Supplier Selection Criteria in Fractal Supply Network

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Abstract. Original Equipment Manufacturers (OEMs) collaborate with their key suppliers in a new form of hands-on partnership. The Fractal supply network is distinct from the traditional supply chain because of the inherent congenital fractal characteristics. This paper uses the Analytic Hierarchy/Network Process (AH/NP) approach to provide a strict methodology and criteria ranking in the complicated decision-making process of exploring the suitability, selection and maintenance of few, albeit reliable and high quality suppliers prior to going into the Fractal Manufacturing Partnership (FMP). Selecting the right set of suppliers without undermining essential competitive factors and material costs is of strategic importance in forming this alliance and could help or hinder the inherent strength in the collaboration. The outcome from this research project is a simple, systematic, logical and mathematical guide to user of OEMs in making robust and informed supplier selection decision prior to going into FMP from a fractal supply network perspective.

Keywords: Fractal supply network, supplier selection.

1 Introduction

The vigorous competition in today's global markets has drawn attention on supply chains and networks [1]. Evolution in manufacturing and management, strategic alliances, technological changes and cycle time compression [2] make frugal resource management relevant [3]. Manufacturers tend to manage their suppliers in different ways leading to supplier development, supplier evaluation, supplier selection, supplier association, supplier coordination etc. [1] & [4], and management of the logistics involved plays a strategic role for organizations that keep pace with market changes and supply chain integration [2]. Alliances, collaborations and networks particularly between Original Equipment Manufacturers (OEMs) and their key suppliers to achieve competitive advantage especially in the face of global volatile and unpredictable markets is gaining popularity [5]. Involving suppliers from initial product development through to final assembly reduces product development time, manufacturing expenses and improves quality [5] by evaluating and managing the inherent logistics. OEMs increasingly hand over their non-core business to key suppliers who can demonstrate the expertise and capability necessary for the task. These key suppliers are responsible for designing, making and assembling their modular components on the assembly line, while co-owning the OEM's facility. The advantages of this new manufacturing formula have been reported to be tremendous. In FMP, OEMs focus on their core capabilities which include specification of envelop size and weight and overall supervision of the production process while handing over non-core business to key suppliers who can demonstrate the expertise and capability necessary providing the synergy and motivation required to form leaner core business units interacting to create mass customized products [5]. Selection of the right set of suppliers is of strategic importance in forming this alliance and could help or hinder the inherent strength in the collaboration.

Therefore, comprehensive framework is needed to facilitate supplier selection process and to cope with trends in various manufacturing strategies [5] & [6]. The basis considered for supplier selection include least invoice, implicit or explicit quality, delivery reliability, lot size, paper work, returns, transportation and expediting costs [3] & [7]. The traditional approach to this selection task in procurement situations and buyer-supplier relationships has been to maintain a competitive supplier base, keeping them at arm's length, and playing them off against each other [3] & [4]. Number of authors have developed and proposed various mathematical frameworks and system modeling such as [6], [8], [9], [10], [11] [12], [13] & [14] to assist in this process. This paper ventures explicitly into the FMP or the OEM/ supplier collaboration which has until now not been addressed comprehensively. The model proposed in this paper is simple, systematic, logical and mathematical using MAT LAB to create a user-friendly interface for the supplier selection to guide user OEMs in making robust and informed choices/ decision in the selection task.

