台灣耐火材料業供應鏈彈性之探討

A Study of Supply Chain Flexibility for Refractory Industry in Taiwan

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Abstract

Taiwan economics miracle was created by diligent entrepreneurs with devotion working on its small and medium sized firms to compete in international market since 1970s. The achievement of Taiwan economic miracle contributes the devotion of small and medium organization which possess flexibility responding to uncertain and fast change business world.

Flexibility has been considered as a major determinant of competitiveness in an increasing intense competition in the market. A number of literatures has been proposing various issues of flexibility in latest years. In line with the advent of the supply chain management concepts, enterprises have been realizing that being flexible in a production system only is insufficient. Thus, flexibility concepts should be broadened from the perspective of enterprise to enterprise into a supply chain to supply chain system.

Refractory industry is a historical and elemental industry in Taiwan, their consumption is too small to attract the concern and care from the authority of government. As a result the enterprises have to find their own way to compete with local competitors for pricing competition, but also face strong competition from high technology and resources international firms.

This study presents a framework for assessing flexibility of a supply chain. Six main parts of flexibility are identified including flexibility of the product, volume, sourcing, delivery, responsiveness and launch flexibility. In each of these dimensions, a number of sub-criterion are defined. Interviewed with experts from the upstream and down steam of supplier chain, analyzed the experts content, and computed the weight of AHP methodology, this study found out that delivery, launch and responsiveness flexibility are the most significant flexibilities in the supply chain of refractory

As a result, to improve performance of refractory enterprises, delivery, launch and responsiveness flexibility are deem to be the first priority to improve. Or when the enterprise make company's strategy is a good indictor to consider.

Keywords: refractory industry, supply chain flexibility, sourcing flexibility, responsiveness flexibility, launch flexibility

Chapter 1 Introduction

1.1 Background

American Chamber of commerce in Taipei released 2009 Taiwan White Paper, According to state in the 2009 White Paper report, the Taiwan government has become increasingly aware of the difficulties many Taiwan exporters will face

if they are excluded from the enlarged regional trade bloc that is emerging as the 10 ASEAN nations begin implementing Free Trade Agreement (FTAs) with China, South Korea, and Japan respectively. From 2005, ASEAN and China have already started tariff reductions, and on January 1, 2010 a large proportion of the products traded among ASEAN, China, Korea, and Japan is likely become duty free. If Taiwan does not achieve a trade agreement with China, it is possible that as early as January 1 next year Taiwan will be at a considerable duty disadvantage in trade with China compared with the 10 ASEAN countries, South Korea, and Japan. For industry and other commodity business, as well as downstream industries and other important manufacturing sectors, that gap would potentially have a huge impact on Taiwan's international competitiveness. The absence of such a breakthrough, likely impact would include substantial loss in export revenues and profitability and manufacturers industries.

As the globalization is a trend that inevitable as a member of global society. Ma administration open business politics and economics environment with world, attract more and more foreign investment to Taiwan. The future of Taiwan looks brighten. However, as an open and free market, still, plenty of obstacles in the way need to solve one by one. Taiwan faced pressure between competition from low labor cost from South East Asia countries (i.e. Thailand, Indonesia, Vietnam etc.) and China, and high quality pressure mainly from government leading strategy countries like South Korea, Singapore. How to survive in today's severe competition business world? It require enterprises to develop strategies. Taiwan enterprises also aware the trend of market growth and rapid evolution, to face more and more unpredictable demands, to fit in more products variety and shorter leading time. Creating highly value added, creating flexibility of enterprises is one response to deal with such challenges facing the global competition, rapidly changing technology and shorter product life cycles.

Since human-being use fire for living, refractory accompanied with fire in life. In general, refractory is used to build structures subjected to high temperatures, ranging from the simple to sophisticated. Refractory industry in Taiwan established in 1918 since Japanese colony period. With the characteristics apply for high heat, refractory become one of the essential materials for basic heavy industry.

Refractory is a user's orientation industry, supplier have to provide what customer's need. As demand extensively by time from basic living field transfer to iron& still, cement, and petro-chem industry. With high tech developing, new material adopting, high end refractory product develop day by day. (陳新上,2006）

1.2 Research Motivation

Understanding supply chain flexibility (SCF) is crucial for many reasons. First of all, as a global trend, such as tailor-made, require supply chains to meet individual customer requirements without adding significant cost (Gilmore and Pine 1997).

Secondly, certain industries, particularly high-tech, require upside and downside flexibility (Hausman 2003). Thirdly, uncertainty of demand is a fact of life and creating a responsive supply chain is one method of avoiding uncertainty (Fisher 1997). Last, companies requires rapid new product introduction, quick response to consumer requirements and orders. In line with competition in the supply chain and time consuming, the flexibility of the supply chain become a critical issue in modern organization.

Refractory industry developed continuously but mainly focused on national defense till to China Steel Corp established in 1971. To upgrade the industry and the development of the country, the government planned to take on ten massive building projects. One of the ten major construction projects is, China Steel Corporation (CSC), the largest integrated steel maker in Taiwan. As high end technique demand by Blast Furnace of steel plant, refractory industry transformed to new stage. Steel and iron share refractory consumption around 70%, the remaining 30% are

for cement, petro-chemical, incinerator and power plant etc.

As Taiwan is a tiny island lacking of natural resource locate in Asian Pacific, politically isolate and block out by China in the world. For refractory manufacture and supplying chain, all raw materials has to import from overseas, especially main aggregates import from China, whereas, supply chain flexibility are vital in the field. Besides that, market demanding scale is limited, technical boundary to access this market is low, competition is severe not only with local makers but also challenge from multi-national leading company.

For reliable and stable resource, in time delivery with cost effective, are main obstacles that refractory industry meet in Taiwan. This study aims to select and defines the importance of supply chain flexibility, then find out priority of flexibility, and its key sub-criteria, providing solution and view point from upstream to downstream of supply chain for managing decision.

1.3 Objectives of Research

The objectives of this research is to define flexibility dimensions of supply chain firstly, to evaluate and weight of importance of flexibility and its criterion. A framework helps clarify supply chain flexibility goal, identify managerial actions that improve supply chain performance in refractory industry of Taiwan.

(1) Determined key dimensions of supply chain flexibility

(2). Assessing the selected dimension of supply chain flexibility

(3). Computing the relative importance of flexibility in each dimension

(4) Computing the relative importance of sub-criteria in each flexibility

(5). Providing the result for refractory enterprise as consideration for managing purpose. Strength the advantage the enterprise, as well as improve the disadvantages

1.4 Research Scope and Limitation

This research mainly target on supply chain flexibility impact on manufacturing industry, connecting with a conventional industry, refractory industry. There are many types of subjects in industrial classification, not all subjects can be assessed in details. Plus limitation of information gathering from the authority of the industry, as well as resources, time and money constrain in this study. These limitations may cause bias in this study, however, hope that the following studies can provide a solution regardless of limitation.

