Different Aspects for Supplier Evaluation and Selection to Improve Supply Chain Performance

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***Abstract*-- with increasing competitive global world markets, companies are under intense pressure to find ways to cut production and material costs to survive and sustain their competitive position in their respective markets. Since a qualified supplier is a key element and a good resource for a buyer in reducing such costs, evaluation and selection of the potential suppliers has become an important component to improve supply chain performance. This paper presents a hybrid model using analytic hierarchy process (AHP), artificial neural networks (ANNs), and Relative Reliability Risk Index (R^3I) to assess supplier performance. The model consists of three modules: Module1 applies AHP using pair wise comparison of criteria for all suppliers. Module2 utilizes the results of AHP into NNs model for selecting the supplier. Three activation functions namely; the sigmoid activation function, the tanh activation function and the arctangent activation function are used to compare the results. Module3 utilizes the results of AHP into R^3I model for selecting the supplier. The results is promising and it gives up an appropriate score to obtain and compare the performance of each supplier and choosing the best one.**

***Index Term*-- AHP, ANN, R^3I, Activation Function, Supply Chain, Supplier evaluation and selection, Performance.**

I. INTRODUCTION

In the business world of today, effective management of supply chain is crucial in controlling the total flow of a distribution channel. Supply chain Management (SCM), which provides consistency in time controlling and material flows, has therefore become one of the central elements of modern business approaches. Due to the widening of distribution networks, the firms started to stretch the principles of SCM in order to improve their manufacturing performances in terms of flexibility, cost, quality and, delivery. Consequently, developing a proper supplier evaluation system has become a must in building an effective SCM. It is commonly believed that without collaboration with suppliers, success in corporate aims and strategies is hard to achieve. Evaluation of the suppliers based on their capacities in fulfilling the needs and objectives of the firm has become crucial for long term success in both local and global markets. Moreover, supplier evaluation systems not only provide decision makers real time awareness about the performances of suppliers but also help them make predictions about the future[1].

In the last few decades supplier evaluation has become a strategic part in any business organization with an aim to reduce risk and maximize the overall output for the purchaser. Supplier evaluation often follows a rigorous and structured approach based on exhaustive survey performed in industry. An effective supplier survey should have certain characteristics such as the comprehensiveness, the objectiveness, the reliability and the flexibility. To ensure that these characteristics are included in a supplier survey it is recommended to follow a step-by-step process. Minimizing cost and maximizing revenue through value addition of suppliers and other management aspects such as, quality management, distributions, competitive pricing etc. are to be incorporated as the criteria of supplier selection. Recent literature proposed that the suppliers could also be categorized into manufacturers, distributors, independent craftspeople and importation sources suggests that outsourcing of the manufacturing activities is a strategy which could be a choice or a competitive and imperative decision. On the other hand, outsourcing is supposed to be a corporate activity in which the role or responsibility or involvement to supply management is above average and increases significantly. The process of selecting a group of competent suppliers for important materials have a large impact on a firm's competitive advantage as it is quite complex decision and should be based on multiple criteria[2].

Sourcing or supplier selection plays an important role on supply chain management. In recent years, determining the best supplier has become a key strategic consideration. The cost of raw materials and component parts includes a big portion of the cost of a product, most firms spend considerable amount of their revenues on purchasing. Purchasing literature discloses that there are three major decisions associated with the sourcing problem including the product to order, the order size, the appropriate supplier to purchase and finally an appropriate schedule purchase plan. Many experts believe that the second question is the most important activity of a purchasing department. Allocating orders from suppliers plays an important role on managing the supply chain and it comes after supplier selection and evaluation [3].

Strong competitive pressure forces many organizations to provide their products and services faster, cheaper and better than their competitors. Managers have come to realize that they cannot do it alone without satisfactory vendors. Therefore the increasing importance of supplier selection decisions is forcing organizations to rethink their purchasing and evaluation strategies and hence the selection of suppliers has received considerable attention in the purchasing literature[4].

One important aspect in SCM is purchasing and selecting an appropriate supplier ensures the success of purchasing function. The importance of supplier selection increased with the widely implementation of just in time (JIT) among manufacturing industry since 1980s. Literature findings estimated that 85% of North American and European multinational companies practice outsourcing [5].

The purchasing function has gained great importance in the SCM due to factors such as globalization, increased value added in supply, and accelerated technological change. Purchasing involves buying the raw materials, supplies, and components for the organization. The activities associated with it include selecting and qualifying supplier, rating supplier performance, negotiating contracts, comparing price, quality and service, sourcing goods and service, timing purchases, selling terms of sale, evaluating the value received, predicting price, service, and sometimes demand changes, specifying the form in which goods are to be received, etc. The key and perhaps the most important process of the purchasing function is the efficient selection of suppliers/ vendors, because it brings significant savings for the organization. The objective of the supplier selection process is to reduce risk and maximize the total value for the buyer, and it involves considering a series of strategic variables. Some authors have identified several criteria for supplier/vendor selection, such as net price, quality, delivery, historical supplier performance, capacity, flexibility, service, communication systems and geographic location. These criteria are key issues in the supplier assessment process since it measures the performance of the suppliers[6].

Supplier selection is considered as the leading component of global purchasing. In proper selection procedure, there is a need for developing a systematic supplier selection process of identifying and prioritizing relevant criteria and evaluating the trade-offs between technical, economic and performance criteria. AHP is a recognized supplier selection tool from decades due to its strong capability of dealing with quantifiable and unquantifiable criteria of the abovementioned problem. A proper supplier selection tool is assumed to be adopted in order to maintain the flow of the raw materials consistently throughout the process of the firm. The supplier evaluation process not only helps defending the shortage of materials for production but also helps in maintaining the buyer-seller relationship and many other business aspects.[7].

The global purchasing in SCM has become more risky, visible and productive position within many organization [8]. As companies implement just-in-time and operations improvement strategies, the importance of developing and managing the suppliers emerges as critical outsourcing strategies in SCM[8].

The paper is organized as follows. Section 2 gives an idea about supply chain management. In section 3, the analytic hierarchy process is illustrated. Section 4 gives an idea about neural networks. In section 5, the entropy technique is outlined. Section 6 shows a detailed analysis and discussion of results. Section 7, outlines a discussion and conclusion.

II. SUPPLY CHAIN MANAGEMENT

A supply chain(SC) is a network of suppliers, factories, warehouses, distribution centers and retailers, through which raw materials are acquired, transformed, produced and delivered to the customer. The supply chain consists all the activities associated with the flow and transformation of goods from the raw material stage, through to the end user, as well as the associated information flows. SCM is a set of synchronized decision & activities, utilized to effectively integrate suppliers, manufacturers, transporters, warehouses, retailers & customers so that the right product or service is distributed at the right quantities, to the proper locations & at the appropriate time, in order to minimize system wide costs while satisfying customer service level requirements[9]. On the other hand, it is a network linking various entities, from the customer to the supplier, through manufacturing and services, so that the flow of materials, money and information can be effectively managed to meet the business requirements[10].

In modern business environments, an effective SCM is crucial to business continuity. Competition between SCs has replaced the traditional competition between companies. Lean, Agile, Resilient and Green (LARG) paradigms are advocated as the foundation of a competitive SCM. To make a SC more competitive, capable of responding to the demands of customers with agility and capable of responding effectively to unexpected disturbance, in conjunction with environmental responsibilities and the necessity to eliminate processes that add no value, companies must implement a set of LARG SCM practices and key performance indicators (KPI) to measure their influence on the SC performance[11].

The integration of supply chain has become an important aspect in business environment due to the various business competitive pressures. The supply chain usually includes suppliers, manufactures, wholesalers, retailers and customers through which raw materials are acquired, transformed, and delivered to final customers. The management of supply chain is to provide a strategy for the coordination and integration of supply chain participants in order to optimize the supply chain performance and improve the competitive advantage[12,13].