2. Framework for Defining the Supplier Selection Criteria in FMP

Determining the buyer-supplier level of integration is the most important decision in the buyer-supplier selection process [15]. Likewise, the level of integration and closeness between manufacturers and suppliers in the FMP is of vital importance in the supplier selection process. The work by [6] is particularly significant and relevant to the FMP because it is not only investigates two basic possible qualitative and quantitative criteria, but most importantly, their approach could assist decision makers in determining the OEM-supplier integration level. This is vital in the long-term relationship inherent in the FMP. Quantitative criterion measures concrete quantitative dimensions such as cost whereas qualitative criterion deals with quality of design. Trade-offs are usually required to resolve conflicting factors between the two criteria [6]. In the FMP business partnership and integration is desired. The OEM fully interacts or cooperates with the suppliers in the long term. It is based on series of production silos arranged serially and highly coordinated with one another [5]. The suppliers are directly involved in the manufacturing process rather than supply and leave. High level of technology facilitates both OEM and suppliers to work towards the same strategic goals. This alliance warrants sharing of business related information to explore new markets with novel ideas and technologies. It also encourages more investment in R&D. It is note-worthy the different degrees of integration and how OEM-supplier integration has evolved from JIT, JIT11, modular sequencing, supplier parks to FMP [5].

2.1. AHP Modelling Procedure

The AHP was originally designed and applied by [16] [17] & [18]; for solving complex multiple criteria problems involving comparison of decision elements difficult to quantify [12] & [14]. It considers both qualitative and quantitative criteria in a hierarchical structure (ranking) for supplier selection. AHP divides a complex decision problem into a hierarchical algorithm of decision elements. A pair wise comparison in each cluster (as a matrix) follows, and a normalized principal eigenvector is calculated for the priority vector which provides a weighted value of each element within the cluster or level of the hierarchy and also a consistency ratio (used for checking the consistency of the data). The main theme is the decomposition by hierarchies, [19] finds that AHP is based on three basic principles, namely; decomposition, comparative judgments, and hierarchical composition of priority. The decomposition level breaks down complex and unstructured criteria into a hierarchy of clusters. The principle of comparative judgments is applied to construct pair wise comparison of all combinations of the elements in a cluster with respect to the parent of that cluster. The principle of hierarchical composition or synthesis is applied to multiply the local priorities of elements in a cluster by the 'global' priority of the parent, producing global priorities throughout the hierarchy.

2.2. Mathematical Formulation Leading to Supplier Selection

Based on the AHP approach, weights of criteria and score of alternatives are called local priorities which are considered as the second step of the decision process [9]. The decision making process requires preferred pair-wise comparison concerning weights and scores. The value of weights v_i and the scores r_{ij} are extracted from the comparison and listed in a decision table. The last step of the AHP aggregates the local priorities from the decision table by a weighted sum as shown on equation (1).

$$R_j = \sum_i v_i \text{ x } r_{ij} \qquad (1)$$

R_j represents the global priorities and is thus obtained for ranking and selection of the best alternatives. Assessment of local priorities based on pair-wise comparison is the main constituent of this method where two elements E_i and E_j at the same level of hierarchy are compared to provide a numerical ratio a_{ij} of their importance. If E_i is preferred to E_j then $a_{ij} > 1$. On the other hand the reciprocal property, $a_{ji} = 1/a_{ij}$, j = 1,2,3,4,….,n and i = 1,2,3...n always holds. Each set of comparison with n elements requires $[n \text{ x } (n - 1)] /2$ judgments [9]. The rest half of the comparison matrix is the reciprocals of those judgments lying above the diagonal and are omitted. The decision maker's judgments a_{ij} are usually estimations of the exact. Hence, a consistency ratio method was introduced by [16] to govern the consistency of judgments. If a decision maker states that criterion x is of equal importance to criterion y, then, a_{xy} = a_{yx} = 1, and if criterion y is extremely more important than criterion z, then, a_{yz} = 9, & a_{zy} = 1/9, then criterion z should be having the same weight to criterion z as criterion y does. However, the decision maker is often unable to express the consistency of the judgment and this could affect the analysis. Hence, [16] consistency method measures the inconsistency of the pair-wise comparison matrix and sets a threshold boundary which should not be exceeded. In the non-consistent case the comparison matrix A may be considered as a perturbation of the previous consistent case. When the entries a_{ij} changes only slightly, the Eigen values change in a similar fashion. The consistency index (CI) is calculated using equation 2.

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{2}$$

where n is number of comparison elements, and $\lambda_{\max}$ is Eigen value of the matrix.