1.5 Research Process

This study designed research process in order to reach the purpose of research. Figure 1.1 illustrates the research process. First, we had our research motivation. According to research motivation, we did data collection to define topic and purpose. Then, we did literature review and set up a framework of supply chain flexibility to evaluate research dimensions. Follow by expert interview, to design AHP questionnaire. Analysis the weight by AHP tool, we did phenomenon analysis and make conclusion.

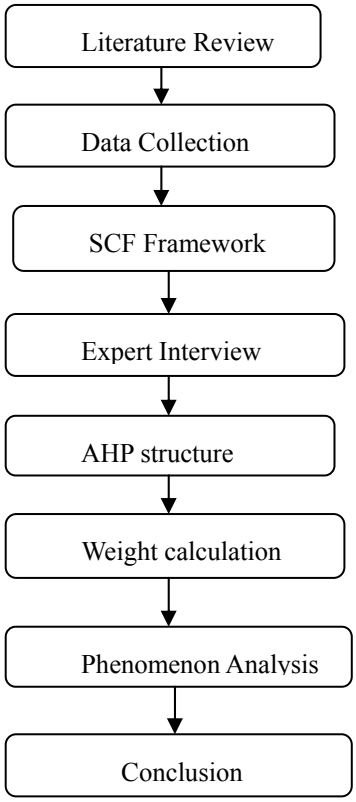

Figure 1. 1 Research Process

Chapter 2 Literature Review

2.1 Flexibility

Upton (1994,1995) defined flexibility as a kind of ability to change or react with little penalty in time, effort, cost or performance. Flexibility can extend the range of products available, improving a firm's ability to respond quickly, and achieving good performance better. Researchers and manufacturing managers struggle that flexibility is a strategic imperative that enables firms to cope with uncertainty (Gerwin, 1987; Sethi and Sethi, 1990). Flexibility is one of the organization ability that increasing variety for customer to meet their expectations without extreme cost, time, labor resource, or quality losses. Flexibility can be understood as characteristic of the interface between a system and its external environment (Correa, 1994). Flexibility likes a degree of homeostatic control and dynamic efficiency in a system 9Mariotti, 1995). Reference is made to a cybernetic system which incorporates mechanisms of measurement, control and regulation aimed at homeostasis, which is to say at the preservation of an existing state in the presence of exogenous changes. Flexibility is thus mainly understood as a degree of cybernetic adaptation (Toni and Tonchia, 1998).

Leeuw and Volberda (1996) treat flexibility as a two-dimensional concept: (1) first, flexibility is seen as a management task and the concern is the extensiveness of control capacity with respect to the environment (i.e. the organization is defined as a controlling organ and the environment as a target system, so flexibility means the ability to successfully control the environment); (2) flexibility is seen as an organization design task and the concern is the controllability of the organization from the environment (i.e. the environment is defined as a controlling organ and the organization as a target system, so high flexibility corresponds with low controllability from the environment). (i.e. the environment is defined as a controlling organ and the organization as a target system, so high flexibility corresponds with low controllability from the environment).

This two- Dimensional conception of flexibility creates a paradox: an organization must possess some procedures

which enhance its flexibility in order to avoid becoming rigid, but it must also be anchored in some way in order to avoid chaos. Slack (1987) concludes that flexibility is completely described by the range of possible states; the time needed to move from one state to another; the cost needed to change the state.

Newman et al. (1993) define flexibility as a fundamental instrument for dealing with uncertainty. The counterbalancing action of flexibility towards uncertainty may be represented by the two plates of a balance, one of which represents flexibility, and the other is uncertainty. Uncertainty can be explained in external and internal uncertainty. External Uncertainty is the demand or the supply of the market and internal uncertainty as failures, lack of materials, delays. Flexibility is able to defined for each machine (therefore on technological grounds) and for each plant (therefore on managerial grounds)and for each plant (therefore on managerial grounds). Internal uncertainty is not independent from external uncertainty; it's sufficient to mention supply and the integration with the suppliers; the uncertainty of the supply (external) also has consequences on the uncertainty of operations within the firm (in terms of quantity and quality of the materials to be processed).

Kim (1991) analysis flexibility along the "value chain". Similarly to Porter's "cost drivers", "flexibility drivers" are found which determined the flexibility of the nich value-generating macro-activities (between brackets are reported some drivers for each type of macro-activity).

2.2 Supply Chain Flexibility

In the book "Supply Chain Management", Chopra and Meindl (2001) define:"A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request.". "The supply chain includes manufacturer , suppliers. In an organization, such as a manufacturer, the supply chain includes all functions involved to satisfy a customer request."

"A supply chain is dynamic and involves the constant flow of information, product and funds between different stages. Each stage of the supply chain performs different process and interacts with other stages of the supply chain.".

On the other hand, in the 1980s and 1990s studies just focused on manufacturing flexibility and these studies confined the study of flexibility to intra-organizational components and to production environment, such as mix, product, volume and routing flexibility. With growth in outsourcing many managers now realize that, as firms successfully streamline their own operation, the next opportunity for improvement need to manage and integrate the whole value chain from raw material provider to final consumer (Stevenson ,2007; Johnson,1999)

Manufacturers must find a way to align their supply chain partners with a common set of goals and metrics to ensure that all the elements of the supply net work are focused on flexibility, speed and cost." (Wimer, 2001)

The objective of every supply chain is to maximize the overall value generated to the customer. Supply chain management is , activities include delivering a product from sourcing raw materials , manufacturing, warehousing, order management, distribution across all channels, delivery to the customer and the information system.

Flexibility in the supply chain adds the requirement of flexibility within and between all partners in the chain, inclusive departments in an organization, the external partners. This includes the flexibility to gather information on market demands and exchange information between organizations.

2.2.1 Dimensions of supply chain flexibility

To define the priority of the flexibility dimensions, and determine the dimensions, table 2-1 shows flexibility dimensions selected and supported by 3 scholars.

(1) Product flexibility:

The ability cope with customer's special orders or request. Product flexibility is a value-adding attribute that

is immediately visible to the customer. (Giunipero et al, 2005). Product flexibility is determined by the ability of the company to produce various new designs in a timely and cost-effective manner. (Pujawan 2004)

(2) Volume flexibility

Volume flexibility refers to the ability to quickly and efficiently adjust output to match demand. Having a wide range on volume for which a plant can operate efficiently as measured by production costs, quality levels, or system profitability indicates a high level of flexibility. One question in this measure should be how to include the cost of changing input volumes. Volume flexibility defined as ability to effectively increase or decrease aggregate production in response to customer demand (Giunipert et al, 2005)

(3) Routing flexibility

It is the capability of processing various routes by using alternative materials and flexible network.

This flexibility reduce the negative impact of environmental uncertainty and unforeseen inefficiencies in the production process (Gupta and Buzacott, 1998).

