Supplier Selection in Shipbuilding Industry – A Review

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Abstract. There are many criteria and methods that can be used to select the right supplier. Selection of a suitable supplier is needed, especially in the shipbuilding industry. Selection of suppliers is to reduce risky purchases, maximize price suppression with the best quality goods for buyers and establish long-term relationships between suppliers and buyers to facilitate future cooperation with today's increasingly competitive industry. This study was made to critically analyze the factors and appropriate methods in selecting suppliers in the shipbuilding industry. With many methods and criteria that are of particular concern to today's industrial developments, in this paper the literature has been thoroughly reviewed to help provide solutions to these problems. The results of the reviews that have been carried out can be seen that the right criteria for selecting suppliers include quality, price, delivery, service, technical ability, financial strength, geographical location, reputation, reciprocal arrangements, etc. Likewise, the methods used, namely ANP-PROMETHEE and LARG, can be taken into consideration for a good supplier selection method.

1. Introduction

In most industries including shipbuilding, one of the proportions that has a large enough value in development financing is the cost of components and raw materials. Therefore, it is necessary to be careful in choosing the right supplier of raw materials in the procurement process as an opportunity for companies to reduce production costs, so that shipyard companies can offer excellent products at competitive price levels, so that shipyard companies can offer excellent products at competitive price levels, each company must try to press or reduce all costs without reducing product quality or the standards that have been set [1]. However, choosing the appropriate supplier is not easy because it requires criteria that must be checked carefully and the fact is that in the field there are still many companies choosing vendors based on their experience and intuition, where this approach is subjective [2, 3]. Over the years the criteria for selecting suppliers have been based on the vendors who are able to provide the lowest prices. However, making price the main criterion for the current era has begun to be inefficient and has transformed into a more comprehensive multi-criteria approach. Apart from price, new criteria that need to be considered include environmental, social, political and customer satisfaction factors in addition to paying attention to quality, delivery, cost and service [4].

Currently, it is commonly used a distributed manufacturing system consisting of manufacturing components at different physical locations and processed by a supply chain management system, combining all components and assembling them into more complex products [5]. The way companies work with their supply chain partners creates a sustainable competitive advantage because the company has claimed suppliers to form a competitive advantage for the buying company [6]. This pattern can also be applied when ship was built. Supply chain itself, if described is a concept that has the aim of being able to connect and manage resources, flow and control of raw materials from various perspectives based on various functions and various levels of suppliers [7]. The shipyard company's ability to set strategies in choosing good quality suppliers will continuously increase customer satisfaction which is expected to increase company profits and also in a sustainable manner can be a more effective way to be able to select suppliers for future projects. This selection is done by selecting
several suppliers to make it easier to compare so that one can choose the one that best fits the company's needs. Noting the strategic importance of the role of suppliers in the supply chain function, researchers have developed a number of criteria, methods, and models for supplier selection. Therefore, this research was conducted to provide a reference in selecting the right supplier, especially in the shipbuilding industry using the ANP-PROMETHEE and LARG methods and based on certain criteria such as quality, price, delivery, service, technical ability, financial strength, geographical location, reputation, reciprocal arrangements, etc. The relevant literature has been thoroughly reviewed and is presented below.

2. Literature Review

A.N. Sariyun [8] wrote an article about "Manajemen Rantai Pasokan (Supply Chain Management): Konsep Dan Hakikat" providing an explanation of supply chain management which has been widely discussed and has become a common thing that is often found in print media, books and discussion forums. However, because it is a relatively new discipline, there are still many who do not quite understand the term as many think that supply chain is a software and can only be owned by manufacturing companies. In the supply chain there are several main players who are companies that have the same interests, namely:

1. Supplies
2. Manufactures
3. Distribution
4. Retail Outlet
5. Customers

From this article it can also be concluded that the supply chain management implemented in the company is expected to increase the effectiveness and efficiency in the process of purchasing raw goods, fulfillment of customer orders and the process of distributing goods. The application of supply chain management today is suitable, because this system has the advantage of being able to regulate the flow of goods or products in a supply chain.