A. Supply chain flexibility

Flexibility is generally perceived as an adaptive response to environmental uncertainty. More specifically, it is a reflection of the ability of a system to change or react with little penalty in time, effort, cost or performance. Hence , flexibility may be seen as a proactive attribute designed into a system, rather than a reactive behavior that may in fact result in a detriment to time, effort, cost and performance. Flexibility may also be seen as having two distinct elements, those internal to the business that describe system behavior, and those that are viewed externally by customers, which determine the actual or perceived performance of the company[14].

Supply chain flexibility is defined as an amalgamation of product flexibility, volume flexibility, new product flexibility, distribution flexibility and responsiveness flexibility. There are two main strategies that could be employed at supply chain level in order to increase the flexibility of a supply chain: improved supplier responsiveness and flexible sourcing. The external flexibility of a supply system is determined by these two internal sources of flexibility: vendor and sourcing flexibility. The external flexibility types can be defined as:

- New product flexibility is the range of, and ability to accommodate the production of new products;
- Mix flexibility is the range and ability to change products currently being produced;
- Volume flexibility refers to the range of and ability to accommodate change in production output;
- Delivery flexibility is the range of and ability to change delivery dates;
- Access flexibility is the ability to provide extensive coverage and reflects the capability of a supply chain to provide the required geographical coverage for different customers.

Supply chain flexibility is rationalized as comprising of two key concepts: vendor flexibility and sourcing flexibility. Based on the literature, the following definitions are proposed:

1. Vendor flexibility – the specific types of flexibility relating to individual vendors that support manufacturing, warehousing or transport operation.
2. Sourcing flexibility – the ability to reconfigure a supply chain network through selection and deselection of vendors[13].

To examine how buying organizations can configure their supply networks to achieve supply chain flexibility. Supply chain flexibility can be rationalized by considering two key antecedents of flexibility, sourcing and vendor flexibility. Network coordinators can group their suppliers under three categories, framework agreement suppliers, preferred suppliers and approved suppliers, each with different flexibility implications. It is possible to maintain a suitable level of supply chain flexibility by maintaining a pool of suppliers in each category[13].

B. Supplier Evaluation and Selection

In today's global marketplace characterized by globalization, increasing customer's value expectations, expanding regularity compliance, global economic crisis, and intense competitive pressure, to thrive and survive manufacturing firms must select and maintain core suppliers. Thus, supplier selection and evaluation represents one of the significant roles of purchasing and supply management functions, attest that "it is impossible to successfully produce low cost, high quality products without satisfactory selection and maintenance of a competent group of suppliers". The purpose of strategic purchasing (and supply management) is to direct all purchasing activities toward opportunities consistent with the firm's capabilities to achieve its long-term goals. Indeed, because purchasing and supply management can play a prominent role in a firm's strategic planning, supply chain management, and profitability. Supplier selection is one of the key decisions to be made in the strategic planning of supply chains that has far-reaching implications in the subsequent stages of planning and implementation of the supply chain strategies[15].

On the other hand, the competition between corporations grows fast. In this highly competitive environment companies which design and manage their supply chains best will be more profitable and hence stronger. 'Supplier' is one of the most important components of a supply chain. A corporation which develops good relationships with its suppliers gain cost advantages through on-time and desired quality deliveries. Therefore supplier evaluation has a strategic importance for the corporations. The results reached by using the right performance criteria and evaluation method would produce robust solutions towards improving the performance of suppliers[16].

Supplier selection, one of the most important issues of a company, must be systematically considered from the decision makers' perspectives. For this reason, the supplier selection process were evaluated by researchers for many years in a large framework comprised of various experimental and analytical techniques and successful applications were done in various sectors[16].

Supplier selection process has been considered as a multiple criteria decision making (MCDM) problem which contains both tangible and intangible factors. If process is done correctly, a higher quality and longer lasting relationship is more attainable. In other word, selection of wrong supplier could be enough to ubset the company's financial and operational position. However, selecting the right suppliers significantly reduces purchasing cost, improves competiveness in market and enhances end user satisfaction[3, 17]. Due to that, in order to select the best suppliers it is crucial to considering both qualitative and quantitative factors simultaneously. In the supply selection process, manger also has to consider multi-criteria factors related. Thus the integration of all the multi-criteria analysis and those analysis results by multi-analysis teams has an important meaning in supply chain design[18, 19].

Global Forces Motivating Supplier Evaluation and Development are: 1) Expanding and increasing global competition; 2) Increasing global risk; 3) Higher energy costs; 4) Increasing market demand for productivity, quality and higher value; 5) Increasing pressure to reduce total cost[20].

III. ANALYTIC HIERARCHY PROCESS

The evaluation of vendors is a complicated decision problem. The complexity comes from: 1) the relative difficulty to conceptualize and structure the numerous components of the evaluation problem into an analytical framework; 2) the nature of the components in this process; some are quantitative whereas others are subjective; and 3) the large number of alternatives as the competition in the marketplace increases.

AHP is a decision making tool that decomposes a complex problem into a multi-level hierarchical structure of objectives, criteria, sub-criteria and alternatives. Application of AHP have been reported in numerous fields such as conflict resolution, project selection, budget allocation, transportation, health care and manufacturing [21].

AHP was developed by Saaty, addresses how to determine the relative importance of a set of activities in a multi-criteria decision problem. The process makes it possible to incorporate judgments on intangible qualitative criteria alongside tangible quantitative criteria. The AHP method is based on three principles: first, structure of the model; second, comparative judgment of the alternatives and the criteria; third, synthesis of the priorities. In the first step, a complex decision problem is structured as a hierarchy. AHP initially breaks down a complex multi-criteria decision-making problem into a hierarchy of interrelated decision criteria, decision alternatives. With the AHP, the objectives, criteria and alternatives are arranged in a hierarchical structure similar to a family tree. A hierarchy has at least three levels: overall goal of the problem at the top, multiple criteria that define alternatives in the middle, and decision alternatives at the bottom. The second step is the comparison of the alternatives and the criteria. Once the problem has been decomposed and the hierarchy is constructed, prioritization procedure starts in order to determine the relative importance of the criteria within each level. The pair-wise judgment starts from the second level and finishes in the lowest level, alternatives. In each level, the criteria are compared pair-wise according to their levels of influence and based on the specified criteria in the higher level. In AHP, multiple pair-wise comparisons are based on a standardized comparison scale of nine levels. Table (II) shows the comparison scale. Let $C = \{C_j \mid j = 1,2,3,\ldots,n\}$ be the set of criteria. The result of the pair-wise comparison on n criteria can be summarized in an n x n evaluation matrix A in which every element a_{ij} (i,j = 1,2,3, …, n), is the quotient of weights of the criteria as shown below:

$$A = \begin{bmatrix} a_{11} & a_{12}\cdots & a_{1n} \\ a_{21} & a_{22}\cdots & a_{2n} \\ \vdots & \vdots & \vdots \\ a_{n1} & a_{n2}\cdots & a_{nn} \end{bmatrix}, a_{ii} = 1, a_{ji} = \frac{1}{a_{ij}}, a_{ij\neq 0}$$

At the last step, the mathematical process commences to normalize and find the relative weights for each matrix [2, 22].

The AHP is designed to solve complex multi-criteria decision problems. It is based on the innate human ability to make sound judgments about small problems. It facilitates decision making by organizing perceptions, feelings, judgments, and memories into a framework that exhibits the forces that influence a decision[4].