(4) Delivery flexibility

It is a capability to adapt the leading time for customer's requirements. The ability of the supply chain to deliver different types of products to the customers in various volume with cost and time efficiency. W

To satisfy requirements such as small quantity or urgent delivery immediately, a delivery system should have the capability to either mix different product into a truckload and/or use different modes of transporation. (Pujawan 2004). It's an ability to cost effectively receives and deliver product as source of supply and customer change.(Duclos, et al, 2003)

(5) Sourcing flexibility

It's an ability in line with the company to find another supplier for product or raw materials. Narasimhan and Das (2000) observe that for a company to compete through flexibility, the sourcing or supply practices are quite important.

One of the keys in achieving supply chain flexibility is flexibility of any activities related to procurement of materials. Often it is the ability of the suppliers that limits the ability of a manufacturer to respond rapidly to customer requirements (Christopher 2000).

The sourcing function is said to be flexible if it has sufficient extra supply capacity to anticipate sudden increase in the volume of materials required, the suppliers are able to delivery materials in various different speed options and to mix different items into a delivery load so that small request can be satisfied easily (Pujawan ,2004).

Sanchez (1995) proposes that strategic flexibility is composed of two dimensions: resource flexibility and coordination flexibility. As in Swafford et al. (2000) considered four dimensions of supply chain flexibility are sourcing, product design, manufacturing/production and delivery.

(6) Responsiveness flexibility

Responsiveness to target market is a flexibility dimension response to market flexibility. Responsibility for this flexibility spread throughout the supply chain to meet customer requirements.

This is a firm's ability to leverage supply chain capabilities to meet exceeded customer needs. (Vickery, et al., 1999) (Sanchez and Perez, 2005).

This flexibility captures the overall ability of the firm tpo respond to the needs of its target markets

(McDonald, 1993).

(7) Launch flexibility

The ability rapidly introduces many new products. Integration of activities across the entire supply chain.

Being first to market generates a variety of competitive advantages; scale and experience economy advantages, innovation leadership advantage, quality image perception advantage, and market share and profitability advantage (Lieberman and Montgomery, 1988; Robinson et al., 1992)

Vickery et al. (1999) defined five flexibilities include, product flexibility, volume flexibility, new product flexibility or the ability to launch new or revised products, distribution flexibility or the ability to provide widespread access and responsiveness flexibility

(8) Access flexibility

Access flexibility is facilitated by close coordination between supply chains downstream.

It's described as logistics flexibility which is ability to cost effectively receives and deliver product as source of supply and customer change. (Duclos, et al., 2003).

As appropriate, closer to customer means closer in time more than distances. (Christopher, et al., 2002).

Table 2-1 Supply Chain Flexibility Dimensions

Flexibility					
Product	Vickery, et al. (1999)	Martinez Sanchez, 2005	Duclos, et al. (2003)	Giunipero et al. (2005)	Pujawan (2004)
Volume	Vickery, et al. (1999)	Eric, et al. (2003)	Duclos, et al. (2003)	Giunipert et al,(2005)	
Routing	Gupta and Buzacott, 1998	Duclos, et al, 2003			
Delivery	Pujawan, (2004)	Duclos, et al, 2003	Christopher, et al, 2002	Swafford et al. (2000)	
Sourcing	Narasimhan and Das, 2000	Christopher, 2000	Pujawan, 2004	Sanchez (1995)	Swafford et al (2000)
Responsiveness	Vickery et al ,1999	Sanchez and Perex (2005)	McDonald, 1993		
Launch	Lieberman and Montgomery, 1988	Robinson et al., 1992	Vickery et al ,1999		
Access	Vickery et al ,1999	Sanchez and Perex ,2005			

2.3 Refractory industry

As state in the book "Refractory of Practice", Refractories are heat-resistant materials that constitute the linings for high-temperature furnaces and reactors and other processing units. In addition to being resistant to thermal stress and other physical phenomena induced by heat, refractories must also withstand physical wear and corrosion by chemical agents. Refractories are more heat resistant than metals and are required for heating applications above 1000°F (538°C). Refractory products fall into two categories: brick or fired shapes, and specialties or monolithic refractories. Refractory linings are made from these brick and shapes, or from specialties such as plastics, castables, gunning mixes or ramming mixes, or from a combination of both.

Depending upon the application, refractories must resist chemical attack, withstand molten metal and slag erosion,

thermal shock, physical impact, catalytic heat and similar adverse conditions. Since the various ingredients of refractories impart a variety of performance characteristics and properties, many refractories have been developed for specific purposes.

Chapter 3 Methodology

3.1 Content Analysis

After World War II, and perhaps as the result of the first integrated picture of content analysis provided by Borelson (1952), the use of content analysis spread to numerous disciplines. Content Analysis has its own approach to analyzing data unit stems largely from now the object of analysis. Contents is conceived. (Krippendorff, 2004)

Content Analysis is a research technique for making replicable and valid inference from tests or other meaningful matter to the contexts of their use.

As a technique, Content Analysis involves specialized procedures. It is learnable and divorceable from the personal authority of the researcher. As a research technique, content analysis provide new insights increase a researches understanding of particular phenomena or informs practical actions.

3.2 Expert interview

The interview is the primary data collection technique for gathering data in qualitative methodologies. Interviews vary based on the number of people involved during the interview, the level of structure, the proximity of the interviewer to the participant, and the number of interviews conducted during the research. In interview can be conducted individually or in groups.(Cooper & Schindler, 2006)

3.3 Analytic Hierarchy Process (AHP)

The AHP methodology, which was developed by Satty (1980), is a powerful tool in solving complex decision problems. The AHP helps the analysts to organize the critical aspects of a problem into a hierarchical structure similar to a family tree. By reducing complex decisions to a series of simple comparisons and rankings, then synthesizing the results, the AHP not only helps the analysts to arrive at the best decision, but also provides them a clear rationale for the choices made (Chin et al., 1999).

In the AHP approach, the decision problem is structured hierarchically at different levels with each level consisting of a finite number of decision elements. The upper level of the hierarchy represents the overall goal, while the lower level consists of all possible alternatives. One or more intermediate levels embody the decision criteria and sub-criteria (Partovi, 1994)

Satty (1980) states that in many practical cases the pairwise judgments of decision makers will contain some degree of uncertainty. It is usually the case that the decision maker is certain about the ranking order of the comparison elements but uncertain about the precise numerical values of his judgments. The classical AHP attempts to overcome this problem by introducing a discrete linguistic set of the comparison ratios, the decision maker chooses an appropriate linguistic phrase, best corresponding to his comparison preferences.

Assume that one is given n stones, A1,….An, with known weights w1…, wn, respectively, and suppose that a matrix of pairwise ratios is formed whose rows give the ratios of the weights of each stone with respect to all others. Thus one has the equation:

Where A has been multiplied on the right by the vector of weights w. The result of this multiplication is nw. Thus, to recover the scale from the matrix of ratios, one must solve the problem Aw=nw or

(A-nI)w=0. This is a system of homogenenous linear equations. It has a nontrivial solution if and only if the determinant of A-nI vanishes, that is, n is an eigenvalue of A. Now A has unit rank since every row is a constant multiple of the first row. Thus all its eigenvalues except one are zero. The sum of the eigenvalues of a matrix is equal to its trace, the sum of its diagonal elements, and in this case the trace of A is equal to n. Thus n is an eigen value of A, and one has a nontrivial solution. The solution consists of positive entries and is unique to within a multiplicative constant.