Then, the consistence ratio (CR) is calculated as the ratio of consistency index and random consistency index (RI). (RI) is the random index representing the consistency of a randomly generated pair-wise comparison matrix. The consistency ratio (CR) is calculated using equation 3.

$$CR(A) = \frac{CI(A)}{RCI(n)} \tag{3}$$

If CR(A) < 0.1 (10%), the pair-wise comparison matrix is considered to be consistent enough. In the case where CR(A) > 0.1, the comparison matrix should be improved. The value of (RI) depends on the number of criteria being compared or considered.

3. Modelling the FMP Supplier Selection Process

The model sorts the decision problem in a hierarchical system of decision elements. Pair-wise comparison matrix of these elements is constructed, normalized principle Eigen vector is calculated for the priority vector which provides the measurement of weights (relative importance) of each element. Supplier selection criteria, sub-criteria and alternatives for the FMP have been formed based on relevant extensive literature [1], [6], [8], [9] & [20] reviewed and consulted for the project. They are grouped as either tangible or intangible depending on how perceptible or realistic they are and include the following; business criteria, manufacturing, quality assessment, performance assessment, organizational culture and strategy, personnel management, compatibility and information technology. The first four are considered tangible while the rest are intangible criteria.

3.1 Modelling Procedure

The general modeling procedure is summarized below:

(i) Construct the hierarchy system, including several independent elements. The model has four levels of hierarchy - the overall goal, main evaluation criteria, sub-criteria and alternatives.

(ii) Pair-wise comparison of criteria and alternatives is done to find comparative weights amongst the attribute decision elements. The mathematical modeling utilizes the 'slider' function of MATLAB GUI (Graphical User Interface) as comparative input tool. The quantified subjective decisions are stored in allocated cells. The outcome is a ranked priority order of criteria and ranked priority order of decision alternatives under each criterion.

(iii) Calculate the weights, test the consistency and calculate the Eigen vector of each comparison matrix to obtain the priority of each decision elements. Hence, for each pair-wise comparison matrix, the Eigen value of the matrix $\lambda_{\max}$ and Eigen vector w (w_1, $w_2 \ldots w_n$), weights of the criteria is estimated.

(iv) The last step in the modeling is finding the overall priorities for decision alternatives. This is calculated by multiplying the priority for each alternative under each criterion by the weight of each criterion (local weights). The calculations is performed from the lower level to the higher level of hierarchy where the outcome of the step is ranked in order of the decision alternatives to aid the decision making process.

(iv) Validation of the model is needed to test the logical and mathematical correctness and reliability of the model. To this end, the result from the case study by [9] is imported into the project. In [9], the authors use Data Envelopment Analysis (DEA) approach and this is embedded into the analytic hierarchy process methodology. The criteria, sub-criteria, and alternatives and the scores of the comparisons are used as they are. The final outcome of the mathematical model is compared and the results show close comparison and validated to 0.07%.

FMP Supplier Criteria. Supplier selection criteria, sub-criteria and alternatives for the FMP have been formed based on relevant extensive literature [6], [8], [9], [20] & [22] reviewed and consulted for the project. These are considered while making optimal supplier selection for the FMP. They are grouped as either tangible or intangible depending on how perceptible and realistic they are. They form the framework on figure 1, and include the following; business criteria, manufacturing, quality assessment, performance assessment, organizational culture and strategy, personnel management, compatibility and information technology. The first four are considered tangible while the rest are intangible criteria.

The input of each element is recorded in a tabular form and the AHP output is calculated once the relevant data is collected and the consistency ratio is calculated along with the AHP weights. Each relevant elements of the model is compared quantitatively and the result is recorded for final calculations. Due to space limitation, results and discussion will be provided in the conference.

