RESEARCH OF SUPPLIER SELECTION IN TRANSFORMER PRODUCTION AND THEIR EFFECTS ON PERFORMANCE

(TRAFO ÜRETİMİNDE TEDARİKÇİ SEÇİMİ VE PERFORMANS ÜZERİNDEKİ ETKİLERİNİN ARAŞTIRILMASI)

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This is to certify that the thesis entitled

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Supplier selection is important for transformer manufacturers as well as all sectors. However, market conditions and obligations make the choice of suppliers in the energy sector a vital and strategic level for companies.

In this thesis, I tried to solve a real-life problem using what I learned during my education. I would like to thank my wife Özge Faydalıel Balcı and my supervisor Asst. Prof. Murat Levent Demircan for their help in this process.

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LIST OF SYMBOLS

AHP	**:** Analytic Hierarchy Process
EU	**:** European Union
FAHP	**:** Fuzzy Analytic Hierarchy Process
ISO	**:** International organization for standardization
MUSD	**:** Million US dollar
OTD	**:** On time delivery
WSM	**:** Weighted Sum Method

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ABSTRACT

The transformer is an indispensable product used in the distribution of electricity in the energy sector. Although transformer production may seem simple, it is a job that requires serious knowledge. There are many markets in this sector and each market has a different priority. There are certain manufacturers in the international market where the profit margin is higher. Competition in this market is high. In this competition, companies try to maintain or even increase their market share. For this reason, companies try to deliver their products on time and maintain quality levels while trying to provide a more competitive price. One of the solutions companies use when trying to reach these goals is outsourcing.

In this thesis, the options of a company that produces transformers and plans to achieve these goals by outsourcing have been evaluated. During the evaluation, AHP and TOPSIS methods, which are multi-criteria decision-making methods, were used. In addition, the effect of the possible choices on the financial performance of the company was also investigated. Three different methods were used in the study and at the end, these methods were compared and discussed. Sensitivity analysis was also done while making the comparison.

Although the results of the three methods that used seem to be different from each other, a definite conclusion was reached as a result of the evaluations made.

ÖZET

Trafo, enerji sektöründe elektriğin dağıtımında kullanılan vazgeçilmez bir üründür. Trafo üretimi basit gibi görünse de ciddi bilgi gerektiren bir iştir. Bu sektörde birçok pazar vardır ve her pazarın önceliği birbirinden farklıdır. Kar payının daha yüksek olduğu uluslararası pazarda ise belli başlı üreticiler mevcuttur. Bu pazarda rekabet üst seviyededir. Bu rekabette firmalar pazar paylarını korumaya hatta artırmaya çalışmaktadırlar. Bu nedenle firmalar daha rekabetçi bir fiyat sunmaya çalışırken ürünlerini zamanında teslim etmeye ve kalite seviyelerini korumaya çalışırlar. Firmaların bu hedeflere ulaşmaya çalışırken kullandıkları çözümlerden biri de dış kaynak kullanımıdır.

Bu tezde, trafo üreten ve bu hedeflere dış kaynak kullanarak ulaşmayı planlayan bir firmanın elindeki seçenekleri değerlendirilmiştir. Değerlendirme sırasında çok ölçütlü karar verme yöntemlerinden AHP ve TOPSIS yöntemleri kullanılmıştır. Ayrıca olası tercihin şirketin finansal performansı üzerindeki etkisi de araştırılmıştır. Çalışmada üç farklı yöntem kullanılmış ve sonunda bu yöntemler karşılaştırılmış ve tartışılmıştır. Karşılaştırma yapılırken duyarlılık analizi de yapılmıştır.

Kullanılan üç yöntemin sonuçları birbirinden farklı gibi görünse de yapılan değerlendirmeler sonucunda kesin bir sonuca varılmıştır.

1. INTRODUCTION

The increase in the world population and globalization have led to the development of trade in every field of industry. With the development of world trade, there is a growth in the field of production and logistics day by day. With the increase in production and logistic, the need for raw materials and energy increased day by day.

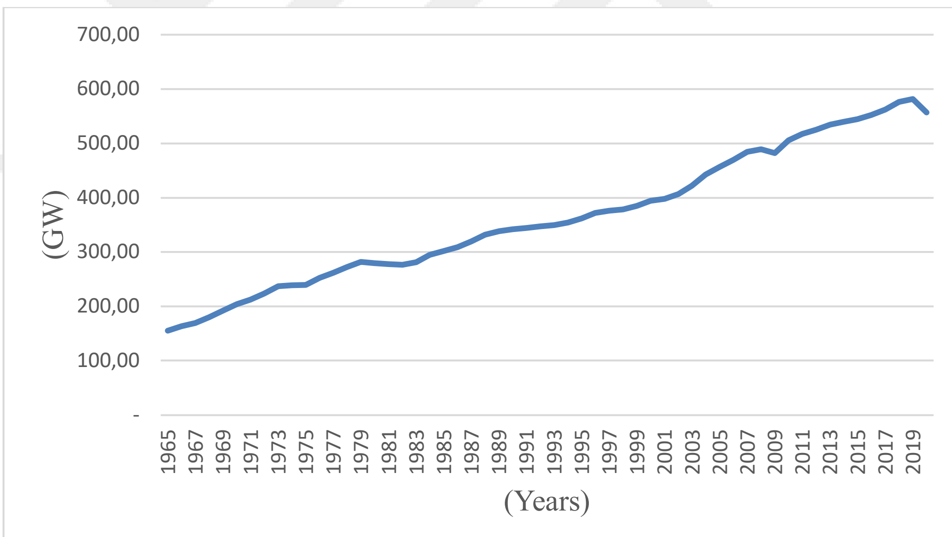

Figure 1.1: World energy consumption by year

The increase in the need for energy day by day has brought along the need for a transformer, which is an essential product in the distribution of electricity. The transformer industry continues to grow both with the increase in energy need and the opening of new markets and the need for renewal in existing markets.

Climate change, the effect of which we have seen more frequently in recent years, has forced countries to convert from fossil fuels to renewable energy. The renewable energy market has become a new market for transformer manufacturers. In addition, a new opportunity has arisen for transformer manufacturers, as the change in the sector means the renewal of the existing transformers in the field. Wind energy and solar energy play a leading role in renewable energy.

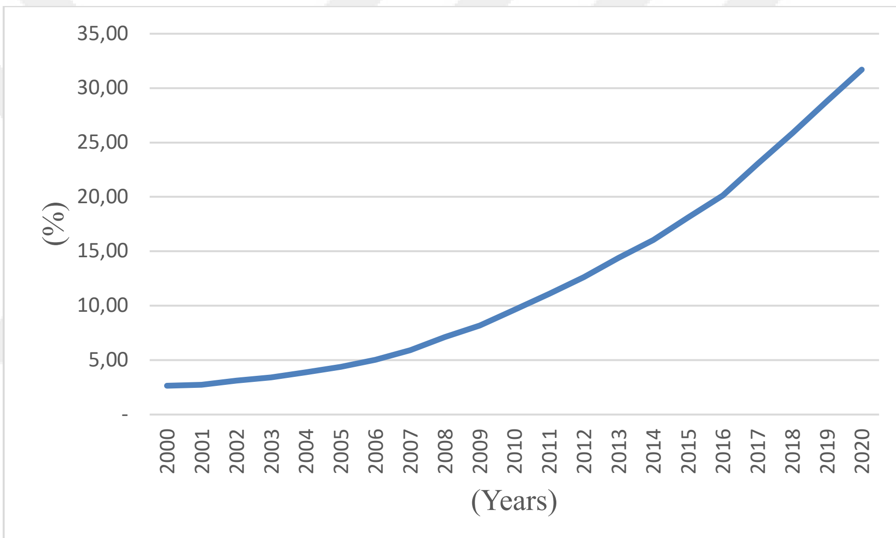

Figure 1.2: Percentage of renewable energy consumption by years

Together with climate change and the increase in energy prices, energy efficiency is one of the main areas of work for countries and companies today. Losses do not occur only in the production or consumption of energy. There are also losses in the distribution of energy. One of the points where losses occur in the distribution of electricity is the transformer itself. Countries have started to increase the energy efficiency levels in transformers by introducing new regulations in their laws as a precaution in this regard. EU has already passed a new law for the transformers to be purchased and revised and has already started to implement it.

For these reasons, in order to reduce losses in transformers, the tendency to materials with higher conductivity is increasing. Along with the changing market, transformer sizes have also had to be reduced due to the structure of the places where solar energy and wind energy fields are established. This has also had an impact on the increase in the use of materials with high conductivity.

The increase in the prices of commodities such as copper with higher conductivity is directly reflected in transformer costs and prices. In addition to copper, the increase in sheet metal, aluminium, oil, core sheet and insulation materials also directly affects production costs. Transformer design and production are basically based on the same principles, although they have progressed in terms of technology and knowledge. However, there are many companies in the sector and there is a serious competition. Due to the above-mentioned reasons, while transformer production costs increase, the manufacturing companies may have to reduce their sales prices and thus waive some of their profits in order to remain competitive in the sector.

The increase in production costs is not only due to the type of materials used, but also to the increase in general commodity prices. Especially recently, the difficulty in accessing commodities has caused companies to look for different solutions in this regard. Some companies are trying to manage the process by stocking materials at low prices, while others go to outsourcing to get rid of the inventory load. According to the changing material prices, the strategic decisions of the companies for the future are gaining more importance day by day.

In order to exist in the market in the transformer industry, manufacturers must have the appropriate technology and have a competitive price. However, this is not enough. Quality, deadline, and on-time delivery have a very important place in the energy sector. In fact, most of the time, these criteria can be more important than the price for the customer. In the transformer sector, especially in the solar energy and wind energy markets, the manufacturers are sold to subcontractors, not directly to the end user.