The AHP consists of three main operations, including hierarchy construction, priority analysis, and consistency verification. First of all, the decision makers need to break down complex multiple criteria decision problems into its component parts of which every possible attributes are arranged into multiple hierarchical levels. After that, the decision makers have to compare each cluster in the same level in a pair-wise fashion based on their own experience and knowledge. For instance, every two criteria in the second level are compared at each time with respect to the goal, whereas every two attributes of the same criteria in the third level are compared at a time with respect to the corresponding criterion. Since the comparisons are carried out through personal or subjective judgments, some degree of inconsistency may be occurred. To guarantee the judgments are consistent, the final operation called consistency verification, which is regarded as one of the most advantages of the AHP, is incorporated in order to measure the degree of consistency among the pair wise comparisons by computing the consistency ratio. If it is found that the consistency ratio exceeds the limit, the decision makers should review and revise the pair wise comparisons. Once all pair wise comparisons are carried out at every level, and are proved to be consistent, the judgments can then be synthesized to find out the priority ranking of each criterion and its attributes[23].

The following mathematical steps for evaluating and selecting the desired alternative based on the AHP approach was followed:

1) Develop a pair-wise comparison matrix for each decision alternative (selected suppliers) for each criterion.
2) Follow the synthesization methodology:
   a. Sum the values in each column of the pair-wise comparison matrices.
   b. Divide each value in each column of the pair-wise comparison matrices by the corresponding column sum. The results represent the normalized matrices.
   c. Arrange the values in each row of the normalized matrices. The results give the preference vectors.
   d. Combine the vectors of preferences for each criterion (from step iic) into one preference matrix that shows the preference for each supplier for each criterion.
3) Develop a pair-wise comparison matrix for the criteria.
4) Compute the normalized matrix by dividing each value in each column of the matrix by the corresponding column sum.
5) Develop the preference vector by computing the row averages for the normalized matrix.
6) Compute an overall score for each decision alternative by multiplying the criteria preference vector (from step 5) by the criteria matrix (from step 2d).

7) Rank the decision alternatives, based on the magnitude of their scores computed in step 6.[24, 25, 26, 21].

The AHP approach has come to be recognized by most experts as a powerful tool for supplier evaluation and selection. The AHP methodology makes it possible to elicit both qualitative as well as quantitative data to arrive at a desired goal. The methodology makes use of various qualitative and mathematical approaches to examine the various data and make informed conclusions based on the data collected[24].

IV. ARTIFICIAL NEURAL NETWORKS

ANNs has been a hot topic in recent years in cognitive science, computational intelligence and intelligent information processing [27]. They have emerged as an important tool for classification[28]. The recent vast research activities in neural classification have established that neural networks are a promising alternative to various conventional classification methods. The advantage of neural networks lies in the following theoretical aspects. *First*, neural networks are data driven self-adaptive methods in that they can adjust themselves to the data without any explicit specification of functional or distributional form for the underlying model. *Second*, they are universal functional approximators in that neural networks can approximate any function with arbitrary accuracy. *Third*, neural networks are nonlinear models, which makes them flexible in modeling real world complex relationships. Finally, neural networks are able to estimate the posterior probabilities, which provides the basis for establishing classification rule and performing statistical analysis[27, 28].

The feedforward neural network[29] is the simplest (and therefore, the most common) ANN architecture in terms of information flow direction. Many of neural network architectures are variations of the feedforward neural network. Backpropagation (BP) is the most broadly used learning method for feedforward neural networks[30]. There are two practical ways to implement the backpropagation algorithm: batch updating approach and online updating approach. Corresponding to the standard gradient method, the batch updating approach accumulates the weight correction over all the training samples before actually performing the update. On the other hand, the online updating approach updates the network weights immediately after each training sample is fed[31].

One of the most commonly used supervised ANN model is backpropagation network that uses backpropagation learning algorithm[32]. Backpropagation algorithm is one of the well-known algorithms in neural networks. The backpropagation neural network is essentially a network of simple processing elements working together to produce a complex output. These elements or nodes are arranged into different layers: input, middle (hidden) and output. The output from a backpropagation neural network is computed using a procedure known as the forward pass.

- The input layer propagates a particular input vector's components to each node in the middle layer.
- Middle layer nodes compute output values, which become inputs to the nodes of the output layer.
- The output layer nodes compute the network output for the particular input vector.

The forward pass produces an output vector for a given input vector based on the current state of the network weights. Since the network weights are initialized to random values, it is unlikely that reasonable outputs will result before training. The weights are adjusted to reduce the error by propagating the output error backward through the network. This process is where the backpropagation neural network gets its name and is known as the backward pass:

- Compute error values for each node in the output layer. This can be computed because the desired output for each node is known.
- Compute the error for the middle layer nodes. This is done by attributing a portion of the error at each output layer node to the middle layer node, which feed that output node. The amount of error due to each middle layer node depends on the size of the weight assigned to the connection between the two nodes.
- Adjust the weight values to improve network performance using the Delta rule.
- Compute the overall error to test network performance.

The training set is repeatedly presented to the network and the weight values are adjusted until the overall error is below a predetermined tolerance.

V. ENTROPY

Information theory is commonly used in coding and communication applications and more recently is has also been used in classification. In information theoretic classification, a learner is viewed as an agent that gathers information from some external sources. Information theoretic quantities have been widely used for future extraction and selection[33]. As defined in information theory, entropy is a measure of the uncertainty of a particular outcome in a random process [34]. The entropy of a random variable is a measure of the uncertainty of the random variable; it is a measure of the amount of information required on the average to describe the random variable. Entropy is a nonlinear function to represent information we can learn from unknown data. In the learning process, we learn some constraints on the probability distribution of the training data from their entropy.

A. Entropy method

After application of AHP, the priority matrix obtained will be treated as our decision matrix. The weights for the four functions considered have been calculated using the information from the decision matrix and the entropy method. The entropy method is Multi Attribute Decision Making method. This method has been adopted as a part of calculating

R^3 I, because it may be inappropriate for a decision maker to compare functions relatively from the function structure. The information contents of the normalized values of the attributes can be measured using entropy values. Let A be the decision matrix of dimension $n \times k$

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1k} \\ a_{21} & a_{21} & \cdots & a_{2k} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ a_{n1} & a_{n2} & \cdots & a_{nk} \end{bmatrix}$$

The entropy V_j of the set of normalized outcomes of attribute j is given by:

$$V_j = -\beta \sum_{i=1}^{n} a_{ij} * ln(a_{ij}) \, forallj \qquad (1)$$

i = 1 to n represents alternatives (suppliers),
j = 1 to k represents attributes (criteria) ,
β is aconstant.

$$\beta = \frac{1}{\ln(n)};$$

a_{ij} = Normalized element of the decision matrix (2)

If there are no preferences available, the weights are calculated using the equation,

$$W_j = \frac{E_j}{\sum_{j=1}^{k} E_j} \text{ and } E_j = (1 - V_j) \quad (3)$$

If the decision maker has the weights available before hand i.e. W_e, then it can be combined with the weights calculated above, resulting in new weights that are W_{new}

$$W_{new} = \frac{W_e * W_j}{\sum_{j=1}^{k} W_e * W_j} \qquad (4)$$

The weights have been calculated using the information from the matrix and the entropy method. Having calculated the weights and priorities, we obtain R^3 I, using the following equation[35].

$$R^3 I_i = \sum_{j=1}^{k} a_{ij} * W_j \ for\ all\ i \qquad (5)$$

VI. ANALYSIS AND DISCUSSION OF RESULTS

Industrial product manufacturers face severe financial pressure, cyclical demand, and customers with unique requirements for progressively more complex products. As business models shift to global operations with outsourced design and manufacturing, manufacturers need to effectively control, manage, and communicate product information with suppliers to drive product costs down, deliver at specified quality levels, and meet schedule commitments. The increasingly important role of the customer in product decisions has forced industrial product manufacturers to improve product line planning, achieve better balance between resources and features, and adjust programs based on customer orders. To stay competitive, superior customer service must be provided throughout the lifecycle of the product. In the high-volume industries, four key trends in supply chain management have been identified in the literature: outsourcing of non-core activities to suppliers; focusing of operations; a reduction in the supplier base as companies shift from multiple to single sourcing; and the establishment of long-term collaborative relationships with suppliers. The outcome of these changes is that companies are establishing new forms of relationships with their suppliers[36]. Industrial corporations are led to adopt the SCM philosophy to cope with market challenges .Managing the purchasing task in the supply chain has been a challenge in the last decade for many corporations . One of the most important processes of the purchasing function is the supplier selection. Identification and evaluation of an appropriate supplier ensures that a firm will receive high-quality materials at a reasonable price, deliver the right quantities at the right time, and provide excellent services in order to satisfy customers' demands [37].