P. Om, K.G. Amit [4] made a review on "Supplier Selection Criteria and Methods in Supply Chains: A Review" concluded that there has been a lot of research on how to select suppliers since 1960. Where is the importance of selecting suppliers that will impact the entire supply chain starting from material procurement raw material until the process of sending the finished product to the customer. Researchers have provided reviews and methods of appropriate methods in making decisions in choosing suppliers. The reviews are price, quality, delivery, track record, policy, technical capability, industry reputation and position, attitude, geographic location, financial position, repair services, quantity, previous business, passion for business, procedural compliance and packaging skills, employee relations and reciprocal arrangement. Based on the review, it is not rational to suggest that the problem of supplier selection needs further attention to align a combination of qualitative and quantitative criteria to develop the best criteria and methods for selecting the best supplier. While the suggested methods to be able to select many suppliers and reduce them to smaller groups with acceptable criteria are categorical methods, Data Envelopment Analysis (DEA) and Cluster Analysis (CA).

M. Wicaksono, S. Bayu, etc. [9] wrote about "Implementasi Metode ANP-PROMETHEE untuk Pemilihan Supplier (Studi Kasus PT. Lamongan Marine Industry)". Analytic Network Process (ANP) has 2 controls, namely the control hierarchy showing the relationship between the criteria and sub-criteria interests and the control of the relationship between criteria and clusters. As a general theory...
The relative measurement of ANP functions as a derivative of the compost priority ratio from the ratio reflecting the relative measurement of the effects of mutually adjustable elements due to control criteria [10]. PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) is a simple and flexible method for analyzing multi-criteria problems using the value in the outranking relationship as an estimate of the dominaso criteria [11].

R.P. Magdalena, J.A.F. Francisco, etc [12] wrote a journal on "Shipbuilding 4.0 Index Approaching Supply Chain". Using the LARG paradigm: Lean, Agile, Resilient and Green. The conclusion that can be drawn from the journal is an evaluation that can be carried out in shipbuilding adapting Industry 4.0, developing factors that make it possible to find out, current supply chain developments and also how to evaluate technology that allows it to adapt more quickly and efficiently to Industry 4.0. This development has been carried out in collaboration by professional experts from the shipbuilding sector and academics who have links to this sector. The shipbuilding industry shows a special interest in the supply chain system being a major factor in various changes, as well as a control tool in carrying out repairs. In addition, the adaptation of supply chain use in industry 4.0 also shows an interest and some disorientation, which can be used by managers to decide which technology has priority over others to achieve their goals. It also highlights the need for future research to establish different criteria to improve the criteria studied.

3. The Criteria for Selecting Suppliers

The process of identifying and analyzing the criteria for selecting suppliers of components and materials used has been widely reviewed by professional experts and related academics. Dickson (1966) in his work sent 300 questionnaires to companies, mostly in the manufacturing industry. The procurement divisions of these companies were asked to identify what factors were most important for selecting suppliers. This questionnaire is divided into two categories, namely vendor selection by companies and individual selection. Then we get what factors influence vendor selection, namely [13]:

1. Quality
2. Price
3. Delivery
4. Service
5. Technical Ability
6. Financial strength
7. Geographical location
8. Reputation
9. Reciprocal Arrangements
10. Another factor

If discussed further, these factors are indeed important criteria in selecting suppliers of materials to be used in the construction process, one of which is for the construction of vessels.

1. Quality

Seeing whether the supplier is able to provide raw materials that are of high quality and at least have the minimum standards required by local organizations and governments to maintain the safety of the final product and the durability of the final product when used for a long time.
2. Price
Suppliers can provide competitive and varied prices. The lowest and competitive price is still the company's priority.