Sustainability in working with subcontractors are important because if subcontractors are satisfied, they continue to work with existing manufacturers and place orders with them. In order to achieve this, it is expected that the manufacturers will be at a satisfactory level in terms of on-time delivery, and quality.
Quality costs are very important in the energy sector both in terms of customer satisfaction and the effect of reworked labour on profitability. If poor quality is noticed at the procurement and production stage, the cost to the manufacturers is less than if this poor quality is noticed at the customer's site. Even if the poor quality noticed inside can be corrected with relatively low labour costs, the product may not be delivered to the customer on time due to the process taking longer than usual. This may cause the subcontractor to delay the product and pay compensation to the end user. Recognizing the poor quality at the customer's site creates serious costs for the manufacturers due to the product technology and market conditions. Most customer sites are quite difficult to reach. Due to the structure of the sector, repairs must be carried out by trained and certified operators in accordance with the legislation. Due to the transportation of the equipment used, the execution of the transactions and the inability of the customer to use the field during this entire period, the costs of the manufacturer company can reach levels where they can lose all their profits for that product. The costs of stopping a power generation plant in the energy sector are quite high. In addition, it is very difficult for a manufacturer to work with a subcontractor whose trust has been lost and to re-enter that market.

In addition to on-time delivery and quality, the deadline is given to customers is also very important. Some manufacturers may be out of the game due to the long deadlines at the order stage. Therefore, production capacity and flexibility are very important for manufacturers.

All these mentioned criteria and their results play an important role in the future strategies of companies. When manufacturers have to choose between investing in their existing operations or outsourcing their operations, they will have to compare the financial advantage they gain with the risk they will take. Companies will want to not compromise on quality while increasing their production capacity and flexibility. Along with all this, they will also want to remain competitive in the market in terms of cost. Companies will make their future plans between this dilemma.

2. THE PURPOSE OF THESIS

As in almost all sectors, there is an increasing competition in the transformer sector. In recent years, the company has had problems in entering new markets due to long deadlines and insufficient capacity. In addition, it had to cover serious costs due to quality inconsistencies from its suppliers. Increasing price pressure with the competition and the recent increase in commodity prices have put the financial structure of the company in a very difficult situation. The company has developed some strategies in the short, medium, and long term in order to be more competitive.

This study includes a simulated version of a real factory problem. The company aims to reduce its costs and maintain its quality level under increasing competition conditions. In addition to all these, it aims to increase production flexibility and capacity in order to meet variable customer demands and not to miss any customer. In addition to all these, it is necessary to reduce the deadlines in order not to lose customers and to gain a competitive advantage in the market. Although these are the steps to reach the main goal of the company, the main purpose of the company is to increase its revenue and profitability in a sustainable way. The company sees outsourcing as an option in its medium-term strategy that it has created to achieve these goals.

The company, which tries to reduce its inventory and other operational burdens with outsourcing, also wants the operation not to be adversely affected. The company wants to make not only an apparently profitable operation, but also a proven decision with operational and financial data in reality.

The company must first determine which part of the operation is most suitable for outsourcing. For this, it is necessary to develop a certain calculation method. The data to be used in this study and the criteria to be considered should also be defined.

After the decision of the operation to be outsourced, the available supplier options will be evaluated. This is a kind of classic multi-criteria decision-making method. For this process, all data should be collected and criteria to be taken into account should be determined in order to choose the best among the suppliers suitable for the study.

It should also be calculated financially whether the choice made really benefits for the company. As mentioned earlier, an option that seems beneficial at first glance has the potential to harm the company in the long term due to poor on-time delivery and quality performance. For this reason, the long-term effects of the decision taken on the company should definitely be examined.

When outsourcing is done for every company that competing in the international market, the performance of the supplier in every subject is very important. The results of both the quality and on-time delivery performance of the supplier will reflect directly on the customer. In the international market, deadline and quality are more important than cost, especially in the energy sector. For this reason, supplier selection in the transformer industry is a strategic and vital decision.

In summary, there is a process in which the company must evaluate all its operations and the supplier options available for each operation. For this, company needs to find a mathematical way, determine the data criteria to be taken into account, and take the most beneficial decision for the operation.

3. LITERATURE REVIEW

The importance of the supplier selection process lies in helping organizations to achieve the maximum ecological-economic benefit. Generally, the supplier selection process consists of several stages. First, the process starts with identifying needs and specification. Then, criteria are formulated. After that, managers or decision makers identify a group of qualified suppliers. Finally, evaluation and final selection are performed. Sustainable supplier selection aims to identify and evaluate appropriate suppliers that perform the best along the upstream supply chain in terms of economic, social, and environmental dimensions. However, the criteria for supplier selection largely depend on individual companies and industries. Therefore, the identification of supplier selection criteria should be generated by specific environments and mainly requires domain experts' assessment and evaluation.

According to Sagar and Singh, supplier selection criteria change over time, depending on the political, economic, social, and environmental characteristics of the business. In addition, Sagar and Singh proposed the following 21 essential criteria used in the automobile sector; price, quality, quality standards, reputation and position in industry, delivery, financial position, quality system adequate, technical capability, production facilities and capacity, long-term relationship, trust, procedural compliance, responsiveness, impression, communication system, warrantees and claim policies, ISO 9000 / ISO 14000 certified, attitude, management and organization, packaging ability, and performance history.

In a study that was made for an automotive industry in Malaysia, the effect of multi-criteria decision-making methods on supplier selection was investigated. The natural disasters that occurred in Japan and Thailand just before the research period increased the importance of finding regional suppliers and became one of the reasons for the study. In addition, the crisis in the automotive industry recently and the subsequent shift of large automotive companies to the ASEAN region, where they can produce cheaper, has made it more important and essential to find new suppliers. In the study, multi-criteria decision-making methods AHP, FAHP, TOPSIS, FTOPSIS, and FAHPiFTOPSIS were used. Various automotive companies with operations in Malaysia participated in the research, and the results of the surveys conducted in these companies and the data provided by the companies were used. In the study, price, factory capacity, supplier infrastructure, production flexibility and the degree of use of the lean production system were determined as criteria. When all methods are applied separately, the results obtained are that all methods give similar results. It was stated that TOPSIS and AHP were easier than other methods and give the same result.

On the other hand, in another study aiming to select suppliers with a multi-criteria decision-making method, only AHP and TOPSIS methods were used. In order to maintain a competitive position in the global market, organizations have to follow strategies to achieve shorter lead times, reduced costs, and higher quality. Therefore, suppliers play a key role in achieving corporate competitiveness, and as a result of this, selecting the right suppliers is a critical stage of these new strategies. Several conflicting quantitative and qualitative factors or criteria like cost, quality, delivery etc. Affect supplier selection problem. Therefore, it is a multi-criteria decision-making problem that includes both quantitative and qualitative factors, some of which conflict to each other. In this study, these conflicting positive and negative criteria for suppliers were evaluated using AHP and TOPSIS methods. The reason for the use of these methods is that they are simple, as stated in the results of the previous study, that all subjective and objective criteria can be considered, and that the results are quite understandable. As a result, both methods gave reliable results in the study.

Again, in the automotive sector, but this time in India, fuzzy AHP and TOPSIS methods were used in a supplier selection study. Suppliers play a major role in the production, delivery, and service of competitive quality products. Purchased materials and services represent up to 80 % of the total product costs in most high technology industries. For any manufacturing or service business, selecting the right upstream suppliers is a key success factor that will significantly reduce purchasing cost, increase downstream customer satisfaction, and improve competitive ability. The increasing demands from end customers force companies to focus on their core competence and let the suppliers carry out a larger part of the work than before. This makes companies much more dependent on their suppliers, and this increases the need of coordination and adoption of supply chain management (SCM). It also means that a larger part of the supply chain has to be managed and to do this the network horizon must be extended. This needs to be done in order to create processes that are more efficient but also to reduce the risk of disruptions. In the study, the superiority of the criteria, one of the classical stages of AHP, against each other was evaluated and a criteria matrix was created. The criteria are classical criteria such as price, quality, capacity, and on-time delivery, as in previous studies. As a result of the study, it is seen that both methods give similar results.

Several studies have defined supplier selection and evaluation criteria as a multi-criteria decision-making problem. Furthermore, previous research has also used the AHP-based decision-making approach to solve the supplier selection problem. For instance, Muraldiharan, Anantharaman, and Deshmukh presented a five-step AHP-based model with the following nine criteria; quality, delivery, price, technical capability, financial position, past performance attitude, facility, flexibility, and service for rating and selecting suppliers in a leading manufacturing bicycle. Moreover, experts from different functions were involved in the selection process. Hou and Su proposed an AHP-based decision support system to select and evaluate potential suppliers. External and internal factors were considered under the changing global environment. Quality, cost, technology, production capability, research and development (R&D), delivery & location, and performance & service are used to solve the supplier selection problem in mass customization, such as a printing manufacturer. Furthermore, Dweiri, Kumar, Khan, and Jain applied an AHP-based decision system in supplier selection in the automotive industry in Pakistan. Suppliers were selected and ranked based on a set of sub-criteria. The results of the ranking showed that the main criteria, in descending order of importance, are price, quality, delivery, and service. Shen, Muduli, and Barve presented the usefulness of the appropriate implementation approach and continuous improvement in green supply chain management (GSCM) practice in the Indian mining sector. AHP was applied to evaluate the competitive priorities, and it was argued that interested organizations can use it as procedural guidance for GSCM implementation. In their review of 143 papers, Zimmer et al. Highlighted that the most common methods in sustainable supplier management are Fuzzy Logic (31.1%), AHP (18.8%), and ANP (11.4%). The authors suggested that future research should not only develop acceptable and comparable indicators, but also explore how to handle sensitive data. In supplier monitoring, common indicators of specific industries should be developed to help supplier selection and performance comparisons. Furthermore, experts from different companies and stakeholders should participate in this process using methods such as AHP, ANP, Fuzzy, or Delphi, to find, rank, and develop industry-specific criteria and indicator sets.