To make w unique, one can normalize its entries by dividing by their sum. Thus, given the comparison matrix, one can recover the scale. In this case, the solution is any column of A normalized. Notice that in A the reciprocal property $a_{ji}=1/a_{ij}$ holds; thus, also $a_{ij}=1$, Another property of A is that it is consistent; its entries satisfy the condition $a_{ji}=a_{ik}/a_{ij}$. Thus the entire matrix can be constructed from a set of n elements which form a chain across the rows and columns.

In the general case, the precise value of w_i/w_j cannot be given, but instead only an estimate of it as a judgment. For the moment, consider an estimate of these values by an expert who is assumed to make small perturbations of the coefficients. This implies small perturbations of the eigen value. The problem now becomes A'w'=λ_{max} w' whereλ_{max} is the largest eigen value. To simplify the notation, we shall continue to write A'w'=λ_{max} w', where A is the matrix of pairwise comparisons. The problem now is how good is the estimate of w. Notice that if w is obtained by solving this problem, the matrix whose entries are W_i/W_j is a consistent matrix. It is a consistent estimate of the matrix a. A itself need not be consistent. In fact, the entries of A need not even be transitive; that is, A_i may be preferred to A_2 an A_2 to A_3 but A_3 may be preferred to A_1. What we would like is a measure of the error due to inconsistency. It turns out that A is consistent if and only ifλ_{max}=n and that we always have $\lambda_{max} \geqq$ n.

$$A \times W = \lambda \times W$$

$$(A - \lambda I) \cdot W = 0$$

$$W = \begin{Bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{Bmatrix}$$

$$A \times W = W'$$

$$\begin{Bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{Bmatrix} \times \begin{Bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{Bmatrix} = \begin{Bmatrix} W'_1 \\ W'_2 \\ \vdots \\ W'_n \end{Bmatrix}$$

$$\lambda_{max} = \frac{1}{n}\left\{\frac{W'_1}{W_1} + \frac{W'_2}{W_2} + \cdots + \frac{W'_n}{W_n}\right\} \qquad (1)$$

Since small changes in any imply a small change inλ_{max} the deviation of the latter from n is a deviation from consistency and can be represented by (λmax-n)/(n-1), which is called the consistency indiex (C.I.). When the consistency has been calculated, the result is compared with those of the same index of a randomly generated reciprocal matrix form the scale 1 to 9, with reciprocals forces. This index is called the random index (R.I.). The following gives the order of the matrix and the average R.I.

Table 3- 1 Ranking R.I.

The ratio of C.I. to the average R.I. for the same order matrix is called the consistency ratio (C.R.). A consistency ratio of 0.10 or less is positive evidence for informed judgment.

$$C.I = (\lambda_{max} - n) / (n - 1) \quad (2)$$

$$C.R = C.I/R.I \quad (3)$$

Chapter 4 Data Analysis

This study used three analysis stages, two questionnaires to collect data. At the first stage, each supply chain flexibility dimensions were determined based on the review of prior literature and methodology of "Consent Analysis" agreed by at least three scholars, finally six dimensions were selected. In the second stage, the selected dimensions acted as mainframe into the first questionnaire. To verify the validity and reliability of the questionnaire, the questionnaire submitted to key persons or top management in the refractory supply chain for scoring, including suppliers, customers and the refractory producer. Eliminated the criterion were scored under 27 points , output the 2nd questionnaire provided in the appendix 2 with 30 sub-criterion retention and six dimensions for weighting AHP score. The 3rd questionnaire were submitted to 11 experts for scoring. The experts also indicated their degree of preference between and within the criteria at each level of the hierarchy in a pairwise form using Satty's scales ranging from 1-equally preferred to 9-extremely preferred.

4.1.1Basic information Analysis

The objective of this study is based on refractory industry in Taiwan. The supply chain of refractory industry mainly focus on raw material, manufacturing, and application at customer end.

This study used all dimensions of the questionnaire to carry out descriptive statistical analysis.

4.1.2 The analysis of sampling interviewees

To meet with objective of supply chain flexibility, the interviews undertaken with 11 key persons from relevant departments & companies, including customers, suppliers and top management of a refractory manufacturer. Five from customers(three superiors from China Steel Corp; one superior from Formosa group, sales manager from Calderys Japan); three from raw material suppliers, three key persons from a refractory manufacturer. (one purchaser two top management).

4.2 AHP Analysis

This study adopt MATLAB computing software as a tool to compute , weight and analyze the influence of dimension and criteria of supply chain of refractory industry in Taiwan. Determine the weight and preferential order for management.

The top level of the hierarchy represents the ultimate goal of the problem, while the second level of the hierarchy consists of six main supplier selection dimensions, which are namely product, volume, sourcing, delivery, responsiveness and launch flexibility. At the third level, these criteria are decomposed into various sub-criteria that may affect the choice for each flexibility.

4.3 Calculation of the weights of the level two

Use MATLAB to conduct matrix computation in order to find eigenvalue & weights. A consistency ratio of 0.10 or less is positive evidence for comparison.

Product flexibility dimension, volume flexibility dimension, sourcing flexibility dimension, delivery flexibility dimension, responsiveness flexibility dimension, and launch flexibility dimension, six dimensions were selected and have scored by eleven experts in different level of supply chain flexibility as customer's point of view, supplier's point of view and manufacturer's view point.