Supplier relationship management entails determining how company buyers interact with suppliers. It is a mirror image of customer relationship management. Just as a company needs to develop relationships with its customers, it needs to foster relationships with its suppliers to ensure quality goods and services, timely and assured deliveries and information flow to assist both organizations in planning. At the strategic level, the output of the process is an understanding of the levels of relationships the firm will maintain, and the process for segmenting the suppliers and working with them to develop appropriate relationships. Once the process team determines the criteria for categorization of suppliers and the levels of customization, the operational supplier relationship management process develops and manages the relationship. [38].

Supplier selection is defined in as the "process of finding the suppliers being able to provide the buyer with the right quality products and/or services at the right price, at the right quantities and at the right time [22]. Supplier is not only a seller but more as business partner for the purchaser's company. Geographical locations, financial status, performance record, company background, and even culture can be important criteria, which might affect the reputation of the supplier [5]. In this study, before defining supplier criteria the classification of suppliers are preferred and they are grouped into three categories:

Potential Suppliers: the vendor companies that we haven't done any business with yet, as either they are new in the market or we do not have any connection.
Suppliers in the pool: the vendor companies which we are doing or have done business with.

Suppliers outed from the pool: the vendor companies which we have done business with in the past but they had serious declines in their performance or jeopardized us by not meeting their promises [39].

The main objective of supplier evaluation is to minimize the risks and costs of purchasing, manufacturing, and distribution processes by finding the best suppliers via measuring their performances in terms of certain indicators. Cost and quality have always been the most popular and commonly accepted performance criteria in supply evaluation. In recent years, delivery time, strategic behavior, and implementation of total quality management have also become criteria of major importance. Nonetheless, it should be noted that, priorities may differ in different firms due to their basic requirements. Thus, in order to develop an effective supplier assessment system, different perspectives should be taken into consideration[1]. In this paper, a new criteria is taken into consideration which represents an important paradigms for improving supplier selection, and at the same time improves the SCM as a whole. These criteria represents Leanness, Agility, Resilience and Greenness.

A. Criteria to be used for Supplier Selection

There are more criteria pertaining to supplier selection process was considered from the perspective of different researchers. Some of them are: Cost criteria, those include unit cost, ordering cost, transportation cost, duties and taxes, warranty cost, total delivery cost, payment terms, price discount. Service criteria comprising after-sales support, warranty support, repair and maintenance service, service response time. Flexibility/responsiveness criteria consisting of flexibility in changing order volume, order due date, order mix, urgent delivery, and product variety. Personnel capability criteria expressed by labor overall skills and labor experience. Technical capability criteria considering R&D capability and design capabilities. Financial capability criteria split into financial condition and stability, last year profit. Degree of cooperation criteria that considered the communication system, the information share, the long-term relationship, the support in value engineering, the cost reduction planning, the involvement in formulating new product or developing the current products and finally Environmental criteria where ISO14000 was considered and also waste management[37]. Delay time criteria: The allowed delay time ranged from one day to maximum certain days. An extra delay time leads to the rejection of the process. Reliability criteria: This measure consists of delivery time, ease of communication, production facility and financial health of the supplier. Efficiency criteria: This measure consists of efficiency of purchase-order cycle time, efficiency of the cash-flow method. Agility criteria: This measure consists of speed and flexibility. Resilience criteria: Flexible sourcing, Lead time reduction and the ability to manage risk. And finally, Greenness criteria: Green purchasing, appropriate sustainability policy.

Although all criteria are concerned to all supply chains, the following criteria are more related to the industry field. Some of them are: Quality criteria, including defective percentage at incoming material, defective percentage at production line, defective percentage from final customer, quality certificate (ISO 9000), quality system, continuous improvement, ability to solve quality problems. Machines capability criteria divided into production capacity and manufacturing technology used. Manufacturing capability criteria including development of process technology and manufacturing planning capability. Leanness criteria: Profitability and manufacturing flexibility, just in time, supplier relationships and cycle / setup time reduction. Capacity criteria: The supplier have an adequate "engine room" to produce goods. Capacity can include equipment, human resources and materials. Supplier profile criteria expressed by supplier position in industry, years in business working, market share, sales trend, business references, past experience, trust [37]. We argue the following criteria in our work as follows:

C1: ***Quality***. This measure consists of supplier's reputation, supplier's current certification, quality of raw materials and proven record of world class service.
C2: ***Delay time***. The allowed delay time ranged from one day to maximum 15 days. An extra delay time leads to the rejection of the process.
C3: ***Cost***. Purchase price, transportation cost and taxes. Operational cost which includes transaction processing; cost of rejects etc. thus, cost is very important criterion for selection of right suppliers.
C4: ***Reliability***. This measure consists of delivery time, ease of communication, production facility and financial health of the supplier.
C5: ***Efficiency***. This measure consists of efficiency of purchase-order cycle time, efficiency of the cash-flow method.
C6: ***Capacity***. The supplier have an adequate "engine room" to produce goods. Capacity can include equipment, human resources and materials.
C7: ***Leanness***. Profitability and manufacturing flexibility, just in time, supplier relationships and cycle / setup time reduction.
C8: ***Agility***. This measure consists of speed and flexibility.
C9: ***Resilience***. Flexible sourcing, Lead time reduction and the ability to manage risk.
C10: ***Greenness***. Green purchasing, appropriate sustainability policy.

B. Simulated Results

The following table (table I) represents the data collected about suppliers:

Table I
Supplier data

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
S1	1%	5	1.80	AV	G	E	VG	AV	G	AG
S2	1%	3	2.71	E	VG	G	AV	P	VG	G
S3	2%	8	2.31	G	G	VG	E	VG	AV	G
S4	3%	10	2.55	P	G	VG	E	VG	G	P
S5	5%	6	1.95	G	VG	AV	E	G	P	G
S6	2%	4	2.22	P	E	AV	G	VG	AV	VG
S7	1%	2	2.79	E	VG	G	P	E	G	E
S8	0%	1	2.80	VG	P	G	G	AV	VG	G

In AHP, preferences between alternatives are determined by making pair-wise comparisons. The function of the pair-wise comparisons is to find the relative importance of the various criteria which is rated by the nine-point scale developed by Saaty [24]. This scale indicates the level of relative importance from equal, moderate, strong, very strong to extreme level by 1,3,5,7, and 9, respectively. The intermediate values between two adjacent comparisons are denoted by 2,4,6, and 8. The nine point scale developed by Saaty has been accepted by most experts as a very scientific and reasonable basis for comparing two alternatives. A fundamental, but very rational assumption for comparing alternatives with the AHP is given as follows:
If criteria A is absolutely more important than criteria B and is rated as 9, then B must be absolutely less important than A and is graded as 1/9. These pair-wise comparisons are carried out for all factors to be considered and the matrix is completed as depicted in table II [24].

Table II
The Saaty rating scale

Intensity of Importance	Definition
1	Equal importance
3	Somewhat more important
5	Much more important
7	Very much more important
9	Absolutely more important
2,4,6,8	Intermediate values

According to the above saaty rating scale, we find that:
Quality has an equal importance with itself. (1)
Quality somewhat more important than delay time.(3)
Quality Much more important than cost.(5)
Quality is between equal importance and somewhat more important than reliability. (2)
Quality is somewhat more important than efficiency.(3)
Quality is between much more important and very much more important than capacity.(6)
Quality is much more important than leanness. (5)
Quality is somewhat more important than agility.(3)
Quality is much more important than resilience.(5)
Quality is between equal importance and somewhat more important than greenness.(2). Table III represents these data.