In another study, the effect of outsourcing on operational performance was investigated. However, this time, this research was conducted not on the basis of the supplier, but on the basis of the operation units. The question to be answered is whether they can increase the overall performance of the company by investing in the existing operation or by outsourcing the existing operation. Data were collected in the study and these data were evaluated through a statistical program called SPSS. As a result of the study, it has been seen that investing is more beneficial than outsourcing on operational performance. In addition, it was stated in the study that outsourcing is mainly beneficial when used to free resources in order to invest in higher manufacturing capability.

There are also studies examining the cash flow and inventory performance of companies over product sales prices and outputs under variable conditions. In the study conducted by Amaia Lusa, inventory and cash flow modelling were tried to be made by determining many production-oriented costs as parameters. Some of these parameters are that maximum amount that can be borrowed from the credit account, balance of cashing and payments, cost of one hour of overtime, firing cost, hiring cost, production cost (exclusive labour cost), inventory holding cost, capacity of the warehouse (m3), number of workers, number of units to be produced, Demand of product and selling price of product. The following results were obtained with the numerical analyses made for a time period in the time dependent function created by this and similar parameters. Firstly, a planning model that integrates production, staff and marketing decisions is proposed. The results of a numerical example and the analysis of different scenarios show the solutions given by the model and the advantages of integrating production, human resources, and marketing decisions and also the situations in which this integration is more desirable. In addition, the results obtained are consistent. The study demonstrates the applicability of this and similar methods by developing a company-specific model directly without depending on any standard calculation method.

4. OPERATION

Transformer production process consists of 7 processes in total. The main assembly line, which consists of these 7 processes, is supplied by 3 sub-workshops.

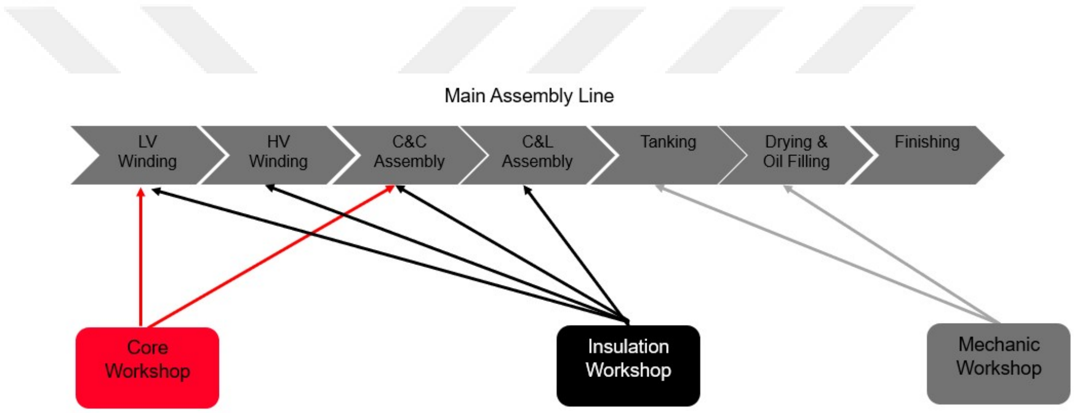

Figure 4.1: Value stream map of transformer production

The workshops in this supplier position supply materials to different processes on the main assembly line. The product starts from the first process on the main assembly line and is completed in the last process. Each material used in processes on the main assembly line is specific. For these reasons, the load on the company's inventory of each of the 7 processes is different from each other. Therefore, the effect of disruption in any process on the company's output and inventory, thus on its revenue and profitability, varies. The difference between the processes is not limited to the material alone. The number of operators in each process is also different.

There are 3 sub workshops supplying the main assembly line. These are core, insulation, and mechanical workshop. The materials used in these workshops, the number of operators working in these workshops and the processes by which these workshops provide materials on the main assembly line differ from each other. The materials produced in all these workshops are determined by the company's design department.

Although the insulation workshop takes up little space and employs less operators, it is the workshop with the highest inventory load. It also supplies materials directly to 4 of 7 processes.

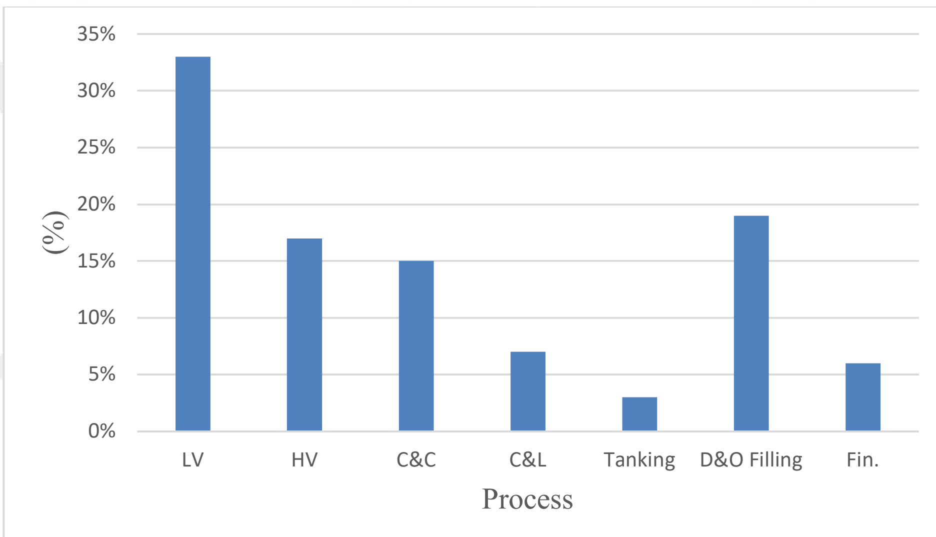

Figure 4.2: Shares of processes in inventory

The core workshop ranks second among the other workshops in terms of material inventory, the number of operators and the area it uses. The core shop supplies the first and third process of the main assembly line.

The mechanical workshop supplies materials to the fourth and fifth processes of the main assembly line. Although this workshop has the lowest inventory among the 3 sub-workshops, it is also in the first place in terms of operator and area.

The reason why the area occupied by the sub-workshops is mentioned is that the company pays the headquarter a monthly rent for each area. In the case of outsourcing, this will be freed from the rental burden. Not only the rental burden but also the labour costs here will be eliminated.

The process in the main assembly line starts with the low voltage winding. High and expensive conductors and insulations are used in the low voltage winding. The low voltage winding basically consists of winding aluminium or copper foils on the core coming from the core workshop, in the number of layers determined by the design, by putting insulation paper between them. The core shop is responsible for supplying the low voltage winding, which is the first process of the whole line.

The second process of the production line is the high voltage winding. The high voltage winding is winded on the low voltage winding. Aluminium and copper are used as in the same low voltage winding. However, this time the material is in the form of wire, not foil. The wire is winded on the low voltage winding by putting insulation paper between the layers and the number of turns determined by the design. The winding stage is the stage that has the largest share in the total inventory in the production of the transformer. The process then continues with the winding core assembly and coil assembly processes. In the core and coil assembly stage, all windings are brought together with their yokes and the active part of the transformer is formed. A transformer consists of three windings. There is a core in each winding. The cores, which are used to connect the cores in the winding, are called yokes. The horizontally arranged windings and the cores in them are joined on both sides by these yokes. During this process, insulation materials are placed in the relevant places.

The active part formed after the core and coil assembly comes to the cleat and lead assembly process. In the cleat and lead assembly process, materials from the mechanical workshop come into play. Here, the internal connection and the external connection of the transformer are combined. The external accessories that the customer can connect the transformer in the field and the terminals inside the transformer are connected with each other. While making these connections, copper braided conductors are used. The amount of conductor used here is very low compared to that used in the winding. Cleat and lead assembly is the last process in which the insulation workshop also supplies materials.

The fifth process of the line is the tanking process. In this process, the tank coming from the mechanical workshop is used. In the cleat and lead process, the active part, whose connections are completed, is lowered into the tank in this process. Thus, the active part is in a kind of a box, isolated from the outside.

The active part, which is lowered into the tank, is then dried, and filled with oil. In transformer production, moisture is an issue that must be eliminated. Since water is a conductor and there is high voltage in the transformer, humidity is the cause of discharge in the transformer. It should be ensured that all the insulation materials used in the active part of the transformer are dried very well and purified from moisture. The drying process works for this. Along with the drying process, oil is put into the transformer under vacuum. The oil acts as insulation and cooling in the transformer. Since the transformer will heat up as it operates, it is intended to cool with oil. In addition, the oil placed under vacuum acts as an insulation. Transformer oil is a very valuable commodity like copper. A large amount of oil is used in this process.

Transformer manufacturing ends with the finishing process. In this process, the accessories for the security and monitoring required for the transformer are mounted. The ratio of the equipment used in this process in the inventory comes after conductors such as copper aluminium and oil.

In transformer manufacturing, the materials used in the processes, the number of operators working in the processes, the inventory in the processes and the financial values of the equipment in the processes are highly variable and fluctuating.

In transformer manufacturing, it is not possible for one process to start before another ends. In addition, all materials are supplied according to the beginning of the process. Manufacturers, who may face serious sanctions for products that are not delivered on time due to the structure of the market, try to procure materials as early as possible to minimize the risk. Since almost all the materials used are project-based special materials, they are prepared before the process starts. The average completion time of a production is 8 days. Due to the disruption in any process, it directly affects the sales of the company. In addition, since the company cannot use the materials purchased from the process, which has a problem, it is faced with a financial side of inventory. In case of any disruption, it may have to cover both the loss of income due to the disruption from the sale and the financial costs due to connecting the cash to the material.