3. Delivery
The company will see suppliers who are able to provide flexible shipping facilities with less complicated rules and are able to deliver the materials on time according to a predetermined schedule.

4. Service
Suppliers provide good service to customers, especially when communicating during the procurement process. A supplier who is nimble and friendly and able to provide good explanations has a plus point.

5. Technical Ability
Suppliers already know what to do on the field from the initial negotiations to product delivery. Can solve technical problems quickly and be able to adapt by utilizing existing technologies that are in accordance with the times so as to make work more efficient.

6. Financial strength
Assessment of financial stability and the physical prospects of suppliers are increasingly important factors in line with the growing trend between suppliers and prospective buyers of goods. Suppliers who do not have a solid and stable financial foundation will find it difficult to contribute to the partnership business, because suppliers will focus more on efforts to improve their financial stability. Both buyers and suppliers will look for partners who can work with in the long and sustainable way who will contribute to good relations so that both suppliers and buyers will pay attention to the financial condition of their partners before making cooperation decisions [13].

7. Geographical location
The position where the vendor is located greatly influences the supplier selection process by the company. The thing that is most considered is the distance between the project that will be running and the vendor because this will affect the delivery process, especially the ones that will be considered are the means of transportation used, the terrain to be traveled and the length of the delivery process which will affect the costs that must be incurred.

8. Reputation
The reputation of the vendor that will be selected must not go unnoticed. It is necessary to investigate the track record of the vendor to minimize the bad possibilities that may occur in the future. Looking for positive feedback from previous customers so that long term trust can be established between companies that will supply materials or materials from the vendor.
9. **Reciprocal Arrangements**

There is an agreement or regulation in writing between the vendor and the company that contains monitoring, supervision and regulation of trade and settlement of transactions.

10. **Another Factor**

The use of the internet to centrally integrate supply chains can greatly contribute to a company's profit and competitiveness. It is possible that the widespread use of e-procurement will allow companies to move closer, saving time and effort. Suppliers will also minimize inventory costs and data can be accessed and updated anywhere without fear of loss or damage [13].

4. **Various Supplier Selection Methods (Prequalification)**

Initial qualification is a process where multiple vendors are selected and eliminated into smaller scopes until suppliers who meet the criteria are found. The methods that can be used are:

1. **Categorical Methods**

Existing or known suppliers are evaluated based on the required criteria, based on the buyer's history and experience. The advantage of using this method is that it helps to make assessments in a clear and systematic manner.

2. **Data Development Analysis (DEA)**

A grouping system which divides suppliers into two categories, namely efficient and inefficient and is assessed based on input and output criteria.

3. **Cluster Analysis (CA)**

CA is a basic statistical method that uses an algorithmic system to classify objects based on clusters that have similar characteristics. This grouping is used to reduce the larger suppliers into smaller subsets so that they are easy to manage.

5. **Multi Attribute Decision Making (MADM) Techniques**

The MADM technique is used to help select suppliers which usually involve more than one criterion where these criteria contradict one another. Some of the MADM techniques are:

1. **Analytical Hierarchical Process (AHP)**

AHP is a method that is quite easy to apply where this method provides an alternative ranking or sequence when there are several criteria and sub-criteria in decision making [14]. These criteria are complete, operational, not excessive and minimum [15].

2. **Analytic Network Process (ANP)**

ANP is a comprehensive decision-making method that captures the results of dependencies and feedback within and between groups of elements. AHP is the starting point of ANP and ANP is the more common form of AHP network. ANP is a combination of two criteria, namely, the first part
consists of a hierarchy of controls or a network of criteria and subcriteria that controls interaction, while the second part is a network of influence between elements and clusters [16].

3. Total Cost of Ownership (TCO) Models

The TCO-based model in supplier selection basically consists of simplifying and calculating all or some of the costs associated with the selected vendor and adjusting the price agreed upon by the supplier [17].