The weight on criteria resulted from the performance on criteria by summing each column in table III and divide each element in the matrix by the sum of this column to obtain a normalized values. After that, we calculate the average of each row as shown in table IV.

In our case: for *Quality* maximum rejection parts is 8% and total scale is divided from 1% to 8% as shown in table V.

Table V
The scale for quality maximum rejection

difference	scale
0%	1
1%	2
2%	3
3%	4
4%	5
5%	6
6%	7
7%	8
8%	9

From this table, we calculate the relative matrix of suppliers with respect to quality as shown in table VI. The weight on quality is calculated as shown in table VII.

For *delay times*, maximum days is 15 and these days are divided into scale of 1 to 9 as shown in table VIII.

Table VIII
The scale for delay times

difference	scale
0	1
1-2	2
3	3
4-5	4
6	5
7-8	6
9	7
10-11	8
12-15	9

For *unit cost*, the total difference of cost is 1.00 pound / unit (i.e. 2.80 - 1.80 = 1.00) and difference of each component cost has been taken and scale is used for these differences between 1 - 9 as shown in table IX.

Table IX
The scale for the unit cost

difference	scale
0	1
.001-.125	2
.126-.250	3
.251-.375	4
.376-.500	5
.501-.625	6
.626-.75	7
.751-.875	8
.876-1	9

For *unmeasurable criteria*, scale is divided between P to E (Poor to Excellent i.e. P = 2, AV = 3, G = 5, VG = 7, E = 9) by 1 to 9 as shown in table X.

Table X
The scale for unmeasurable criteria

difference	scale
1 - 2	2
3	3
4 - 5	5
6 - 7	7
8 - 9	9

From this table, we calculate the relative matrix of suppliers with respect to Greenness (unmeasurable criteria) as shown in table XI. The weight on Greenness are shown in table XII, and the weight matrix of suppliers are shown in table XIII. The output values using AHP Model is shown in table XIV and Fig.1.

For the neural network model, data of eight vendors(suppliers) with ten important criteria are taken. The position of AHP model is to analyze and calculate weight of each criteria and supplier(vendor) for neural network. Input value for all neurons is the same and it depends on the number of suppliers. Input value and weight(assumed) for all bias neurons are the same.

In tables (XV, XVI), the sigmoid activation function are used for hidden and output layer. In table XVI total score for all vendors are calculated and see that vendor 7 is the best vendor because it has maximum score in comparison to all other vendors.

Value of output layer $Y_{vi} = \frac{1}{1+e^{-\alpha(X_i W_{vi})}}$, $\alpha = 1$.

Where,

Y_{ci}= input value for output layer.

W_{vi} = weights of the vendors w.r.to criteria.

Y_{vi} = total score of vendor , α = 1.

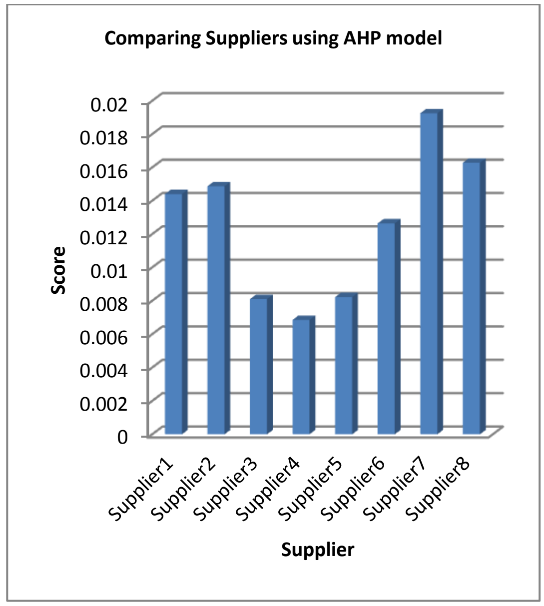

Fig.1. comparing suppliers using AHP Model

Output value for hidden layer is calculated in table XV which is the input values for output layer.

Let input value for all bias neuron = 1.

Let weight for all bias neuron = 0.2.

X_i = input value for input layer = 1/8 = 0.125.

W_{ci} = Weight of criteria.

Y_{ci} = output value for hidden layer

$= \frac{1}{1+e^{-\alpha(X_i W_{ci})}}$, $\alpha = 1$.

= input value for output layer.

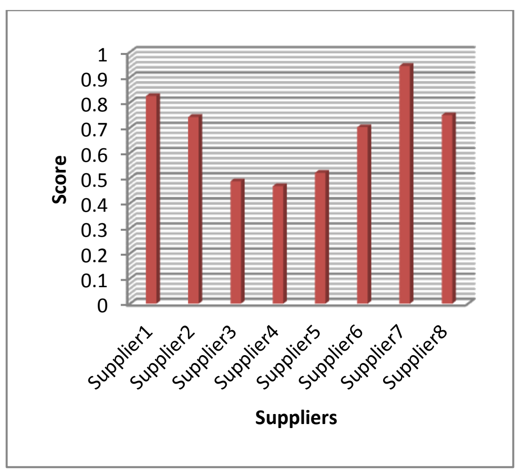

Fig.2. The evaluation and selection of a best supplier using sigmoid Activation Function.

In table XVII, the sigmoid activation function is used in the hidden layer and the hyperbolic activation function is used in the output layer.

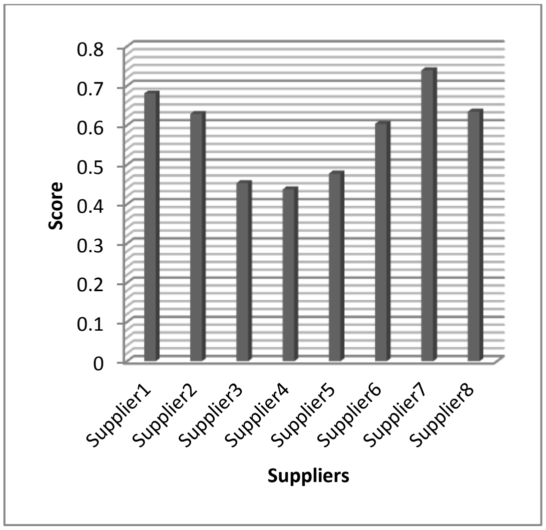

Fig.3.the evaluation and selection of a best supplier using (Sigmoid-Tanh) Activation Function.

In the three figures (2,3,4), although different activation functions are used, the evaluation of the suppliers are arranged (ranked) as follows:1) supplier 7 is the best supplier and he/she has a more score. 2) Supplier 1 is the second supplier, 3) supplier 8 is the third supplier; 4) supplier 2 is the fourth supplier; 5) supplier 6 is the fifth supplier; 6) supplier 5 is the sixth supplier; 7) supplier 3 is the seventh supplier; and finally supplier 4 is the eighth (last) supplier.

In table XVIII, the sigmoid activation function is used in the hidden layer and arctangent activation function is used in the output layer as shown in Fig.4.

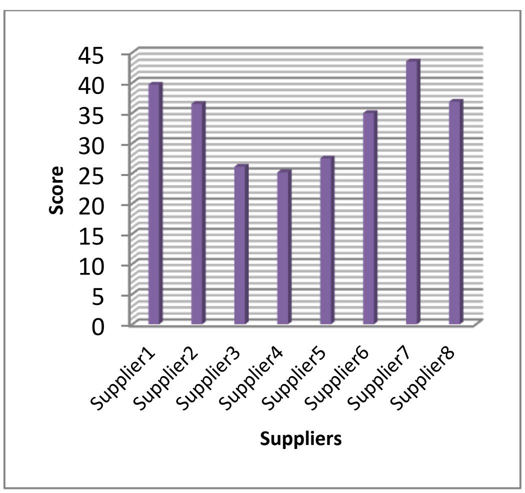

Fig. 4.the evaluation and selection of a best supplier using (Sigmoid-arctan) Activation Function.