The insulation workshop can be thought of as a carpentry shop. Here, the paper used in transformer production and serving as insulation is cut. In addition, wooden materials used as carriers are cut. These processed materials are prepared by assembling in a suitable way if necessary.

In the mechanical workshop, similar works are carried out in the insulation workshop. But this time the material is metal. Here, the outer part of the transformer is made. Cutting, bending, welding, and painting processes are available.

The core workshop produces the material in the center of the transformer, namely the core. The material used is a metal of high value. Slitting and cutting and process is done.

5. PROBLEM AND OPTIONS

This company operating in the transformer industry and like every organization company is in a tough competition in the market in which they operate, and this company tends to increase its revenue and profitability by increasing its market share. Due to the company's structure, it has determined outsourcing as one of its actions in achieving this goal in the medium and long term. Therefore, company wants to evaluate all possible options before making a decision.

As mentioned before, the production structure of the company consists of a main assembly line and three sub-workshops that supply materials to this main assembly line. These three sub-workshops are responsible for supplying materials to certain operations on the main assembly line.

Disruption in any process in the main assembly line affects the daily sales of the company and the financial burden of the inventory. The distribution of the total inventory in the main assembly line processes is given in figure 4.2.

The area occupied by these three workshops, the amount of equipment, the number of operators they employ, and the financial burden of the materials they use are different from each other. The company has a different number of supplier options for each workshop. Certain data are already available for these suppliers in the company. While there is only one supplier option for the core workshop, the company has two supplier options for the insulation workshop and four options for the mechanical workshop. Criteria, and the data on available supplier options and sub-workshops will be presented separately in order to be evaluated.

5.1 Core workshop

A total of 7 people work in the core workshop. The machinery and equipment cost of the workshop is 3 MUSD. Monthly rental expense is 25.000 dollars and maintenance expenses are 8500 dollars. The salary burden of a total of 7 people on the company is 7350 dollars per month. The weekly inventory of the core workshop to the company is 6 MUSD.

There is one supplier option for the core workshop. This supplier belongs to same company, but this factory locates in different city and financially separate. The company wants the core workshop to be outsourced for two reasons. The first reason is that the price the company will pay for the service does not go out, and the second is that if the core workshop is outsourced, the company will not have to lay off the employees in this workshop. Employees here will be transferred to the company's other factory.

5.2 C1 Supplier

The core supplier is defined as C1. If service is received, the company will have to pay the C1 supplier 4 MUSD in weekly material expenses. Supplier C1 wishes to receive payment on the day the material is delivered. The on-time delivery performance of the C1 supplier is 98% and the quality performance is 96%.

5.3 Insulation workshop

A total of 3 people work in the core workshop. The machinery and equipment cost of the workshop is 400.000 dollars. Monthly rental expense is 10.000 dollars and there is no maintenance expenses. The salary burden of a total of 3 people on the company is 3150 dollars per month. The weekly load of the core workshop to the company is 8 MUSD.

5.4 I1 and I2 Supplier

There are two suppliers for the insulation workshop. These suppliers are identified as I1 and I2. Supplier I1 requests payment on the day the material is delivered, and supplier I2 demands 90 days after material delivery. While the on-time delivery performances of I1 and I2 suppliers are 99,2% and 98,5%, respectively, their quality performances are 94,8% and 99,5%, respectively. If agreed with these suppliers, the company will pay supplier I1 6,6 MUSD per week for service and 7,2 MUSD to supplier I2.

5.5 Mechanic workshop

A total of 16 people work in the core workshop. The machinery and equipment cost of the workshop is 5 MUSD. Monthly rental expense is 50.000 dollars and maintenance expenses are 8500 dollars. The salary burden of a total of 16 people on the company is 16800 dollars per month. The weekly load of the core workshop to the company is 1 million dollars.

5.6 M1, M2, M3, and M4 Supplier

There are 4 supplier options for the mechanical workshop. These suppliers are defined as M1, M2, M3, and M4. Mechanical suppliers are defined as M1, M2, M3 and M4, respectively.

The first of these is the M1. If service is received, the company will have to pay the M1 supplier 1 MUSD in weekly material expenses. Supplier M1 wishes to receive payment on the day the material is delivered. The on-time delivery performance of the M1 supplier is 100% and the quality performance is 99,2%.

The second supplier is the M2. If service is received, the company will have to pay the M2 supplier 0,92 MUSD in weekly material expenses. Supplier M2 wishes to receive payment on the day the material is delivered. The on-time delivery performance of the M2 supplier is 100% and the quality performance is 100%.

The third supplier is the M3. If service is received, the company will have to pay the M3 supplier 0,9 MUSD in weekly material expenses. Supplier M3 wishes to receive payment on the day the material is delivered. The on-time delivery performance of the M3 supplier is 100% and the quality performance is 100%.

The last supplier is M4. If service is received, the company will have to pay the M4 supplier 1 MUSD in weekly material expenses. Supplier M4 wishes to receive payment on the day the material is delivered. The on-time delivery performance of the M4 supplier is 99,6% and the quality performance is 99,2%.

5.7 Criteria

The company must first determine which of the sub-workshops can contribute the most to the company's operational performance if outsourced. For this, it is necessary to evaluate the sub-workshops with certain criteria. Existing criteria for workshops are inventory, number of operators, rental load due to the area they occupy, initial investment cost and maintenance expense.

The equipment that the company purchase in the workshop has an initial investment cost. The lifetime of these equipment's is determined as ten years. For this reason, even if it is a one-time payment, it should be considered as a criterion as it is a high amount of payment. The initial investment costs are 3 MUSD, 5 MUSD and 0,4 MUSD for the core workshop, mechanical workshop, and insulation workshop, respectively.

The number of operators the company employs in its workshops varies. The company therefore has a monthly salary expense for the operators it employs. Although this seems like a gain for the company's financials, the company management does not want to lay off employees and avoids it. The number of operators employed by the company for the core, mechanical and insulation workshop is 7, 16 and 3, respectively. The monthly salary for these operators is 7350, 16800 and 3150 dollars, respectively. Considering that the company management avoids layoffs, although the insulation workshop seems to be the most advantageous workshop since it has the least number of operators, the core workshop is preferred for the company management since the supplier option of the core workshop is another factory belonging to the same company. Because operators in the core workshop can be transferred to another factory belonging to this same company.

The company pays a rental fee for the area it uses to the headquarter. This monthly rental fee is different for each workshop. The area covered by each of the sub-workshops is different. The rental price for the core, mechanical, and insulation workshop is 25000, 50000 and 10000 dollars, respectively. The company will get rid of this monthly payment liability for the workshop it has outsourced.

The values of the materials used in the sub-workshops are also different like other criteria. The commodities used in the core and insulation shops are relatively valuable to the commodities used in the mechanical shop. The weekly value for the company of materials used in the workshops is 6 MUSD, 1 MUSD and 8 MUSD million for the core, mechanical and insulation workshop, respectively. Even if the company gets rid of the cost for the workshop it outsources, it will instead pay for the material it supplies. Therefore, even in the case of outsourcing, there is no possibility to get rid of this entire inventory.

The equipment used in the workshops has monthly maintenance needs. For the insulation workshop, this is negligible and is therefore not taken into account and rated as zero. The same level of expense is determined for the core and mechanical workshop. The monthly maintenance expense for these two workshops is 8500 dollars.

The company has 7 supplier options in total. There are also certain criteria for supplier selection, such as determining the most suitable workshop for outsourcing. The criteria determined for supplier selection are product price, payment period, on-time delivery and quality performance.

The price for each product that the company will pay to the supplier is an important criterion in supplier selection. Inventory is very important for the financial performance of the company. However, the payment period is also very important for the financing cost of the company. While some suppliers such as C1 and I1 accept payment on material delivery, suppliers such as I2 and M4 accept payment 90 days after material supply. This means that the company can pay after using the material, completing the production and making the sale.

On-time delivery rate and quality performance directly affect the company's revenue and profitability due to the company's performance on the main assembly line. Therefore, the sum of the on-time delivery and poor-quality rate, for the type of material produced will affect the company's main assembly line performance. It is given on table 5.5.1

Table 5.5.1: Effect of suppliers' OTD and quality performance on daily revenue

Options	Daily Revenue (MUSD)	Total Performance (%)	OTD Performance (%)	Quality Performance (%)
Current Situtaion	4,80	1,000	1,000	1,000
C1	4,61	0,960	0,980	0,980
I1	4,51	0,940	0,992	0,948
I2	4,70	0,980	0,985	0,995
M1	4,76	0,992	1,000	0,992
M2	4,80	1,000	1,000	1,000
M3	4,80	1,000	1,000	1,000
M4	4,74	0,988	0,996	0,992

A certain weight has been determined for all criteria. These weights have been determined by surveys conducted within the company. In the surveys, it was requested that the superiority of the criteria over each other be evaluated by the professionals in the company.

Details of AHP and TOPSIS methods will not be entered throughout the study and intermediate calculation values will be given. For the calculation stages of the AHP and TOPSIS methods, references written on this subject can be consulted.

The steps of the AHP method used in the first and second methods were applied directly. First, a criterion evaluation matrix was created. Then, the vector normalization process of this matrix was performed. Then, each criterion weight was found, and consistency analysis was performed. After the consistency analysis, the most suitable option was found with the TOPSIS method by using the criteria weights at hand in the decision matrix.

Criterion evaluation matrix was created by applying a survey to professional. According to the survey results, geometric averages were taken, and then a criterion matrix was obtained in consensus.