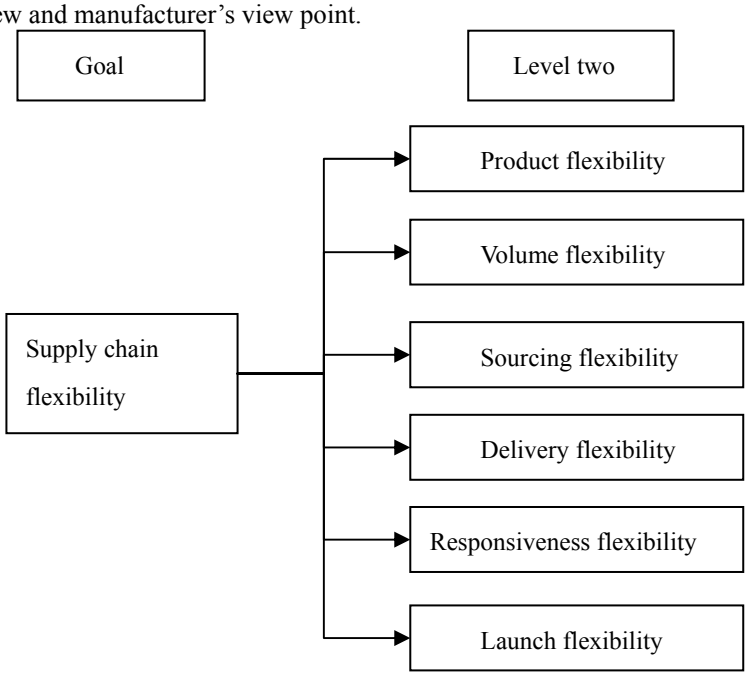

Figure 4. 1 Supply chain flexibility

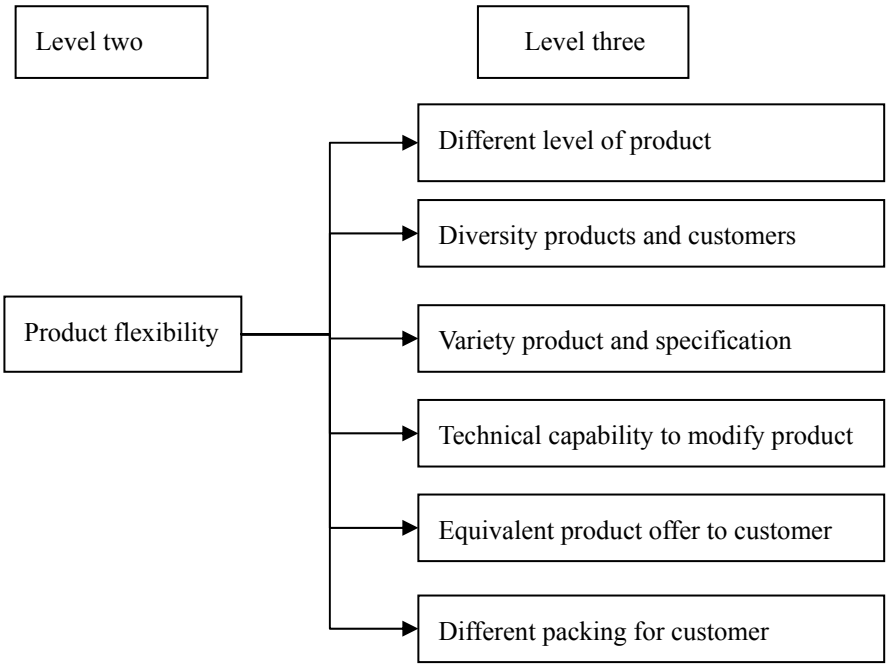

Figure 4. 2 Product flexibility

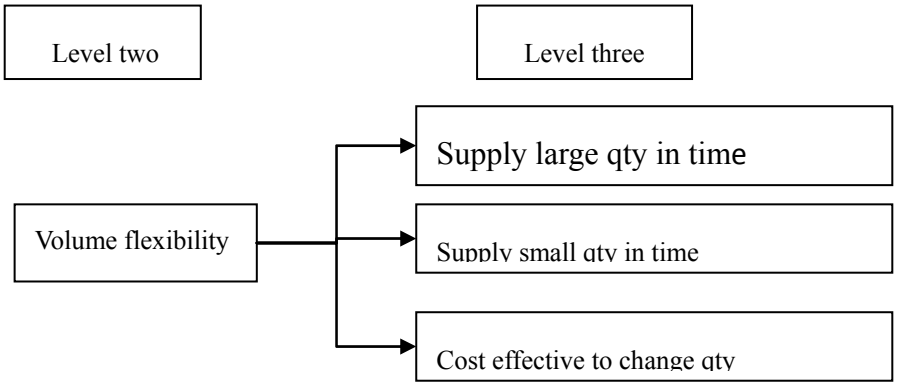

Figure 4. 3 Volume flexibility

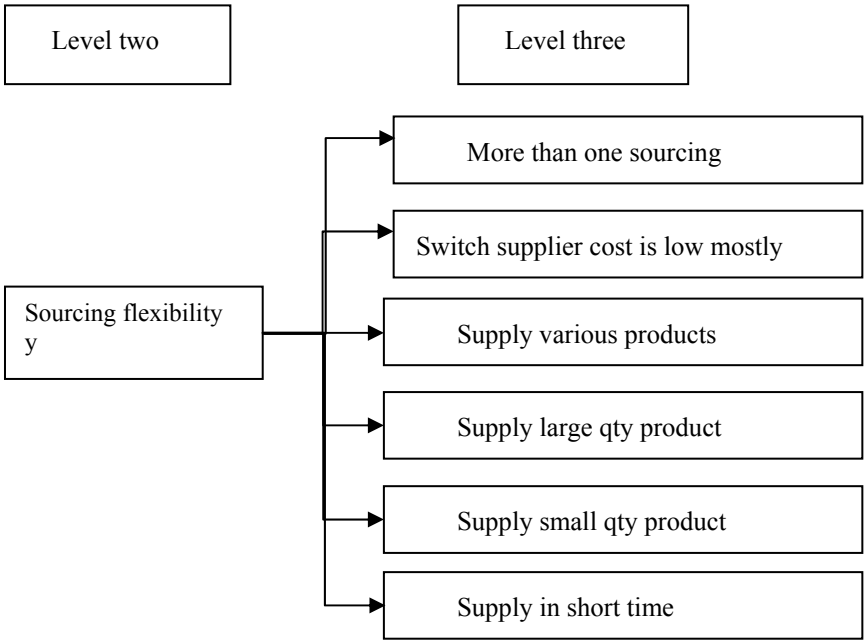

Figure 4.4 Sourcing flexibility

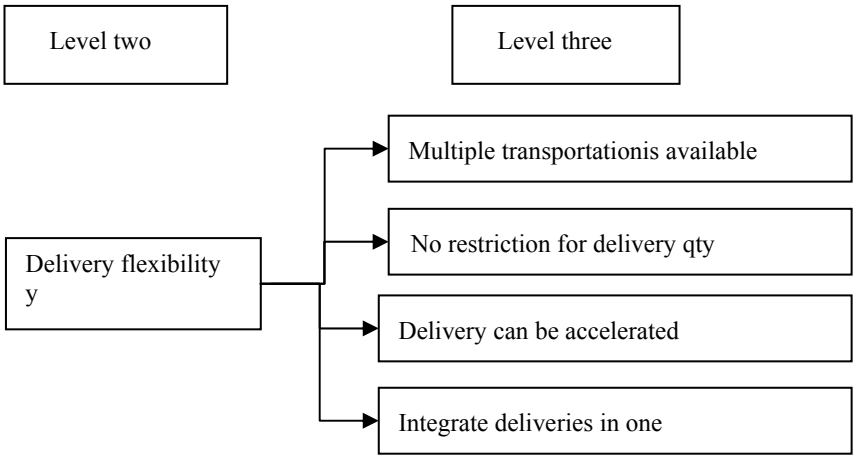

Figure 4. 5 Delivery flexibility

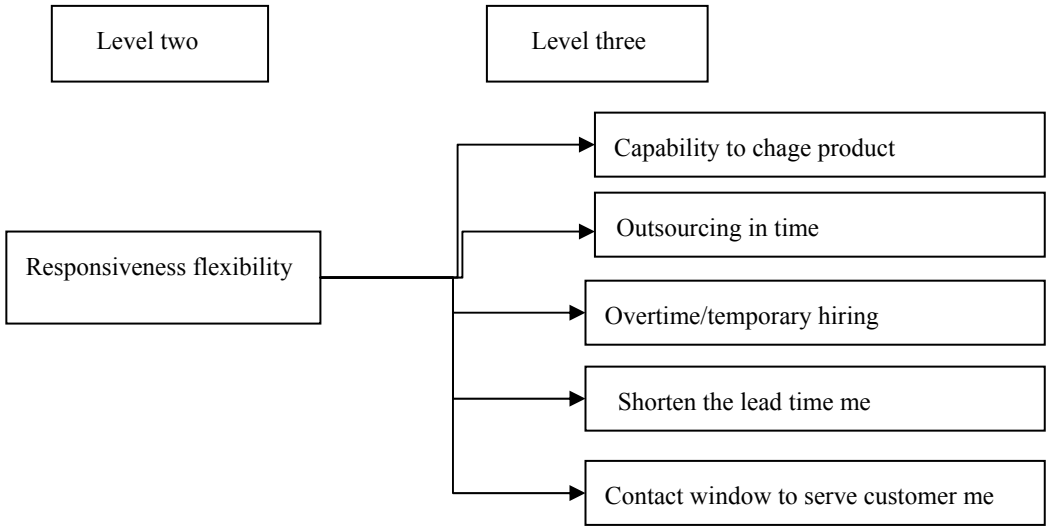

Figure 4.6 Responsiveness flexibility

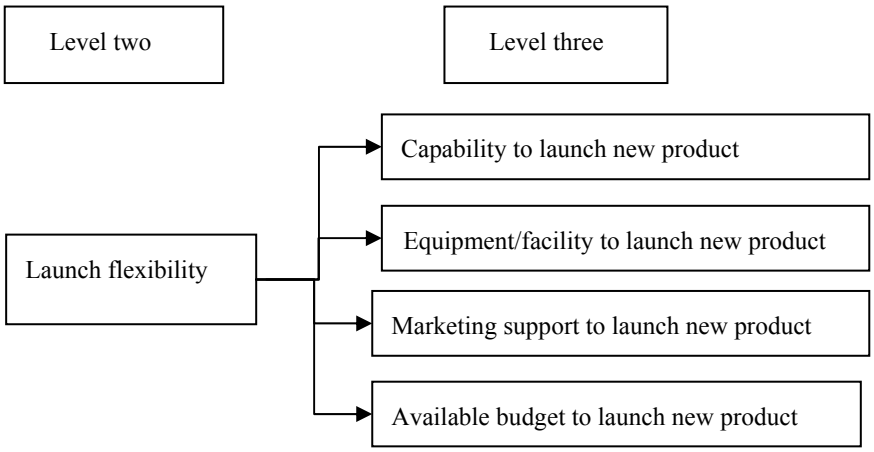

Figure 4. 7 Launch flexibility

4.3.1 Weight analysis for level two in supply chain flexibility

To realize the importance, difference and preference of priority in different level of the supply chain, further analysis for the weight and result of customers, suppliers and top management of a refractory manufacturer were followed for level two.

Table 4- 1 Customers weight Ranking of level two

Supply chain flexibility	Customer	Ranking
Product flexibility	0.113	4
Volume flexibility	0.090	6
Sourcing flexibility	0.091	5
Delivery flexibility	0.269	1
Responsiveness flexibility	0.176	3
Launch flexibility	0.261	2
C.I.	0.10	
C.R.	0.08	

Table 4- 2 Supplier weight Ranking of level two

Supply chain flexibility	Supplier	Ranking
Product flexibility	0.246	2
Volume flexibility	0.071	6
Sourcing flexibility	0.072	5
Delivery flexibility	0.455	1
Responsiveness flexibility	0.082	3
Launch flexibility	0.075	4
C.I.	0.09	
C.R.	0.07	

Table 4- 3 Top management of a manufacturer weight ranking for level two

Supply chain flexibility	Manufacturer	Ranking
Product flexibility	0.193	2
Volume flexibility	0.133	4
Sourcing flexibility	0.274	1
Delivery flexibility	0.189	3
Responsiveness flexibility	0.105	5
Launch flexibility	0.105	5
C.I.	0.11	
C.R.	0.09	

Table 4- 4 Supply chain weight Ranking of level two

Supply chain flexibility	AVERAGE	Ranking
Product flexibility	0.149	4
Volume flexibility	0.098	6
Sourcing flexibility	0.112	5
Delivery flexibility	0.294	1
Responsiveness flexibility	0.152	3