For the entropy method, using relative reliability risk index model are calculated in table XIX and shown in Fig.5, where:

V_j represents the entropy of the criteria (attribute) j.

$E_j = 1 - V_j$

W_j is the weight of the criteria j.

R^3I_i is the relative reliability index for supplier i.

The large value in the column of R^3I_i represents the best supplier.

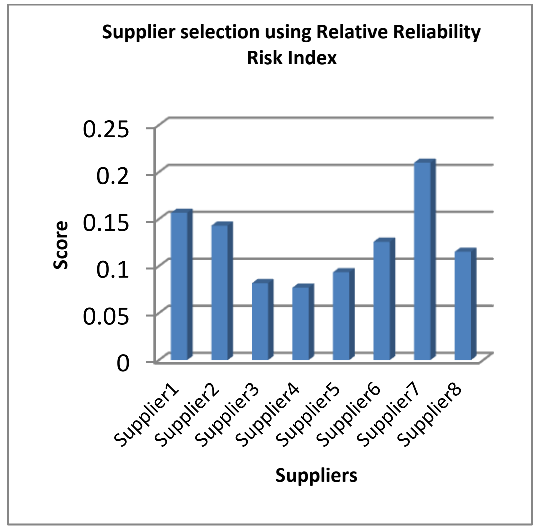

Fig.5.the evaluation and selection of a best supplier using Relative Reliability Index.

Table XX ranks the supplier selection consists of 1) the AHP model, 2) the AHP and NN model which uses the sigmoid activation function in both hidden layer and output layer, the AHP and NN model which uses the sigmoid activation function in the hidden layer and the hyperbolic activation function in the output layer, the AHP and NN model which uses the sigmoid activation function in the hidden layer and the arctangent activation function in the output layer, 3) the last model consists of using the AHP model integrated with the entropy method represented in relative reliability index model.

Using the applied different methods, table XX, and Fig. 6, shows the differences and similarities between them. It also ranks the suppliers showing that supplier 7 is the best supplier, and supplier 4 is the worst one.

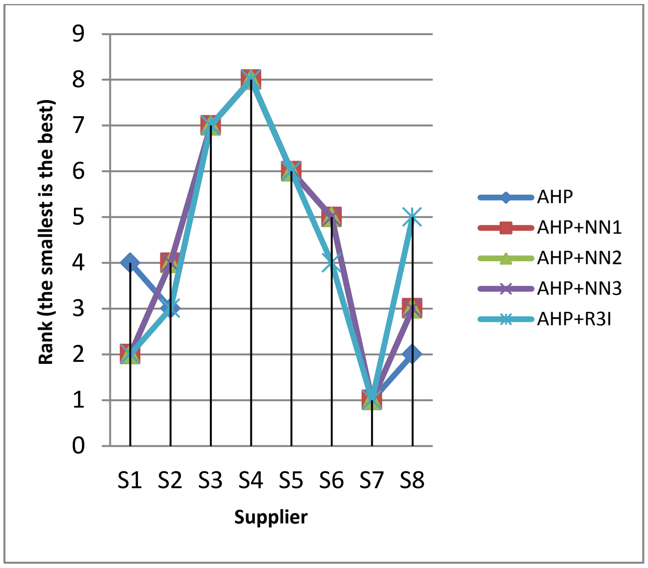

Fig.6. shows the different methods used, the differences and similarities between them.

For validation of this method through the input data in table (I), we find that supplier 7 has less rejection parts, less delay time. Excellent in reliability, very good in efficiency, good in capacity, poor in leanness, excellent in agility, good in resilience, and excellent in greenness although the cost criteria is not low.

In this work, data of eight vendors (suppliers) with ten important criteria are taken. The position of AHP model is to analyze and calculate weight of each criteria and supplier (vendor) for neural network. Input value for all neurons is the same and it depends on the number of suppliers. Input value and weight (assumed) for all bias neurons are the same.

Table III
Performance criteria

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	1	3	5	2	3	6	5	3	5	2
C2	1/3	1	7	4	5	7	1/2	1	1/2	1/2
C3	1/5	1/7	1	1/2	1/2	2	2	3	2	1
C4	1/2	1/4	2	1	1	2	2	3	3	1
C5	1/3	1/5	2	1	1	3	2	2	3	1
C6	1/6	1/7	1/2	1/2	1/3	1	2	2	1	1/2
C7	1/5	2	1/2	1/2	1/2	1/2	1	1	2	1
C8	1/3	1	1/3	1/3	1/2	1/2	1	1	2	1
C9	1/5	2	1/2	1/3	1/3	1	1/2	1/2	1	1/2
C10	1/2	2	1	1	1	2	1	1	2	1
Sum	3.766	11.735	19.833	11.1667	12.667	*25*	17	17.5	21.5	9.5

Table IV
Weight criteria

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	AV
C1	0.27	0.26	0.25	0.18	0.24	0.24	0.29	0.17	0.23	0.21	0.23
C2	0.09	0.09	0.35	0.36	0.39	0.28	0.03	0.06	0.02	0.05	0.17
C3	0.05	0.01	0.05	0.04	0.04	0.08	0.12	0.17	0.09	0.11	0.08
C4	0.13	0.02	0.10	0.09	0.08	0.08	0.12	0.17	0.14	0.11	0.10
C5	0.09	0.02	0.10	0.09	0.08	0.12	0.12	0.11	0.14	0.11	0.10
C6	0.04	0.01	0.03	0.04	0.03	0.04	0.12	0.11	0.05	0.05	0.05
C7	0.05	0.17	0.03	0.04	0.04	0.02	0.06	0.06	0.09	0.11	0.07
C8	0.09	0.09	0.02	0.03	0.04	0.02	0.06	0.06	0.09	0.11	0.06
C9	0.05	0.17	0.03	0.03	0.04	0.04	0.03	0.03	0.05	0.05	0.05
C10	0.13	0.17	0.05	0.09	0.03	0.08	0.06	0.06	0.09	0.11	0.09

Table VI
Relative matrix of suppliers w.r.t. quality

	S1	S2	S3	S4	S5	S6	S7	S8
S1	1	1	2	3	5	2	1	1/2
S2	1	1	2	3	5	2	1	1/2
S3	1/2	1/2	1	2	4	1	1/2	1/3
S4	1/3	1/3	1/2	1	3	1/2	1/3	1/4
S5	1/5	1/5	1/4	1/3	1	1/4	1/5	1/6
S6	1/2	1/2	1	2	4	1	1/2	1/3
S7	1	1	2	3	5	2	1	1/2
S8	2	2	3	4	6	3	2	1
SUM	6.53	6.53	11.75	18.33	33	11.75	6.53	3.58

Table VII
weight on quality

	S1	S2	S3	S4	S5	S6	S7	S8	AV
S1	0.15	0.15	0.17	0.16	0.15	0.17	0.15	0.14	0.16
S2	0.15	0.15	0.17	0.16	0.15	0.17	0.15	0.14	0.16
S3	0.08	0.08	0.09	0.11	0.12	0.09	0.08	0.09	0.09
S4	0.05	0.05	0.04	0.05	0.09	0.04	0.05	0.07	0.06
S5	0.03	0.03	0.02	0.02	0.03	0.02	0.03	0.05	0.03
S6	0.08	0.08	0.09	0.11	0.12	0.09	0.08	0.09	0.09
S7	0.15	0.15	0.17	0.16	0.15	0.17	0.15	0.14	0.16
S8	0.31	0.31	0.26	0.22	0.18	0.26	0.31	0.28	0.26