6. NUMERIC ANALYSIS

For the evaluation, the factory management determined 3 different ways. The first of these aims to determine certain criteria and to use multi criteria decision making methods with these criteria. In this method, firstly, the workshop to be outsourced is decided, and then to evaluate the options for the relevant workshop and to determine the most suitable supplier.

The second method is based on the evaluation of all options. In the first method, it is aimed to evaluate the suppliers who are out of the scope as a result of supplier evaluation, together with this method. Thus, it was ensured that an option that was out of scope, although it could be more advantageous, was taken into consideration. Also, a proof of the first method has been tried to be made.

The third and final method examines the impact of all these options on cash flow, profitability, and inventory. With this method, it is aimed to calculate financially how the decisions made in line with the criteria affect the factory targets. In this method, if different results occur after the first two methods, it is aimed to calculate how this will affect the factory outputs in monetary terms.

The criteria for the first method were determined differently for the two stages. The first stage of this method is workshop evaluation, and the second stage is the evaluation of the supplier options available for that workshop. In the workshop evaluation stage, the criteria determined by the factory management were listed as inventory, investment cost, rental cost, maintenance cost and salary. On the other hand, in the supplier evaluation, which is the second stage, payment period, product price, on-time delivery performance and quality performance are determined as criteria. Quality and on-time delivery performances have been statistically evaluated for these companies over their existing performances so far. AHP and TOPSIS methods were used in the workshop evaluation process. In order to evaluate the criteria for AHP, a survey was conducted among the employees in different departments and the weight of the criteria on each other was decided in this way. Supplier evaluation was made directly with WSM, and criterion weights were determined directly by the factory management.

AHP and TOPSIS methods were used in the second method as in the first method. Again, as in the first method, a survey was created in the factory to evaluate the criteria. In this way, the advantages of the criteria over each other were evaluated. However, in the second method, in addition to inventory, investment cost, rental cost, maintenance cost and salary, in the first method, the daily sales amount is also added. Because each supplier has a direct impact on the company's revenue due to on-time delivery and quality performance. In this method, all workshops and sub-suppliers are evaluated together. A problem has been created with the logic of whether sub-workshops should be invested or outsourced. AHP and TOPSIS methods were preferred because 3 different methods were used and simply gave reliable results.

In the third method, the effect of each workshop and supplier on cash flow and profitability is examined. A period of five years has been set for this evaluation. In this calculation, investment cost, fixed expenses such as rent and energy, labour cost, maintenance cost, material cost are recorded as expenses, and the gain from sales is recorded as income in the table. Here, investment cost is one-time, labour and maintenance costs are monthly, material costs are weekly (varies according to the supplier's conditions) and other fixed costs are recorded monthly. Earnings from sales are entered daily. According to the scenario where the company starts with zero capital and withdraws annual loans in case of need, transactions have been made. Credit was drawn at every point that was negative daily and the financing cost was reflected to the company.

6.1 Method -1

In this method, the evaluation of the 3 workshops that are considered to be outsourced is made through the multi-criteria decision-making method. In the first stage, core, insulation, and mechanical workshop are evaluated with the criteria of inventory, initial investment cost, rental cost, maintenance cost and salary. In the first stage, the AHP method is used for workshop evaluation.

A survey was conducted among the factory employees in order to evaluate the determined criteria and to determine their superiority against each other. As a result of the narrative, the criteria evaluation matrix is as follows.

Table 6.1.1: Criteria evaluation matrix for workshop selection

	Investment	Area	Material	Maintenence	Labour Cost
Investment	**1,0000**	4,0000	3,0000	8,0000	3,0000
Area	0,2500	**1,0000**	0,3333	5,0000	2,0000
Material	0,3333	3,0000	**1,0000**	8,0000	3,0000
Maintenence	0,1250	0,2000	0,1250	**1,0000**	0,1111
Labour Cost	0,3333	0,5000	0,3333	9,0000	**1,0000**

In addition, the data in the workshops for all criteria are given in the table below.

Table 6.1.2: Values of criteria for each workshop

	Investment (MUSD)	Area (MUSD)	Material (MUSD)	Maintenence (MUSD)	Labour MUSD)
Core	3	0,025	6	0,0085	0,00735
Mechanic	5	0,05	1	0,0085	0,0168
Insulation	0,4	0,01	8	0	0,00315

As a result of the normalization of the criterion evaluation matrix, the following matrix is obtained.

Table 6.1.3: Normalization of criteria evaluation matrix for workshops

	Sales	**Area**	**Material**	**Maintenence**	**Labour Cost**
Investment	0,4898	0,4598	0,6261	0,2581	0,3293
Area	0,1224	0,1149	0,0696	0,1613	0,2195
Material	0,1633	0,3448	0,2087	0,2581	0,3293
Maintenence	0,0612	0,0230	0,0261	0,0323	0,0122
Labour Cost	0,1633	0,0575	0,0696	0,2903	0,1098

The criteria weights obtained after taking the average of each row are given in the table below.

Table 6.1.4: Criteria weights found with AHP

Criteria	Weight
Investment	0,4115
Area	0,1470
Material	0,2642
Maintenence	0,0254
Labour Cost	0,1519

The value obtained after the consistency analysis is less than 0,1. This indicates that the criteria weights obtained can be used. These weights are determined by using the TOPSIS method to determine the most suitable workshop for outsourcing.

In order to use the TOPSIS method, vector normalization of the decision matrix is done first. Since all the criteria here are nonbeneficial criteria, the lowest values in each column are used in the TOPSIS method.

Table 6.1.5: Weighted values of workshops for each criteria in TOPSIS

	Investment	Area	Material	Maintenence	Labour Cost
Core	0,2220	0,0606	0,1557	0,0219	0,0545
Mechanic	0,3701	0,1211	0,0260	0,0219	0,1247
Insulation	0,0296	0,0242	0,2076	0,0000	0,0234
Vi+	0,0296	0,0242	0,0260	0,0000	0,0234
Vi-	0,3701	0,1211	0,2076	0,0219	0,1247

As a result of all calculations, the insulation workshop was found to be the most suitable workshop for outsourcing. It is followed by core and mechanical workshops, respectively.

Table 6.1.6: Workshop evaluation results after TOPSIS

Workshop	Si+	Si-	Pi
Core	0,2380	0,1822	0,4336
Mechanic	0,3688	0,1817	0,3300
Insulation	0,1817	0,3688	0,6700

The company has two options for the insulation workshop that has been decided to be outsourced. These options are named I1 and I2. In the second stage, suppliers will be evaluated with the WSM method. The criteria weights to be used in the WSM method are directly determined by the company. The company's criteria for supplier evaluation are payment period, on-time delivery, product price and quality percentage. The values of each supplier for all criteria and the weights determined by the company for these criteria are given in the tables below.

Table 6.1.7: Values of criteria for each supplier

Supplier	Payment Period (day)	Price Per Product (MUSD)	OTD Performance (%)	Quality Performance (%)
I1	0	6,6	99,2	5,2
I2	90	7,2	98,5	5

Table 6.1.8: Criteria weights for supplier

Payment Period (day)	Price Per Product (MUSD)	OTD Performance (%)	Quality Performance (%)
0,3	0,4	0,15	0,15

Among the evaluated criteria, the product price and the percentage of poor quality are non-beneficial, and the on-time delivery and payment period are beneficial criteria. For the WSM method, the decision matrix is first normalized. Then, the following table is obtained by multiplying the criteria weights determined. As can be seen from the table below, the most suitable supplier for outsourcing was found to be I2.

Table 6.1.9: Normalization of criteria's value matrix

Supplier	Payment Period (day)	Price Per Product (MUSD)	OTD Performance (%)	Quality Performance (%)
I1	0,0000	0,0110	0,5018	0,0189
I2	1,0000	0,0101	0,4982	0,0196

Table 6.1.10: Supplier evaluation results after WSM

Supplier	Value
I2	0,3817
I1	0,0825

6.2 Method-2

In the second method, all workshops and supplier options for each workshop were evaluated together. All workshops were evaluated as a supplier, just as suppliers. Unlike the first method, there will not be an option that is not considered in this method. Thus, a useful supplier, which was among the options of a remaining workshop at the first stage, was prevented from being excluded. In the second method, AHP and TOPSIS methods were used also. The criteria determined in this method were determined as initial investment cost, revenue, rental cost, material cost, maintenance expenses and salary. Unlike the first method, there is an added revenue criterion in this method. This criterion differs for each supplier due to the company's loss of sales because of on-time delivery and low quality of the suppliers. This differs from supplier to supplier. In this method, the criteria were evaluated with a survey within the company and are given below. It is given in table 6.2.1.

Table 6.2.1: Criteria evaluation matrix for workshop and supplier selection both

	Investment	Sales	Area	Material	Maintenence	Labour Cost
Investment	**1,0000**	1,0000	9,0000	3,0000	9,0000	5,0000
Sales	1,0000	**1,0000**	7,0000	5,0000	9,0000	7,0000
Area	0,1111	0,1429	**1,0000**	0,3333	9,0000	3,0000
Material	0,3333	0,2000	0,3333	**1,0000**	9,0000	2,0000
Maintenence	0,1111	0,1111	0,1111	0,1111	**1,0000**	0,1111
Labour Cost	0,2000	0,1429	0,2000	0,5000	9,0000	**1,0000**

There is also a decision matrix where the values of these criteria are available for each option. This is given in the table 6.2.2

Table 6.2.2: Values of criteria for each option

	Investment (MUSD)	Daily Revenue (MUSD)	Area (MUSD)	Material (MUSD)	Maintenence (MUSD)	Labour (MUSD)
Core	3,00	4,80	0,03	6,00	0,0085	0,0074
Mechanic	5,00	4,80	0,05	1,00	0,0085	0,0168
Insulation	0,40	4,80	0,01	8,00	0	0,0032
CCC	0,00	4,61	0,00	2,00	0	0
I1	0,00	4,51	0,00	6,60	0	0
I2	0,00	4,70	0,00	7,20	0	0
M1	0,00	4,76	0,00	0,90	0	0
M2	0,00	4,80	0,00	0,92	0	0
M3	0,00	4,80	0,00	0,90	0	0
M4	0,00	4,74	0,00	1,00	0	0

As a result of the normalization of the criterion evaluation matrix, the following matrix is obtained. It is given in table 6.2.3.