Launch flexibility	0.194	2
C.I.	0.09	
C.R.	0.07	

In line with the computation result, in the loop of supply chain flexibility delivery flexibility was hierarchy in the top priority by 0.294. Launch flexibility ranked in the 2nd at 0.194. Responsiveness flexibility was in the third by 0.152, just a bit higher than product flexibility by 0.149.

This result prove that delivery flexibility from bottom of supply chain to top mainly focus on in time and speedy delivery with cost effective consideration. In the mean time, innovation of product is demanded in the supply chain. In addition to, a certain channel to serve and respond to customers requirement rapidly is indispensible in enterprises of refractory industry.

4.3.1.5. Conclusions of weight calculation result for level two

An overview of weight for individual party in the chain, it recognized that in different anchor that preference of flexibility may differ. Nevertheless, delivery flexibility was always in the top of three weights in the view point of all supply chain. As a result, this is no surprise to see that delivery flexibility ranked in the top among the selected flexibilities. This result also explains that agility in manufacturing industry of Taiwan is of the first magnitude.

Even refractory industry is a historical and conservative industry in Taiwan, however product life circle is considering to meet customer's satisfaction in this rapid change world. In line with this trend, new product launch flexibility and fast responsiveness are another key concerns in the supply chain loop of refractory industry in Taiwan.

4.3.2 Weight analysis for level three in supply chain flexibility

This stage involves construction of 28 sub-criteria under six dimensions. Experts indicated their degree of preference between and within the criteria at the third level of the hierarchy in pairwise. The weight calculation of each criteria to obtain the overall score of each flexibility and hierarchy the priority for managing purpose.