4. Multiple Attribute Utility Theory (MAUT)

MAUT is a linear weighting technique. Enable professionals to formulate a viable sourcing strategy capable of addressing the problem of conflicting attributes. However, this method is only used to select international suppliers which are more complicated and risky [18].

5. Outranking Methods

Used to solve multi-criteria problems. This method only partially solves the problem and handles situations where there is uncertainty [19].

6. Technique for the Order Performance by Similarity to Ideal Solution (TOPSIS)

The closest coefficient is defined to determine the supplier ranking and the linguistic value is used to assess the rating and factor weights. TOPSIS based on the optimal alternative must have the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS) [20].

6. Mathematical Programming (MP) Models

MP is a model that only considers quantitative criteria and allows considering various constraints in choosing the best supplier. This model is ideal because it uses a single objective model and a multiple objective model with maximum results in supplier selection. There are 2 MP programs namely Multi-Objective Models and Goal Programming Models [21], [22], and [23].

7. Artificial Intelligence [AI] Method

Systems that use computers as a basis for processing based on historical data and experience. This system has the advantage of overcoming complex and uncertain supplier selection.

1. Case-Based-Reasoning (CBR) Systems

CBR is a relatively new system. Used to access useful information and experience from previous decisions that are similar to making decisions.

2. Artificial Neural Network (ANN)

Models that require qualified experts but the ANN model can save time and money in processing.
8. Fuzzy Logic Approach

Ranks and weights are assessed using linguistic values and expressed in trapezoidal or triangular fuzzy numbers [4].

9. Hybrid Methods

Hybrid method is a method that combines several methods in the process of supplier selection. Such as MAUT and LP as solving problems in supplier selection, ANP and TOPSIS to identify interdependent criteria, and Fuzzy and TOPSIS as decision makers when facing uncertainty [4].

10. Using the ANP-PROMETHEE Method to Select Suppliers in Shipyard Companies

The ANP and PROMETHEE methods have their respective functions in solving supplier selection problems at shipyards. The ANP method can solve the problem in terms of the complexity of the large number of supplier choices available and the sub-criteria variable so that it remains objective in making an assessment or it can be called ANP tends to solve problems in terms of MODM. While the PROMETHEE method is able to handle problems in terms of MADM because it is used to deal with problems in terms of the complexity of the attributes of each variable in order to be precise in determining the level of importance of each predetermined attribute. A significant impact is seen on the values that exist in PROMETHEE when compared with the ANP values from weighting results in determining the final decision for supplier ratings. By combining the ANP-PROMETHEE method, the best alternative supplier output results are more rational when compared to doing manual and subjective assessments [10]. For example, research conducted by Ma'had, Bayu and Farikhin (2020) at the shipyard PT. Lamongan Marine Industry, for the supplier of plate 6 feed 14 mm. Selected data from 8 different suppliers (MG, ATT, ESA, YSA, INT, GC, SUT, BIZ). The data is then classified into criteria, namely bid price, discount, delivery accuracy, shipping costs, packing, document completeness, product quality, ability to provide consistent quality, distance between locations, management role, information technology, reward systems, organizational structure and cooperation. Research is carried out manually and based on the values made by experts (P). The results of the experts' net flow calculations were made from P1-P6 with a consistency ratio (CR) value that should not be more than 0.1 (their opinion is considered consistent). The output from P1-P6 is then recapitulated to be the final result of the alternative ranking. The supplier with the largest Net flow value from the recapitulation is the best supplier. According to the calculation results that have been carried out, the best supplier for the 6 feed 14 mm plate is the supplier of SUT.