Table 6.2.3: Normalization of criteria evaluation matrix

	Investment	Sales	Area	Material	Maintenence	Labour Cost
Investment	0,3629	0,3851	0,5101	0,3017	0,1957	0,2761
Sales	0,3629	0,3851	0,3967	0,5028	0,1957	0,3865
Area	0,0403	0,0550	0,0567	0,0335	0,1957	0,1656
Material	0,1210	0,0770	0,0189	0,1006	0,1957	0,1104
Maintenence	0,0403	0,0428	0,0063	0,0112	0,0217	0,0061
Labour Cost	0,0726	0,0550	0,0113	0,0503	0,1957	0,0552

The criteria weights obtained after taking the average of each row are given in the table 6.2.4.

Table 6.2.4: Weight of criteria

Criteria	CW
Investment	0,33857769
Sales	0,371610463
Area	0,091137628
Material	0,103919471
Maintenence	0,021409063
Labour Cost	0,073345685

The value obtained after the consistency analysis is less than 0,1. This indicates that the criteria weights obtained can be used. These weights are determined by using the TOPSIS method to determine the most suitable workshop for outsourcing.

In order to use the TOPSIS method, vector normalization of the decision matrix is done first and then weight of the criteria are used.

As a result of all calculations, the M3 was found to be the most suitable workshop for outsourcing. It is followed by core and mechanical workshops, respectively.

Table 6.2.5: Weighted values of options for each criteria in TOPSIS

	Investment	Sales	Area	Material	Maintenence	Labour Cost
Core	0,1738	0,1192	0,0401	0,0437	0,0151	0,0290
Mechanic	0,2896	0,1192	0,0802	0,0073	0,0151	0,0662
Insulation	0,0232	0,1192	0,0160	0,0582	0,0000	0,0124
CCC	0,0000	0,1144	0,0000	0,0146	0,0000	0,0000
Yalıtım-1	0,0000	0,1120	0,0000	0,0480	0,0000	0,0000
Yalıtım-2	0,0000	0,1168	0,0000	0,0524	0,0000	0,0000
M1	0,0000	0,1182	0,0000	0,0066	0,0000	0,0000
M2	0,0000	0,1192	0,0000	0,0067	0,0000	0,0000
M3	0,0000	0,1192	0,0000	0,0066	0,0000	0,0000
M4	0,0000	0,1177	0,0000	0,0073	0,0000	0,0000
Vi+	0,0000	0,1192	0,0000	0,0066	0,0000	0,0000
Vi-	0,2896	0,1120	0,0802	0,0582	0,0151	0,0662

Table 6.2.6: Options evaluation results after TOPSIS

Options	Si+	Si-	**Pi**
M3	0,0000	0,3119	**1,0000**
M2	0,0001	0,3119	**0,9996**
M1	0,0010	0,3119	**0,9970**
M4	0,0016	0,3118	**0,9950**
C1	0,0348	0,3084	**0,8985**
I1	0,0392	0,3083	**0,8871**
I2	0,0427	0,3082	**0,8783**
Insulation	0,0571	0,2798	**0,8306**
Core	0,1846	0,1291	**0,4115**
Mechanic	0,3081	0,0479	**0,1345**

6.3 Method-3

In this method, the company's profitability and turnover are calculated separately for each possibility, taking into account the company's inputs and outputs. Thus, we will be able to see the financial equivalent of the criteria evaluated in the previous methods for each possibility separately and have the chance to compare.

The calculation is planned for a period of 5 years. The outputs included in the calculation are initial investment cost, rental cost, salaries, material, and maintenance costs. The input is the income from the sale.

All calculations are made in dollars. outputs such as salary, maintenance and rent are taken into account on a monthly basis, and outputs such as materials are taken into account on a weekly and daily basis. The initial investment cost is included in the calculation for a single trip. Calculations are scenarios where the company starts operations with zero capital and will take out a loan when the cash flow drops to negative. According to this scenario, the company will borrow with the same interest rate in each option and will pay the interest of the loan it has taken in a 12-month period.

The initial investment cost applies only to the core, insulation, mechanical and main assembly line of the company. There are no initial investment costs for suppliers.

The maintenance cost differs for all workshops. Again, there is no maintenance cost for suppliers.

Salary expenses are determined according to the number of people working in each workshop. Seven people work in the core workshop, 16 people in the mechanical workshop and three people in the insulation workshop. Since the supplier of the core workshop is another factory within the company, there is no dismissal on behalf of the company cost centre is changing and will be solved by person transfer between factories. however, it will be taken into account as the cost will decrease from the factory expenses. In terms of human resources management, this information will be used as an evaluation criterion in the last stage, as the company avoids layoffs. Sure, there is no labour cost for suppliers.

There is an inventory load due to raw material in the factory's own workshops. For the outsourced workshop, this inventory load will be eliminated and instead will be the cost of the material received from the supplier. The suppliers will deliver the materials in accordance with the specifications, on the agreed days and at the agreed prices. These criteria differ for each supplier.

Expenses such as rent, electricity and water vary for each workshop. According to the size of the machines in the workshop, an area has been determined for each workshop and this cost has been recorded in the table on a monthly basis. Rental cost will be eliminated for the workshop to be outsourced. The company has a cost due to the design and manufacturing-related poor-quality rates and, on the other hand, due to rework and products that cannot be delivered on time.

This rate is zero percent in operations carried out within the factory. However, this differs for suppliers. As each material has a different effect on the main assembly line, each supplier has a different quality and on-time delivery performance. On the other hand, the effect of each material and supplier on the company's output differs. For these reasons, revenue from sales may differ in all scenarios. This directly affects the turnover, cash flow and profitability of the company.

Calculations were made for 8 different scenarios in total. These consist of the situation where no workshop is outsourced, the situation where the core workshop is outsourced, two different scenarios where the insulation workshop is outsourced to two different suppliers, and 4 different scenarios where the mechanical workshop is outsourced to 4 different suppliers.

6.3.1 Current State

In the current situation, it is assumed that the company uses all its workshops and does not make any outsourcing. In this case, the cost of the investment made by the company in its workshops, its monthly and annual fixed expenses and material expenses are given in the table.

6.3.1.1: Current state financials

Cost Item	Core (MUSD)	Insulation (MUSD)	Mechanic (MUSD)	Assembly (MUSD)
Investment	3	0,4	5	30
Rent (monthly)	0,025	0,01	0,05	0,2
Salary (monthly)	0,00735	0,00315	0,0168	0,168
Material (weekly)	6	8	1	2
Maintenance (monthly)	0,0085	0	0,0085	0

Also, as given in the table, the operational performance in this case is 100% and the company's daily revenue is 4.8 MUSD. According to the calculation, the company made sales of 6009 MUSD in total at the end of 5 years and achieved a net profit of 303 MUSD. During this period, the company had to use a total of 47 MUSD loans. The net profit margin for the company is 5.05%.

6.3.2 C1 Supplier

In this scenario, it is assumed that the core workshop is closed, and the core material requirement is supplied from a supplier called C1. With the closure of the core workshop, the company was freed from costs such as salary, rent, investment and maintenance. Also, the weekly material expense decreased from 6 MUSD to 4 MUSD.

Table 6.3.2.1: Financials in case of supplier C1

Cost Item	Core (MUSD)	Insulation (MUSD)	Mechanic (MUSD)	Assembly (MUSD)
Investment	0	0,4	5	30
Rent (monthly)	0	0,01	0,05	0,2
Salary (monthly)	0	0,00315	0,0168	0,168
Material (weekly)	4	8	1	2
Maintenance (monthly)	0	0	0,0085	0

Also, as given in the table 5.5.1, the operational performance in this case is 96% and the company's daily revenue is 4,61 MUSD. According to the calculation, the company made sales of 5769 MUSD in total at the end of 5 years and achieved a net profit of 489 MUSD. During this period, the company had to use a total of 40 MUSD loans. The net profit margin for the company is 8,47%.

6.3.3 I1 Supplier

In this scenario, it is assumed that the insulation workshop is closed, and the insulation material requirement is supplied from a supplier called I1. With the closure of the insulation workshop, the company was freed from costs such as salary, rent, investment and maintenance. Also, the weekly material expense decreased from 8 MUSD to 6,6 MUSD.

Also, as given in the table 5.5.1, the operational performance in this case is 94% and the company's daily revenue is 4,51 MUSD. According to the calculation, the company made sales of 5649 MUSD in total at the end of 5 years and achieved a net profit of 241 MUSD. During this period, the company had to use a total of 40 MUSD loans. The net profit margin for the company is 4,26%.

Table 6.3.3.1: Financials in case of supplier I1

Cost Item	Core (MUSD)	Insulation (MUSD)	Mechanic (MUSD)	Assembly (MUSD)
Investment	3	0	5	30
Rent (monthly)	0,025	0	0,05	0,2
Salary (monthly)	0,00735	0	0,0168	0,168
Material (weekly)	6	6,6	1	2
Maintenance (monthly)	0,0085	0	0,0085	0

6.3.4 I2 Supplier

In this scenario, it is assumed that the insulation workshop is closed, and the insulation material requirement is supplied from a supplier called I2. With the closure of the insulation workshop, the company was freed from costs such as salary, rent, investment and maintenance. Also, the weekly material expense decreased from 8 MUSD to 7,2 MUSD.