Table 4- 5 Customers weight ranking of product flexibility

Product flexibility sub-criteria	Customer	Ranking
Different level of product development	0.216	2
Diversity products and customers	0.135	3
Variety product and specification	0.092	5
Technical capability to modify product	0.382	1
Equivalent product offer to customer	0.118	4
Different packing for customer	0.057	6
C.I.	0.07	
C.R.	0.06	

Table 4- 6 Supplier weight ranking of product flexibility

Product flexibility sub-criteria	Supplier	Ranking
Different level of product development	0.226	2
Diversity products and customers	0.290	1
Variety product and specification	0.145	4
Technical capability to modify product	0.207	3
Equivalent product offer to customer	0.084	5
Different packing for customer	0.047	6
C.I.	0.09	
C.R.	0.07	

Table 4- 7 Manufacturer weight ranking of product flexibility

Product flexibility sub-criteria	Manufacturer	Ranking
Different level of product development	0.129	4
Diversity products and customers	0.088	5
Variety product and specification	0.159	3
Technical capability to modify product	0.338	1
Equivalent product offer to customer	0.236	2
Different packing for customer	0.050	6
C.I.	0.07	
C.R.	0.06	

Table 4- 8 Overall weight ranking of product flexibility

Product flexibility sub-criteria	AVERAGE	Ranking
Different level of product development	0.197	2
Diversity products and customers	0.166	3
Variety product and specification	0.140	5
Technical capability to modify product	0.299	1
Equivalent product offer to customer	0.143	4
Different packing for customer	0.055	6
C.I.	0.08	
C.R.	0.06	

Table 4- 9 Customers weight ranking of volume flexibility

Volume flexibility sub-Criteria	Customer	Ranking
Supply large qty in time	0.378	2
Supply small qty in time	0.241	3
Cost effective to change qty	0.381	1
C.I.=	0.02	
C.R.=	0.03	

Table 4- 10 Supplier weight ranking of volume flexibility

Volume flexibility sub-Criteria	Supplier	Ranking
Supply large qty in time	0.682	1
Supply small qty in time	0.236	2
Cost effective to change qty	0.082	3
C.I.=	0.05	
C.R.=	0.09	

Table 4- 11 Manufacturer weight ranking of volume flexibility

Volume flexibility sub-Criteria	Manufacturer	Ranking
Supply large qty in time	0.632	1
Supply small qty in time	0.150	3
Cost effective to change qty	0.218	2
C.I.=	0.02	
C.R.=	0.03	

Table 4- 12 Overall weight ranking of volume flexibility

Volume flexibility sub-Criteria	AVERAGE	Ranking
Supply large qty in time	0.422	1
Supply small qty in time	0.210	3
Cost effective to change qty	0.368	2
C.I.=	0.02	
C.R.=	0.03	

Table 4- 13 Customers weight ranking of sourcing flexibility

Sourcing flexibility sub-criteria	Customer	Ranking
More than one sourcing	0.203	3
Switch supplier cost is low mostly	0.066	6
Supply various products	0.119	5
Supply large qty product	0.214	1
Supply small qty product	0.192	4
Supply in short time	0.205	2
C.I.=	0.05	
C.R.=	0.04	

Table 4- 14 Supplier weight ranking of sourcing flexibility

Sourcing flexibility sub-criteria	Supplier	Ranking	Manufacturer
More than one sourcing	0.149	3	0.061
Switch supplier cost is low mostly	0.177	2	0.062
Supply various products	0.134	5	0.102
Supply large qty product	0.133	6	0.187
Supply small qty product	0.136	4	0.310
Supply in short time	0.272	1	0.277
C.I.=	0.12		0.02
C.R.=	0.09		0.03

Table 4- 19 Manufacture weight ranking of sourcing flexibility

Sourcing flexibility sub-criteria	Manufacturer	Ranking
More than one sourcing	0.061	6
Switch supplier cost is low mostly	0.062	5
Supply various products	0.102	4
Supply large qty product	0.187	3
Supply small qty product	0.310	1
Supply in short time	0.277	2
C.I.=	0.02	
C.R.=	0.03	

Table 4- 15 Overall weight ranking of sourcing flexibility

Sourcing flexibility sub-criteria	AVERAGE	Ranking
More than one sourcing	0.145	4
Switch supplier cost is low mostly	0.087	6
Supply various products	0.123	5
Supply large qty product	0.192	3
Supply small qty product	0.207	2
Supply in short time	0.247	1
C.I.=	0.02	
C.R.=	0.03	

Table 4- 16 Customers weight ranking of delivery flexibility

Delivery flexiblity sub-criteria	Customer	Ranking
Multiple transportation is available	0.218	4
No restriction for delivery qty	0.228	3
Delivery can be accelerated	0.278	1
Integrate deliveries in one	0.276	2
C.I.=	0.02	
C.R.=	0.02	

Table 4- 17 Supplier weight ranking of delivery flexibility

Delivery flexiblity sub-criteria	Supplier	Ranking
Multiple transportation is available	0.251	2
No restriction for delivery qty	0.325	1
Delivery can be accelerated	0.228	3
Integrate deliveries in one	0.196	4
C.I.=	0.03	
C.R.=	0.04	

Table 4- 18 Manufacturer weight ranking of delivery flexibility

Delivery flexiblity sub-criteria	Manufacturer	Ranking
Multiple transportation is available	0.170	4
No restriction for delivery qty	0.212	3
Delivery can be accelerated	0.300	2
Integrate deliveries in one	0.318	1
C.I.=	0.04	
C.R.=	0.04	

Table 4- 19 Overall weight ranking of delivery flexibility

Delivery flexiblity sub-criteria	AVERAGE	Ranking
Multiple transportation is available	0.192	4
No restriction for delivery qty	0.258	3
Delivery can be accelerated	0.287	1
Integrate deliveries in one	0.263	2
C.I.=	0.02	
C.R.=	0.02	

Table 4- 20 Customers weight ranking of responsiveness flexibility

Responsiveness flexibility sub-criteria	Customer	Ranking
Capability to change product	0.281	1
Outsourcing in time	0.196	2
Overtime/temporary hiring	0.192	3
Shorten the lead time	0.187	4
Contact window to serve customer	0.144	5
C.I.=	0.090	
C.R.=	0.080	

Table 4- 21 Supplier weight ranking of responsiveness flexibility

Responsiveness flexibility sub-criter	Supplier	ranking
Capability to change product	0.174	3
Outsourcing in time	0.096	5
Overtime/temporary hiring	0.159	4
Shorten the lead time	0.240	2
Contact window to serve customer	0.332	1
C.I.=	0.06	
C.R.=	0.05	

Table 4- 22 Manufacturer weight ranking of responsiveness flexibility

Responsiveness flexibility sub-criteria	Manufacturer	Ranking
Capability to change product	0.218	3
Outsourcing in time	0.082	5
Overtime/temporary hiring	0.174	4
Shorten the lead time	0.247	2
Contact window to serve customer	0.278	1
C.I.=	0.07	
C.R.=	0.06	

Table 4- 23 Overall weight ranking of responsiveness flexibility

Responsiveness flexibility sub-criteria	AVERAGE	Ranking
Capability to change product	0.185	4
Outsourcing in time	0.139	5
Overtime/temporary hiring	0.197	3
Shorten the lead time	0.238	2
Contact window to serve customer	0.240	1
C.I.=	0.07	
C.R.=	0.07	

Table 4- 24 Customers weight ranking of launch flexibility

Launch flexibility sub-criteria	Customer	Ranking
Capability to launch new product	0.356	1
Equipment/facility to launch new product	0.232	3
Marketing support to launch new product	0.282	2
Available budget to launch new product	0.130	4
C.I.=	0.04	
C.R.=	0.04	