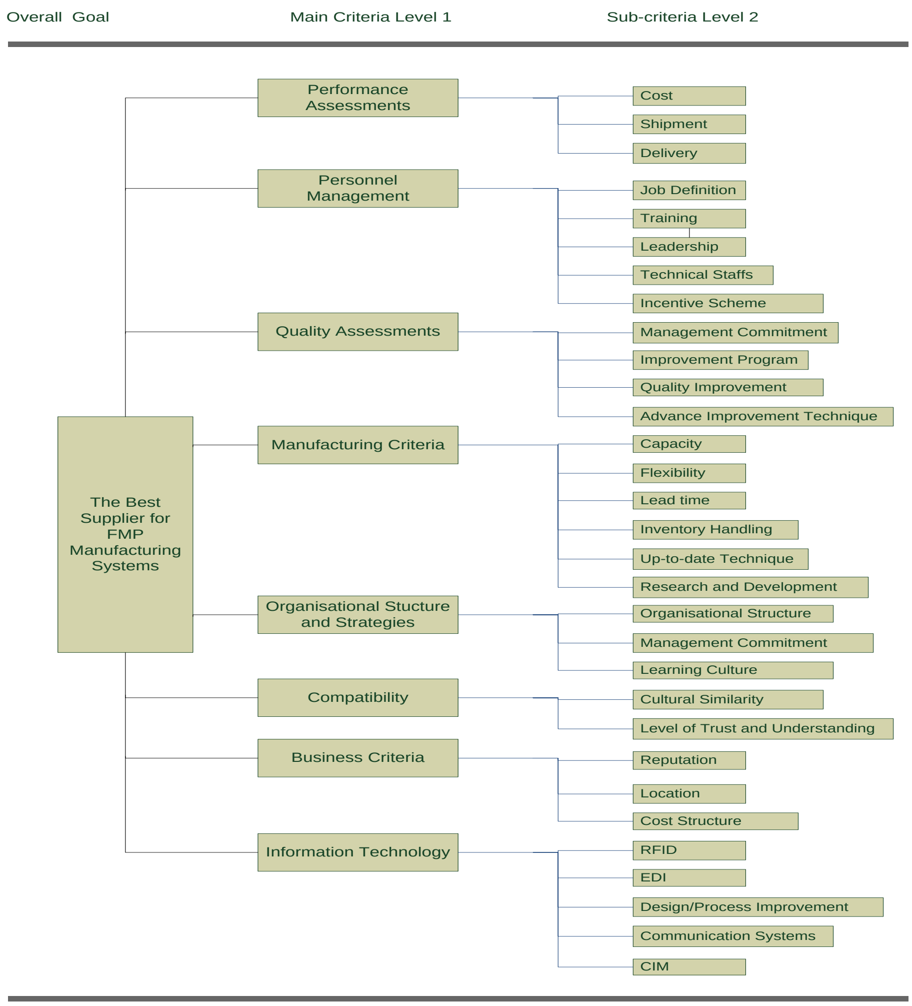

Fig.1. Framework of supplier selection process

4. Conclusion

Selection and maintenance of high quality and reliable Suppliers is key component of successful implementation of the FMP. One objective of the selection process is determination of optimal supplier criteria particularly suited to the fractal manufacturing philosophy. The fractal company advocates a great learning, 'open book' culture and more sophisticated communication link between fractals in order to maintain the transparency of information and to facilitate continuous improvement program and Research and Development. This paper has reviewed conventional criteria used mainly in the buyer-supplier/ procurement selection process and short listed some important criteria which are relevant to the FMP. These criteria are classified as tangible and intangible criteria. A mathematical argument is put forward to justify the process of the supplier selection. To further evaluate the importance of each criterion to FMP, this study utilizes the AHP methodology implemented using MAT LAB programming language to generate a framework that robustly identifies different criteria most of which are conflicting, and suppliers. The approach is flexible enough to allow decision makers to make their choices in a qualitative manner while the framework transforms the decision into quantitative results and helps in selecting the right set of suppliers without undermining the inherent strengths in the collaboration as obtained in the FMP.

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