Table 6.3.4.1: Financials in case of supplier I2

Cost Item	Core (MUSD)	Insulation (MUSD)	Mechanic (MUSD)	Assembly (MUSD)
Investment	3	0	5	30
Rent (monthly)	0,025	0	0,05	0,2
Salary (monthly)	0,00735	0	0,0168	0,168
Material (weekly)	6	7,2	1	2
Maintenance (monthly)	0,0085	0	0,0085	0

Also, as given in the table 5.5.1, the operational performance in this case is 98% and the company's daily revenue is 4,70 MUSD. According to the calculation, the company made sales of 5889 MUSD in total at the end of 5 years and achieved a net profit of 356 MUSD. During this period, the company had to use a total of 39 MUSD loans. The net profit margin for the company is 6,05%.

6.3.5 M1 Supplier

In this scenario, it is assumed that the mechanic workshop is closed, and the mechanic material requirement is supplied from a supplier called M1. With the closure of the mechanic workshop, the company was freed from costs such as salary, rent, investment and maintenance. Also, the weekly material expense decreased from 1 MUSD to 0,9 MUSD.

Table 6.3.5.1: Financials in case of supplier M1

Cost Item	Core (MUSD)	Insulation (MUSD)	Mechanic (MUSD)	Assembly (MUSD)
Investment	3	0,4	0	30
Rent (monthly)	0,025	0,01	0	0,2
Salary (monthly)	0,00735	0,00315	0	0,168
Material (weekly)	6	8	0,9	2
Maintenance (monthly)	0,0085	0	0	0

Also, as given in the table 5.5.1, the operational performance in this case is 99,2% and the company's daily revenue is 4,76 MUSD. According to the calculation, the company made sales of 5961 MUSD in total at the end of 5 years and achieved a net profit of 285 MUSD. During this period, the company had to use a total of 42 MUSD loans. The net profit margin for the company is 4,78%.

6.3.6 M2 Supplier

In this scenario, it is assumed that the mechanic workshop is closed, and the mechanic material requirement is supplied from a supplier called M2.

With the closure of the mechanic workshop, the company was freed from costs such as salary, rent, investment and maintenance. Also, the weekly material expense decreased from 1 MUSD to 0,92 MUSD.

Table 6.3.6.1: Financials in case of supplier M2

Cost Item	Core (MUSD)	Insulation (MUSD)	Mechanic (MUSD)	Assembly (MUSD)
Investment	3	0,4	0	30
Rent (monthly)	0,025	0,01	0	0,2
Salary (monthly)	0,00735	0,00315	0	0,168
Material (weekly)	6	8	0,92	2
Maintenance (monthly)	0,0085	0	0	0

Also, as given in the table 5.5.1, the operational performance in this case is 100 % and the company's daily revenue is 4,80 MUSD. According to the calculation, the company made sales of 6009 MUSD in total at the end of 5 years and achieved a net profit of 328 MUSD. During this period, the company had to use a total of 43 MUSD loans. The net profit margin for the company is 5,46%.

6.3.7 M3 Supplier

In this scenario, it is assumed that the mechanic workshop is closed, and the mechanic material requirement is supplied from a supplier called M3.

With the closure of the mechanic workshop, the company was freed from costs such as salary, rent, investment and maintenance. Also, the weekly material expense decreased from 1 MUSD to 0,9 MUSD.

Table 6.3.7.1: Financials in case of supplier M3

Cost Item	Core (MUSD)	Insulation (MUSD)	Mechanic (MUSD)	Assembly (MUSD)
Investment	3	0,4	0	30
Rent (monthly)	0,025	0,01	0	0,2
Salary (monthly)	0,00735	0,00315	0	0,168
Material (weekly)	6	8	0,9	2
Maintenance (monthly)	0,0085	0	0	0

Also, as given in the table 5.5.1, the operational performance in this case is 100 % and the company's daily revenue is 4,80 MUSD. According to the calculation, the company made sales of 6009 MUSD in total at the end of 5 years and achieved a net profit of 333 MUSD. During this period, the company had to use a total of 42 MUSD loans. The net profit margin for the company is 5,54%.

6.3.8 M4 Supplier

In this scenario, it is assumed that the mechanic workshop is closed, and the mechanic material requirement is supplied from a supplier called M4. With the closure of the mechanic workshop, the company was freed from costs such as salary, rent, investment and maintenance. There are no material cost advantages for this option. Material cost is the same and it cost 1 MUSD weekly.

Table 6.3.8.1: Financials in case of supplier M4

Cost Item	Core (MUSD)	Insulation (MUSD)	Mechanic (MUSD)	Assembly (MUSD)
Investment	3	0,4	0	30
Rent (monthly)	0,025	0,01	0	0,2
Salary (monthly)	0,00735	0,00315	0	0,168
Material (weekly)	6	8	1	2
Maintenance (monthly)	0,0085	0	0	0

Also, as given in the table 5.5.1, the operational performance in this case is 98,8 % and the company's daily revenue is 4,74 MUSD. According to the calculation, the company made sales of 5937 MUSD in total at the end of 5 years and achieved a net profit of 252 MUSD. During this period, the company had to use a total of 42 MUSD loans. The net profit margin for the company is 4,25%.

6.4. Overall

In summary, three different results were obtained with three methods. The results are given in the table 6.4.1 collectively.

Table 6.4.1: Best three suppliers in each method

	Method-1	Method-2	Method-3
1	I2	M3	C1
2	I1	M2	I2
3	C1	M1	M3

Table 6.4.2: All outputs of calculation on method 3

Optioms	Total Loan	Profit (MUSD)	Revenue (MUSD)	Profitability
C1	40	489	5769	8,48%
I2	40	356	5889	6,05%
M3	42	333	6010	5,54%
M2	43	329	6010	5,47%
Baz	47	304	6010	5,05%
M1	42	285	5962	4,78%
M4	42	253	5937	4,26%
I1	40	241	5649	4,26%

7. SENSITIVITY ANALYSIS

The effect of a 10% improvement in the material price paid to the suppliers in the third method on the factory profit is given in the table below.

Table 7.1: The effect of 10% change in material expense on profit

	Profit-1 (MUSD)	Profit-2 (MUSD)	Improvement (MUSD)	% Impact
I1	241	379	138	57,14
I2	356	506	150	42,16
C1	489	572	83	17,06
M4	253	272	20	7,75
M1	285	304	19	6,59
M2	329	348	19	5,86
M3	333	352	19	5,64

The effect of a 1% improvement in the quality and on-time delivery performance of the suppliers on the factory's output is as follows. The reason why there is no change in the M2 and M3 suppliers is that their performance is already 100% in the current situation.

Although the performance increase in the M4 supplier has the biggest impact on the factory output, there is no opportunity for them to add more value and make a difference by increasing their performance, as all suppliers are approaching the maximum level in performance.

Table 7.2: Profit impact of 1% increase in supplier performance

	Profit-1 (MUSD)	Profit-2 (MUSD)	Improvement (MUSD)	% Impact
M4	253	325	72	28,53534936
I1	241	297	56	23,39595314
M1	285	333	48	16,87360163
I2	356	415	59	16,5248108
C1	489	547	58	11,77848329
M2	329	329	0	0
M3	333	333	0	0

In a scenario where a 50% decrease is achieved in the fixed expenses of the company such as rent, maintenance and salary, the effect of each supplier on the factory output is as shown in the table.

Table 7.3: The effect of 50% decrease in fixed expenses on profit

<table>
<tr><th></th><th>Profit-1 (MUSD)</th><th>Profit-2 (MUSD)</th><th>Improvement (MUSD)</th><th>% Impact</th></tr>
<tr><td>C1</td><td>489</td><td>500</td><td>11</td><td>2,18</td></tr>
<tr><td>I1</td><td>241</td><td>252</td><td rowspan="2">11</td><td>4,60</td></tr>
<tr><td>I2</td><td>356</td><td>367</td><td>3,14</td></tr>
<tr><td>M1</td><td>285</td><td>294</td><td rowspan="4">10</td><td>3,22</td></tr>
<tr><td>M2</td><td>329</td><td>338</td><td>3,03</td></tr>
<tr><td>M3</td><td>333</td><td>343</td><td>2,98</td></tr>
<tr><td>M4</td><td>253</td><td>262</td><td>3,73</td></tr>
</table>

As can be seen from the table, the effect of even a large improvement of 50% in 5 years is quite low. The reason for this result is that the share of fixed expenses in total expenses is 1%.

8. DISCUSSION

Three different results were obtained in three different methods used to reach the solution. As a result of the calculations, the best option for outsourcing was found to be I2 in the first method and M3 in the second method, but C1 was the best option in the third method used. It is necessary to discuss whether the 3 methods really give 3 different results as seen at first glance, and if this is true, why there are differences.

First of all, the similarities are seen when the first and second methods are compared. The first stage of the first method was the evaluation of the workshops. In this evaluation, it was investigated which workshop would provide the highest contribution in case of outsourcing. As a result of this evaluation, the workshops were listed as insulation, core and mechanical workshops, respectively. In the second method, all workshops and suppliers were evaluated together.

The order of the workshops did not change in both methods. However, when we add all the suppliers to the evaluation in the second method, it is seen that the contribution of the mechanical suppliers is the highest.