Table XI
Relative matrix of suppliers w.r.t. greenness

	S1	S2	S3	S4	S5	S6	S7	S8
S1	0	1/2	1/2	2	1/2	1/5	1/7	1/2
S2	2	0	0	3	0	1/2	1/5	0
S3	2	0	0	3	0	1/2	1/5	0
S4	1/2	1/3	1/3	0	1/3	1/5	1/7	1/3
S5	2	0	0	3	0	1/2	1/5	0
S6	5	2	2	5	2	0	1/2	2
S7	7	5	5	7	5	2	0	5
S8	2	0	0	3	0	1/2	1/5	0
SUM	20.5	7.833333	7.833333	26	7.833333	4.4	41645.39	7.833333

Table XII
weight on greenness

	S1	S2	S3	S4	S5	S6	S7	S8	AV
S1	0.00	0.06	0.06	0.08	0.06	0.05	0.00	0.06	0.05
S2	0.10	0.00	0.00	0.12	0.00	0.11	1.00	0.00	0.17
S3	0.10	0.00	0.00	0.12	0.00	0.11	0.00	0.00	0.04
S4	0.02	0.04	0.04	0.00	0.04	0.05	0.00	0.04	0.03
S5	0.10	0.00	0.00	0.12	0.00	0.11	0.00	0.00	0.04
S6	0.24	0.26	0.26	0.19	0.26	0.00	0.00	0.26	0.18
S7	0.34	0.64	0.64	0.27	0.64	0.45	0.00	0.64	0.45
S8	0.10	0.00	0.00	0.12	0.00	0.11	0.00	0.00	0.04

Table XIII
Weight matrix of suppliers

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
S1	0.16	0.09	0.38	0.06	0.11	0.32	0.23	0.04	0.11	0.05
S2	0.16	0.16	0.02	0.24	0.11	0.14	0.06	0.16	0.24	0.17
S3	0.09	0.04	0.11	0.09	0.08	0.08	0.16	0.09	0.07	0.04
S4	0.06	0.03	0.06	0.04	0.08	0.16	0.16	0.09	0.11	0.03
S5	0.03	0.07	0.24	0.09	0.11	0.03	0.16	0.09	0.05	0.04
S6	0.09	0.12	0.13	0.04	0.38	0.03	0.09	0.09	0.07	0.18
S7	0.16	0.21	0.03	0.24	0.11	0.18	0.06	0.39	0.11	0.45
S8	0.26	0.29	0.03	0.20	0.04	0.06	0.09	0.04	0.24	0.04

Table XIV
Output values using AHP model

	W_{c1} =.23	W_{c2} =.17	W_{c3} =.08	W_{c4} =.1	W_{c5} =.1	W_{c6} =.05	W_{c7} =.07	W_{c8} =.06	W_{c9} =.05	W_{c10} =.09	$\sum_{i=1}^{10} W_{ci} W_s$	AV
S1	0.16	0.09	0.38	0.06	0.11	0.32	0.23	0.04	0.11	0.05	0.1440	0.01440
S2	0.16	0.16	0.02	0.24	0.11	0.14	0.06	0.16	0.24	0.17	0.1487	0.01487
S3	0.09	0.04	0.11	0.09	0.08	0.08	0.16	0.09	0.07	0.04	0.0810	0.00810
S4	0.06	0.03	0.06	0.04	0.08	0.16	0.16	0.09	0.11	0.03	0.0685	0.00685
S5	0.03	0.07	0.24	0.09	0.11	0.03	0.16	0.09	0.05	0.04	0.0822	0.00822
S6	0.09	0.12	0.13	0.04	0.38	0.03	0.09	0.09	0.07	0.18	0.1264	0.01264
S7	0.16	0.21	0.03	0.24	0.11	0.18	0.06	0.39	0.11	0.45	0.1925	0.01925
S8	0.26	0.29	0.03	0.20	0.04	0.06	0.09	0.04	0.24	0.04	0.1628	0.01628

Table XV
Output values for hidden layer using sigmoid activation function

Criteria	Weight	Input value X_i	$\sum X_i W_{Ci}$	Output value for hidden layer Y_{ci}
C1	0.23	0.125	0.43	0.606
C2	0.17	0.125	0.37	0.592
C3	0.08	0.125	0.28	0.570
C4	0.10	0.125	0.3	0.574
C5	0.10	0.125	0.3	0.574
C6	0.05	0.125	0.25	0.562
C7	0.07	0.125	0.27	0.567
C8	0.06	0.125	0.26	0.565
C9	0.05	0.125	0.25	0.562
C10	0.09	0.125	0.29	0.572

Table XVI
Matrix for output layer (Sigmoid function)

S	**Y_{c1}= 0.606**	**Y_{c2} = 0.592**	**Y_{c3} = 0.570**	**Y_{c4} = 0.574**	**Y_{c5} = 0.574**	**Y_{c6} = 0.562**	**Y_{c7} = 0.567**	**Y_{c8} = 0.565**	**Y_{c9} = 0.562**	**Y_{c10} = 0.572**	$\sum Y_{ci} W_{vi}$	Y_{vi}
S1	0.16	0.09	0.38	0.06	0.11	0.32	0.23	0.04	0.11	0.05	0.83	0.696
S2	0.16	0.16	0.02	0.24	0.11	0.14	0.06	0.16	0.24	0.17	0.74	0.677
S3	0.09	0.04	0.11	0.09	0.08	0.08	0.16	0.09	0.07	0.04	0.49	0.620
S4	0.06	0.03	0.06	0.04	0.08	0.16	0.16	0.09	0.11	0.03	0.47	0.615
S5	0.03	0.07	0.24	0.09	0.11	0.03	0.16	0.09	0.05	0.04	0.52	0.627
S6	0.09	0.12	0.13	0.04	0.38	0.03	0.09	0.09	0.07	0.18	0.70	0.668
S7	0.16	0.21	0.03	0.24	0.11	0.18	0.06	0.39	0.11	0.45	0.95	0.721
S8	0.26	0.29	0.03	0.20	0.04	0.06	0.09	0.04	0.24	0.04	0.75	0.679

Table XVII
Matrix for output layer (hidden layer sigmoid – output layer tanh activation function).

S	**Y_{c1}= 0.606**	**Y_{c2} = 0.592**	**Y_{c3} = 0.570**	**Y_{c4} = 0.574**	**Y_{c5} = 0.574**	**Y_{c6} = 0.562**	**Y_{c7} = 0.567**	**Y_{c8} = 0.565**	**Y_{c9} = 0.562**	**Y_{c10} = 0.572**	$\sum Y_{ci} W_{vi}$	Y_{vi}
S1	0.16	0.09	0.38	0.06	0.11	0.32	0.23	0.04	0.11	0.05	0.83	0.681
S2	0.16	0.16	0.02	0.24	0.11	0.14	0.06	0.16	0.24	0.17	0.74	0.629
S3	0.09	0.04	0.11	0.09	0.08	0.08	0.16	0.09	0.07	0.04	0.49	0.454
S4	0.06	0.03	0.06	0.04	0.08	0.16	0.16	0.09	0.11	0.03	0.47	0.438
S5	0.03	0.07	0.24	0.09	0.11	0.03	0.16	0.09	0.05	0.04	0.52	0.478
S6	0.09	0.12	0.13	0.04	0.38	0.03	0.09	0.09	0.07	0.18	0.70	0.604
S7	0.16	0.21	0.03	0.24	0.11	0.18	0.06	0.39	0.11	0.45	0.95	0.740
S8	0.26	0.29	0.03	0.20	0.04	0.06	0.09	0.04	0.24	0.04	0.75	0.635

Table XVIII

Matrix for output layer (hidden layer sigmoid – output layer arctan activation function).

