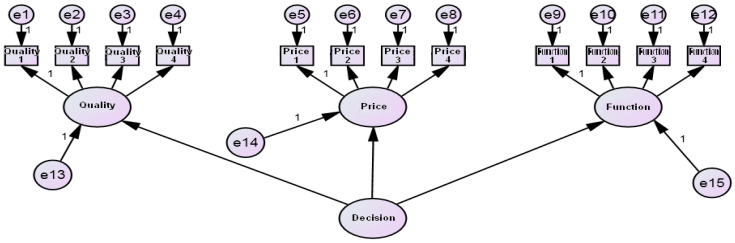


Figure 7: SEM structure on influential factors and elements

3.3 Design supplier selection questionnaire

Based on the SEM structure in Figure 7, a 3-tier questionnaire is created. The first tier focuses on the evaluation sequence of influential factors during supplier evaluation. The second tier focuses on the evaluation sequence of influential elements during the process. The third tier inquires interviewees whether their opinion stays unchanged when facing real-world scenario, especially when facing issues like the critical market downturn in 2007 and the Euro-zone crisis. The questionnaire is passed to experts within the communication and computing industry. The aim is to fully understand the weight between influential factors and elements in order to increase research accuracy.

3.4 Hierarchy structure

The hierarchy is divided into three levels. The first is the goal of the research. The second level contains the influential factors that are involved in the research. The third level is the evaluation principle. The hierarchy structure is as follows

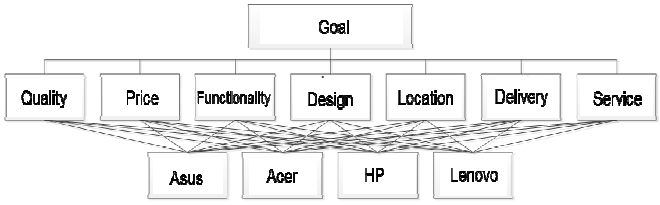


Figure 8: Hierarchy structure(Source: organized by the research)

3.5 Create AHP pairwise comparison matrix

The research uses Formula (1) and Formula (2) to examine the reliability and validity of questionnaire returned by experts in the communication and computing industry. All valid questionnaires are used to build up a pairwise comparison matrix. The figures are shown in Table 2.

Table 2: The weight of influential factors to suppliers

	Quality (0.166)	Price (0.166)	Functionality (0.073)	Design (0.166)	Location (0.166)	Delivery (0.166)	Service (0.095)	Total	Total weight	Ranking
ASUS	0.3	0.3	0.308	0.3	0.3	0.4	0.2	0.307	0.308	2

Acer	0.4	0.4	0.308	0.4	0.4	0.3	0.4	0.376	0.377	1
HP	0.2	0.1	0.231	0.2	0.2	0.2	0.3	0.195	0.195	3
Lenovo	0.1	0.2	0.154	0.1	0.1	0.1	0.1	0.120	0.121	4
							SUM =	0.998		

It is observed that when resellers and distributors order goods from the four suppliers, their selection priority is to consider Acer first, followed by ASUS, and followed by HP. Lenovo is the last supplier to consider.

IV. CONCLUSION

The research goal is to provide a reference on supplier selection for resellers and distributors in the communication and computing industry. The questionnaire helps to understand what factors affect the selection process. These factors are further analyzed in SEM model to examine the validity and the reliability of the questionnaires. Valid data is used to examine factor loading and discuss whether the latent variables are sufficient to explain observed variables. The weight is used to create an AHP hierarchy to examine result consistency. In this study, the result is found to be consistent, indicating the research is valid. The final example illustrates the study is applicable to real-world scenario. It's expected that this research can be applied as a supplier selection reference in the communication and computing industry.

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