Table 4- 30 Supplier weight ranking of launch flexibility

Launch flexibility sub-criteria	Supplier	Ranking
Capability to launch new product	0.332	1
Equipment/facility to launch new product	0.329	2
Marketing support to launch new product	0.183	3
Available budget to launch new product	0.156	4
C.I.=	0.04	
C.R.=	0.04	

Table 4- 25 Manufacturer weight ranking of launch flexibility

Launch flexibility sub-criteria	Manufacturer	Ranking
Capability to launch new product	0.209	4
Equipment/facility to launch new product	0.284	1
Marketing support to launch new product	0.272	2
Available budget to launch new product	0.236	3
C.I.=	0.04	
C.R.=	0.04	

Table 4- 26 Overall weight ranking of launch flexibility

Launch flexibility sub-criteria	AVERAGE	Ranking
Capability to launch new product	0.302	1
Equipment/facility to launch new product	0.284	2
Marketing support to launch new product	0.239	3
Available budget to launch new product	0.175	4
C.I.=	0.03	
C.R.=	0.04	

4.3.2.7. Conclusions of weight calculation result for level three

Six flexibilities with total 28 sub-criteria were evaluated by the experts from upstream to downstream of supply chain. Analysis the weighting result, this study proofed that experts in different position of company or different layer of supply chain have different view point , this is no wrong answer, but just view point differ.

4.4 Local and global weight of sub-criteria

This study computed the local weight of criteria under structure of each flexibility in level three, which was unable to compare the weight between different dimensions. Consequently, if this study could compare the importance and

preference of each other could be much valuable. To recognize the importance of every sub-criteria for managing implication in supply chain flexibility. This study, computed global weight of sub-criteria compared with local weight, ranking the priority at table 4.33

Table 4- 27 Local and global weight among six flexibilities

Product flexibility	Local W.	Global W.	Ranking
Different level of product development	0.197	0.029	15
Diversity products and customers	0.166	0.025	18
Variety product and specification	0.140	0.021	23
Technical capability to modify product	0.299	0.045	8
Equivalent product to customer	0.143	0.021	21
Different packing for customer	0.055	0.008	28
Volume flexibility			
Supply large qty in time	0.443	0.044	9
Supply small qty in time	0.203	0.020	24
Cost effective to change qty	0.360	0.035	12
Sourcing flexibility			
More than one sourcing	0.145	0.016	25
Low switching cost	0.087	0.010	27
Supply various products	0.123	0.014	26
Supply large qty product	0.192	0.021	20
Supply small qty product	0.207	0.023	19
Supply in short time	0.247	0.028	17
Delivery flexibility			
Multiple transportation available	0.191	0.056	5
No restriction for delivery qty	0.257	0.076	3
Delivery can be accelerated	0.286	0.084	1
Integrate deliveries in one	0.262	0.077	2
Responsiveness flexibility			
Capability to change product	0.185	0.028	16
Outsourcing in time	0.139	0.021	22
Overtime/temporary hiring	0.197	0.030	14
Shorten the lead time	0.238	0.036	11
Contact window to serve customer	0.240	0.036	10
Launch flexibility			
R&D capability to launch new product	0.300	0.058	4
Equipment to launch new product	0.280	0.054	6
Marketing support to launch new product	0.240	0.047	7
Available budget to launch new product	0.170	0.033	13

There are several findings concluded as follows.

1. All sub-criterion of delivery flexibility were in the top 10 weight, this explained the reason why delivery flexibility was ranked in the first among all six flexibilities.
2. Three out of four criterion in launch flexibility were in top 10 criteria, this proposed why launch flexibility ranked as second in six dimensions.
3. A criteria in product flexibility, “technical capability to modify product” ranked in eight among all criterion. This proved that technical capability is one key concern in supply chain flexibility.
4. “Supply large quantity in time” was the key concerns in the volume flexibility which was also ranked in the

nine among other criteria.

5. “Contact window to serve customer” was the key concerns in the responsiveness flexibility, ranked in 10 among other criteria.

Chapter 5 Conclusions

To be successful, firms must elevate flexibility from an operational perspective to cross organizational perspective. At the same time, companies must realize that real competition is not only firm to firm, but also supply chain to supply chain. The evolution from individual organization flexibility to cross-firm flexibility results in the requirement of entire supply chain flexibility.

Adopted the methodology mentioned above, this study indicated that the top preferential flexibility in supply chain flexibility is delivery flexibility. A capability deliver commodity in cost effective and timely to meet with customer’s urgent request.

Standing alone, launch flexibility is in the second, which plays significant role in the refractory industry, as require for high performance and long life of product in service. In product life circle, any commodity has a certain product life, a capacity to research and develop a new product to meet with customer’s expectation is indispensable in organization. It also prove and empirically confirms that product competence that firm have to improve product or customize product to enhance customer satisfaction.

In addition to, responsiveness flexibility proposed to be a crucial competence that enterprises offer to rapidly respond to customer’s request no matter with product or service. It enhances satisfaction of customer.

With regard to 28 criteria of six flexibilities, all criteria were weighted and ranked in a comparison table with local weight in individual dimension and global weight across six dimensions. The top 10 criteria distributed in delivery flexibility and launch flexibility, this result matched the finding and conclusion in level two.

5.1 Theoretical and Managerial Implications

Refractory manufacturers in Taiwan are less than 20 enterprises, includes small & middle firms, join venture firm with international company, subsidiary of international company and agent of international company. As limited market scale and production capacity, sales activities focus in domestic market, no capability exporting to overseas for most of refractory makers.

As small turnover in the market is less than 5,000 million in the market, not like electronic industry and other high turnover industry attract the attention and support from government. Plus successfully to block out products made in China into Taiwan till today. As the globalization trend among the world, products circulate in various level, as well as importing product from international company of renown. For low technical level, product are easy to copy and access, this attract more small and middle firms to join the market as competitors, increase competition of the market, most likely focus on price competition. For middle technical level, big firms try to keep their advantage in the market, small & middle firm try to break in, competition exist not only pricing issue but also reference and relationship. Furthermore, for the high tech product, this is a niche market for international company which is difficult to access by small & middle enterprise. Supply chain flexibility in this study focus on middle technical level and high tech level.

In this paper, recognize problems that the industry faced at present, associated with the demand priority among the supply chain flexibility and criteria. All the top management in this field could consider to accommodate this result as one of their strategy for challenge in future.

5.2 Suggestion for Future Research

There are several research questions that can be raised to advance the understanding of supply chain flexibility and improve its practice in the Taiwanese refractory industry. Some of these are suggested below:

1. How is the impact of supply chain flexibility with each other in the framework ?
2. Future study can provide a case analysis to the realistic structure model and complete the study.

The results from this study should have implications for management in various organizations in the supply chain of refractory industry. Research must be conducted that can add the firms in understanding how flexibility can improve their competitive position.

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