S	Y_{c1}= 0.405	Y_{c2} = 0.354	Y_{c3} = 0.273	Y_{c4} = 0.291	Y_{c5} = 0.291	Y_{c6} = 0.245	Y_{c7} = 0.264	Y_{c8} = 0.254	Y_{c9} = 0.245	Y_{c10} = 0.282	$\sum Y_{ci}W_{vi}$	Y_{vi}
S1	0.16	0.09	0.38	0.06	0.11	0.32	0.23	0.04	0.11	0.05	0.44	39.69
S2	0.16	0.16	0.02	0.24	0.11	0.14	0.06	0.16	0.24	0.17	0.43	36.50
S3	0.09	0.04	0.11	0.09	0.08	0.08	0.16	0.09	0.07	0.04	0.24	26.11
S4	0.06	0.03	0.06	0.04	0.08	0.16	0.16	0.09	0.11	0.03	0.23	25.17
S5	0.03	0.07	0.24	0.09	0.11	0.03	0.16	0.09	0.05	0.04	0.26	27.47
S6	0.09	0.12	0.13	0.04	0.38	0.03	0.09	0.09	0.07	0.18	0.36	34.99
S7	0.16	0.21	0.03	0.24	0.11	0.18	0.06	0.39	0.11	0.45	0.56	43.53
S8	0.26	0.29	0.03	0.20	0.04	0.06	0.09	0.04	0.24	0.04	0.41	36.87

Table XIX

Evaluating each supplier using entropy technique and relative risk index.

S	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	R^3I_i
S1	0.16	0.09	0.38	0.06	0.11	0.32	0.23	0.04	0.11	0.05	0.156712
S2	0.16	0.16	0.02	0.24	0.11	0.14	0.06	0.16	0.24	0.17	0.143023
S3	0.09	0.04	0.11	0.09	0.08	0.08	0.16	0.09	0.07	0.04	0.081823
S4	0.06	0.03	0.06	0.04	0.08	0.16	0.16	0.09	0.11	0.03	0.077041
S5	0.03	0.07	0.24	0.09	0.11	0.03	0.16	0.09	0.05	0.04	0.093437
S6	0.09	0.12	0.13	0.04	0.38	0.03	0.09	0.09	0.07	0.18	0.125903
S7	0.16	0.21	0.03	0.24	0.11	0.18	0.06	0.39	0.11	0.45	0.210003
S8	0.26	0.29	0.03	0.20	0.04	0.06	0.09	0.04	0.24	0.04	0.115179
Vj	0.8414	0.8126	0.7277	0.8107	0.8129	0.7917	0.8637	0.7751	0.8406	0.6994	β = 0.434294
Ej	0.1586	0.1874	0.2723	0.1893	0.1871	0.2083	0.1363	0.2249	0.1594	0.3006	$\sum E_j$ = 2.024163
Wj	0.0784	0.0926	0.1345	0.0935	0.094	0.1029	0.0673	0.1111	0.0788	0.1485	$\sum W_j$ = 1

Table XX

Ranks for supplier selection.

Supplier	AHP	AHP+NN_1	AHP+NN_2	AHP+NN_3	AHP+R^3I
S1	4	2	2	2	2
S2	3	4	4	4	3
S3	7	7	7	7	7
S4	**8**	**8**	**8**	**8**	**8**
S5	6	6	6	6	6
S6	5	5	5	5	4
S7	**1**	**1**	**1**	**1**	**1**
S8	2	3	3	3	5

VII. DISCUSSION AND CONCLUSION

It is important to note that SCs, can be viewed as a network of suppliers, manufactures, distributors, and retailers. The efficiency of the network is dictated mainly by the characteristics of suppliers and also is influenced by mode of transportation, information flow, and financial infrastructure. Choosing the best supplier improves the performance of the supply chain and increases customer satisfaction.

The need to minimize product costs makes effective supply chain management vital. The organization should have good relation with the supplier to enhance efficiency. An organization that employs effective supply chain officers is able to achieve efficiency of its operations since only those values adding activities are encouraged. This ensures that the organization's processes flow smoothly and output keeps in line with the organization's needs. The employees who are highly motivated works towards achieving the goals of the organization. The organization should ensure that they have competent supply chain staffs who focus on ensuring buyer supplier relationships are met. A supplier who is treated with courtesy, honesty, and fairness will deliver a quality product at the best price, will provide good service, and will be responsive to emergency situations and special requests. There is also a public relations aspect to purchasing that should not be overlooked. An organization's public image can be a valuable asset. A supplier who is treated equitably and professionally is likely to communicate his positive experiences with your organization to his associates. Effective buyer-supplier relationships help both exchange parties manage uncertainty and increase efficiency of the supply chains. There is need to have mutual cooperation among all supply chain partners which is essential to achieve better supply chain performance in terms of increasing sales with fewer inventories in the total system and matched supply and demand as lack of cooperation can lead to delays and poor quality of goods distributed. In recent decades, globalization, outsourcing, and information technology have enabled many organizations, to successfully operate collaborative supply networks in which each specialized business partner focuses on only a few key strategic activities [40].

As more and more manufacturing firms have realized the importance of supplier performance in establishing and maintaining their competitive advantage, purchasing research has tended to focus on supplier development programs and explore how these initiatives impact on buyer and supplier performance which eventually leads to organizational improvement. There are reasons why supplier development has become a key element in maintaining or improving a company's competitiveness which in turn leads to organizational improvement. Firstly, technological and competitive pressures have resulted in a greater trend towards specialisation. Secondly, the nature of competition itself has changed. Facing up to the challenge of stiffer competition and having to supply the global markets, manufacturers have quickly learned the importance of improving productivity and quality. Suppliers play a very vital role in the production value chain. They indirectly determine the quality of the final product. There is therefore need for the manufacturing firms to put in place measures to develop and equip suppliers with prerequisite skills in order to ensure quality supplies and this is done through supplier development [41]. Thus, the industry offers a classic model for implementing supply-chain management techniques. In a supply-chain, a company is linked to its upstream suppliers and downstream distributors as materials, information, and capital flow through the supply-chain [42].

Most supplier selection models consider the buyer’s viewpoint and maximize only the buyer’s profit. This does not necessarily lead to an optimal situation for all the members of a supply chain. To select the suppliers, there is a need to rank all the potential suppliers according to a performance measure because in this industry almost all items are outsourced from suppliers and input material cost constitute almost 80% cost of the product. For this reason any organization is required to select suitable suppliers who can supply input materials and components to the organization as per the need timely with right specification and requisite quantity. It is preferred that all supply management organizations should have and use a supplier scorecard system to evaluate supplier performance and ensure early identification of supplier problems.

The selection of right vendor for an organization should not only meet customer requirements, bring profit to the firm, but also help in fulfilling various criteria such as cost, delivery, quality objectives and technical specifications. It is needed to develop, a systematic vendor selection process for identifying and prioritizing relevant criteria and to evaluate the trade offs between technical, economic and performance criteria. The method used should also reduce time in vendor selection and develop consensus decision making.

In this paper, it is very attractive to use AHP, NNs and Relative Reliability Risk Index (R^3I) models to develop an integrated model, which involves the advantages of these models. The model enables us to deal with the complexity and criteria embedded in the supplier selection problem. Leanness, Agility, Resilience and Greenness paradigms are used in this paper as a new criteria for evaluating and selecting the best supplier.

The model consists of three modules: Module1 applies AHP and pair wise comparison of criteria and suppliers with respect to each criterion to obtain the weight of each criteria and suppliers. Module2 utilizes the results of AHP into NNs model for supplier evaluation and selection. In the NNs model, three activation functions, namely the sigmoid activation function, the hyperbolic activation function and arctangent activation function are used and gives the same arrangement. Module3 utilizes the results of AHP into R^3I model for supplier evaluation and selection. The results are meaningful and promising in that this study provides a hybrid framework to integrate AHP, NNs and R^3I techniques and demonstrate its application to supplier selection problem. A hybrid model of these modules yield an appropriate score to evaluate and know the performance of all suppliers and choosing the best supplier. By validating this hybrid method, vendor 7 is the optimal supplier.

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