11. Paradigma LARG on the Supply Chain

The survey results show that Lean gets the highest score for the LARG paradigm as a shipbuilding supply chain followed by Agile and Resilient with the lowest weight. Lean is the most widespread paradigm and can be used for a long time. Lean is considered optimal because it is able to produce on a large scale in small batches, focuses on customers producing a lot of production with less waste, fast customer response, reduces inventory, increases work cycle efficiency, helps achieve more concise processes and provides instructions and advanced delivery times. The Agile Paradigm is not completely in line with the volume and variation of production required in the shipbuilding supply chain, while the Resilient Paradigm is the paradigm that most requires supply chain visibility. It is also known that Resilient is quite difficult to practice, this is due to the high cost required to practice
this paradigm and the possible results will be close to the results of the lean paradigm. As for the Green paradigm, it shows surprising results because it has a lower value, where this paradigm is actually considered a key factor in shipbuilding to increase company competitiveness and improve energy efficiency [12].

12. Method Comparison

After conducting a literature study on the method of selecting suppliers, then a comparison of the methods that have been studied is made, it is intended to select how the suitable supplier selection method to be applied in shipyards. Table 1 below give resume about characteristic of each method.

| No | Method | Characteristic |
|----|--------|----------------|
| 1  | Categorical Methods | helps to make assessments in a clear and systematic manner |
| 2  | Data Envelopment Analysis | assessed based on input and output criteria |
| 3  | Cluster Analysis (CA) | reduce the larger suppliers into smaller subsets so that they are easy to manage |
| 4  | Analytical Hierarchical Process | provides an alternative ranking or sequence when there are several criteria and sub-criteria in decision making |
| 5  | Analytic Network Process (ANP) | combination of two criteria, namely, the first part consists of a hierarchy of controls or a network of criteria and subcriteria that controls interaction, while the second part is a network of influence between elements and clusters |
| 6  | Total Cost of Ownership (TCO) Models | simplifying and calculating all or some of the costs associated with the selected vendor |
| 7  | Multiple Attribute Utility Theory (MAUT) | formulate a viable sourcing strategy capable of addressing the problem of conflicting attributes |
| 8  | Outranking Methods | Used to solve multi criteria problems |
| 9  | Technique for the Order Performance by Similarity to Ideal Solution (TOPSIS) | determine the supplier ranking and the linguistic value is used to assess the rating and factor weights |
| 10 | Mathematical Programming (MP) Models | uses a single objective model and a multiple objective model with maximum results in supplier selection |
| 11 | Case-Based-Reasoning (CBR) Systems | access useful information and experience from previous decisions |
| 12 | Artificial Neural Network (ANN) | save time and money in processing |
| 13 | Fuzzy Logic Approach | Ranks and weights are assessed using linguistic values |
| 14 | Hybrid Methods | combines several methods in the process of supplier selection |
| 15 | ANP-PROMETHEE Method | best alternative supplier output results are more rational when compared to doing manual and subjective assessments |
| 16 | Paradigma LARG | focuses on customers producing a lot of production with less waste, fast customer response, reduces inventory, increases work cycle efficiency, helps achieve more concise processes and provides instructions and advanced delivery times |
Through the comparison table that has been made, it can be seen that not all supplier selection methods are suitable for use in the shipbuilding industry. This is because shipbuilding industry is one of industry manufacture type that based on demand or projects and their characteristic are not same with mass industry. From the review, it can be conclude that ANP-Promethee Method and Paradigma LARG is the method of supplier selection that suitable to use in shipbuilding industry. It is because ANP-Promethee method is supplier selection method that can solve the problem in terms of the complexity of the large number of supplier choices available. This method accommodate MADM method in making decision that need in supplier selection process for shipbuilding because number of supplier are large and variated. Paradigma LARG method focuses on customers satisfaction, efficiency in production and delivery times, so this method give a lot of parameters in supplier selection process. Therefore this method is suitable in shipbuilding industry.

13. Conclusion

The conclusion that can be drawn based on the review that has been made is that the selection of suppliers for shipyards can be done by taking into account criteria such as quality, price, delivery, service, technical capability, financial strength, geographical location, reputation, reciprocal arrangements and other factors. As well as the ANP-PROMETHEE and LARG methods can be taken into consideration in determining a good supplier.

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