However, there are similarities as well as differences between the results obtained from the two methods. In the evaluation made among insulation material suppliers in the first method, supplier I2 seemed to be more advantageous than supplier I1. However, in the second method, when only two workshops are compared among themselves, it is seen that they are of the same value. The reason for this different result is that the criteria such as on-time delivery performance and quality performance in the evaluation stage in the first method are changed to revenue in the second method. In the second method, these performance criteria are considered as the effect of the company's output, and this is included in the evaluation as a revenue criterion. In the first method, the weight of the on-time delivery performance and quality performance criteria is 30% of the total weight, while in the second method, the weight of the revenue criterion is 37% of the total weight. Although this situation provides an additional advantage to the already strong I2 supplier, removing the payment period from the evaluation was reflected as an advantage to the I1 supplier. Because, in the first method the weight of the payment period is 30% of the total weight and the I2 supplier has an advantage of 90 days. Since it was thought that the real effect of the payment period could not be reflected in the evaluation, this criterion was excluded from the evaluation.

When we look at the top 4 suppliers in the second method, we see that their values are close. This data shows that these 4 suppliers do not have a clear advantage over each other in line with the determined criteria.

On the other hand, when the suppliers are ranked, it is seen that the mechanical suppliers take the first four places, followed by the core supplier, and insulation suppliers are at the bottom of the list. When we examine it in detail, we can see that this is not a coincidence. In the second method, one of the criteria is daily revenue and the weight of the revenue criterion is 30% of the total criteria. When the daily revenue for all options is listed from largest to smallest, we see that mechanical suppliers similarly take the top 4 places.

On the other hand, when the suppliers are ranked according to the income from the material, we see that the first three places are respectively C1, I1 and I2 suppliers. However, since the weight of the material criterion is only 10% of the total weight, this advantage was not enough to put these suppliers ahead of the mechanical suppliers.

Although the material gain did not put supplier C1 ahead of the mechanical suppliers in the second method, this gain in the third method enabled us to obtain supplier C1 as the best supplier by far. In addition, in the third method, the I2 supplier was able to surpass the mechanical suppliers. So, what is the reason for this different result between the two methods? Can this difference be explained only by the material expense gain? If it can be explained, how?

In third method as you can see on the result, the C1 supplier is in the first place, the I2 supplier is the second, and then the mechanical suppliers are listed.

As mentioned above, in the second method, the weight of the material price criterion was only 10% of the total value of all criteria. However, when we evaluate the expenses included in the calculation in the third method, it is seen that the place of material expenses in the total expenses is much higher. When we evaluate the fixed expenses, such as rent, salary and maintenance collectively and compare this total expense with the monthly material cost, we see that the material expense has a great advantage.

The investment cost is almost as much as the weekly material cost for the suppliers. For this reason, it was not even necessary to make comparisons for a five-year period.

When we compare the revenue results, it is seen that the mechanical suppliers are ahead of the other suppliers. Considering that the factory's output affects the revenue result and the on-time delivery and quality performance of the suppliers affect the factory's output, we can see that there is a linear connection between them. This data shows why the mechanical suppliers take the first four places in the second method because revenue was one of the criteria in the second method and the criterion weight was 37%.

When a choice must be made between profitability and revenue, it is inevitable to choose profitability. However, low revenue is also an indicator of lost customers in the market. Choosing supplier C1, which is the core supplier of the company, is clearly seen as the most appropriate option. The C1 supplier is another factory owned by the same company, as mentioned earlier. Therefore, there will be no layoffs. This was already a desired situation by the company management. In addition, the business volume of another factory of the company will increase and money will be transferred within the company. In addition, while the gain in material expense is not an issue that can be improved, on-time delivery performance and quality performance are an issue that can be improved. If the company can improve the performance of its C1 supplier over time, the company will be able to increase its revenue and thus its profit.

9. CONCLUSION AND RECOMANDATIONS

As a result of the revaluation in the first method, the workshops were listed as insulation, core and mechanical workshops, respectively. In the second method, all workshops and suppliers were evaluated together, and the order was as given in the table below.

Table 9.1: Similarity between first and second method results

Method-1			Method-2		
Ranks	Workshops	Pi	Ranks	Workshops	Pi
1	Insulation	0,78	8	Insulation	0,82
2	Core	0,45	9	Core	0,41
3	Mechanic	0,22	10	Mechanic	0,14

As can be seen from the table, the order of the workshops did not change in both methods. But as mentioned before mechanic suppliers take the top four in the second method. As you can see from the table it is not coincidence, it is directly related with revenue effect of each supplier.

Table 9.2: Distribution in the result of the second method

	Workshop	Daily Revenue (MUSD)	Pi
1	M3	4,80	1
2	M2	4,80	0,999547189
3	M1	4,76	0,996956541
4	M4	4,74	0,994915281
5	C1	4,61	0,932390463
6	I1	4,51	0,882760123
7	I2	4,70	0,873534024

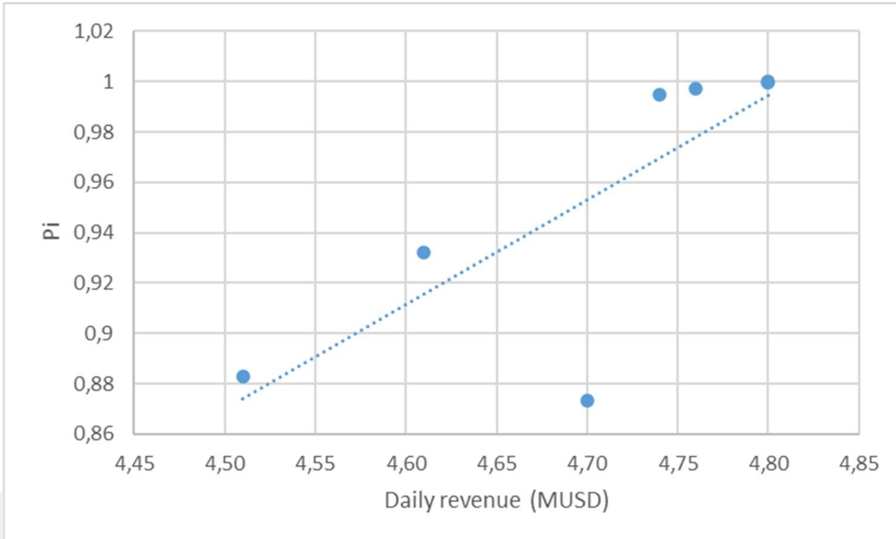

Figure 9.1: Relation of daily revenue and Pi for all options

Table 9.3: Material expense gain and Pi for all options

	Workshop	Weekly Material Saving (MUSD)	Pi
1	C1	2	0,93
2	I1	1,4	0,88
3	I2	0,8	0,87
4	M3	0,1	1,00
5	M1	0,1	1,00
6	M2	0,08	1,00
7	M4	0	0,99

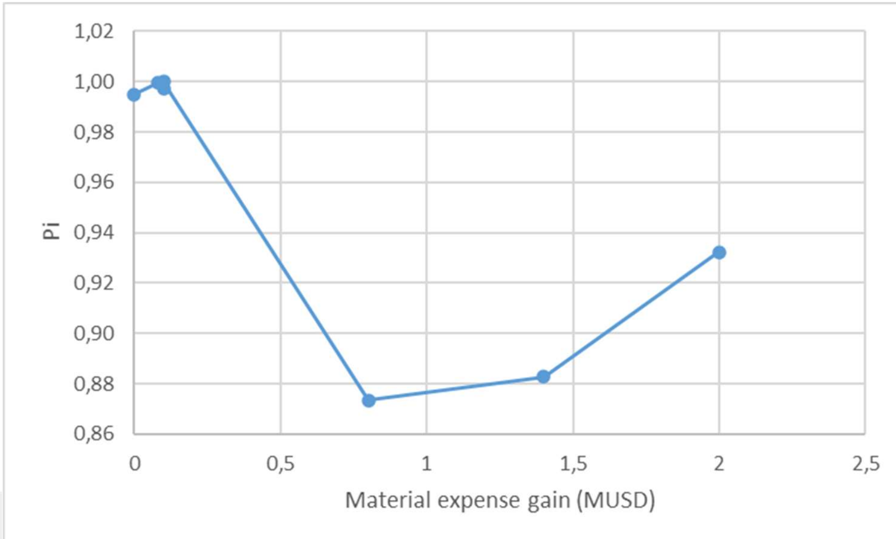

Figure 9.2: Relationship between material expense gain and Pi

On the other hand, you can see that material gain has not direct effect on the results in second method. But when we examine the profits of each option in the third method, we see the effect of material gain. Because for long-term material gain has huge impact on the results.

Table 9.4: Material expense gain and profit

Option	Weekly Material Cost Saving (MUSD)	Profit (MUSD)
C1	2	489
I1	1,4	241
I2	0,8	356
M1	0,1	285
M2	0,08	329
M3	0,1	333
M4	0	253

As mentioned above, in the second method, the weight of the material price criterion was only 10% of the total value of all criteria. However, when we evaluate the expenses included in the calculation in the third method, it is seen that the place of material expenses in the total expenses is much higher. When we evaluate the fixed expenses, such as rent, salary and maintenance collectively and compare this total expense with the monthly material cost, we see that the material expense has a great advantage.

The following are the things I would recommend to do when faced with a problem similar to the one investigated and tried to be solved in this thesis.

First of all, AHP and TOPSIS methods can be used as a multi-criteria decision-making method. These methods are both easy to use and the results they give are understandable. In addition, the results they give are the same and reliable as with more complex methods. As much data as possible should be collected during the supplier evaluation process. The criteria on which these data depend must be determined correctly. The real-life counterpart of the criteria and the main goal of the company should be well understood. In the criteria evaluation process, the experience of professionals and especially those who know the main goals of the company should be used. Otherwise, wrong result will be obtained with an incorrect criterion evaluation.

Finally, the verification or comparison of the work to be done with different methods will enable the decision maker to find the right way.

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