T.C.
MARMARA UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES IN
PURE AND APPLIED SCIENCES

SELECTION OF MACHINE STATIONS AND LINES VIA ANALYTIC HIERARCHY PROCESS IN AN AUTOMOTIVE INDUSTRY

Güçlü UÇAK

THESIS

FOR THE DEGREE OF MASTER OF SCIENCE

IN

MECHANICAL ENGINEERING

SUPERVISOR
Assistant Professor Aykut KENTLİ

İSTANBUL 2012

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PREFACE

I have been working for a global company in the automotive industry since 2002. The economic crisis has affected directly automotive industry and with global economic crisis the importance of the selection of the most suitable method for production is increasing day by day. Therefore, I study on an application of multi-criteria decision making techniques to support my work life in the automotive industry.

I would like to express my deep appreciation and thanks to my family, sheet metal suppliers, MSc. Management Engineer Funda Yılmaz and my thesis supervisor Assistant Professor Aykut KENTLİ.

Güçlü UÇAK

AUGUST 2012

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OTOMOTİV ENDÜSTRİSİNDE UYGUN ÜRETİM EKİPMANLARININ VE HATLARININ ÇOK KRİTERLİ KARAR VERME YÖNTEMİ KULLANILARAK SEÇİMİ

Herhangi bir konu hakkında zamanında ve doğru karar verebilmenin önemi hem kişiler hem de kuruluşlar için giderek artmaktadır. Dolayısı ile karar verme konusundaki çalışmalar da günden güne önem kazanmaktadır.

Bu çalışmada karar verme yöntemleri arasında sıkça kullanılan Analitik Hiyerarşi Prosesi (AHP) tanıtılmıştır. Daha sonra AHP ile ilgili modellemelerin ve hesaplamaların rahatlıkla yapıldığı Expert Choice Programı tanıtılmış; kullanımı hakkında bilgiler verilmiştir.

2008 yılında yaşanan küresel ekonomik kriz birçok ülkede önemli değişikleri beraberinde getirirken Türkiye‟nin birçok sektörünü olduğu gibi özellikle otomotiv sektörünü direkt olarak etkilemiştir. Yaşanan ekonomik kriz sadece ekonomik alanda değil, sosyal ve politik alanda da etkisini göstererek belirsizliği, riski ve artan rekabet gücünü de beraberinde getirmiştir.

Çalışmamız otomotiv sektöründe üretim yapan bir işletmenin pres hatlarını değerlendirerek bunların içerisindeki en iyi ve en kötü ürünlerini ortaya koymayı amaçlamaktadır. Amaca ulaşabilmek adına daha önce ortaya konulmuş pres hatları ve otomotiv sektörünün kritik başarı faktörleri incelenmiş, bu bilgiler çerçevesinde uygulama yapılacak işletmelerde yöneticilerle derinlemesine mülakat yapılarak işletmenin pres hatlarının değerlendirmesinde kullanılacak performans kriterleri saptanmıştır. Performans kriterlerinin amaç içerisindeki önem derecelerini ve her bir ürünün performans kriterlerine göre puanını saptayabilmek için Analitik Hiyerarşi Prosesinde yararlanılmıştır. Anket yardımıyla yöneticilerden 1-9 skalasını kullanarak kriterleri ikili karşılaştırmaları ve her bir ürüne kriterler bazında başarı puanları vermeleri istenerek çalışma amacına ulaşılmıştır.

Ağustos, 2012 **Güçlü UÇAK**

ABSTRACT

SELECTION OF MACHINE STATIONS AND LINES VIA ANALYTIC HIERARCHY PROCESS IN AN AUTOMOTIVE INDUSTRY

The importance of decisions about any subject is increasing every day for both personally and for companies. Along with the importance of the studies about decision making processes are also increasing.

In this study Analytic Hierarchy Process (AHP) is used. AHP is a very common decision making process. Super Decisions program is used for calculations and modeling.

Growing rate of change in the economic, political and social environments of business today has lead to growing competitiveness, uncertainties and risks. Turkey's automotive industry has been dented by the dramatic slowdown in the sector that began in the autumn of 2008 with economic crisis in Europe and in the world.

In the study the general performance criteria was presented for the press lines based on the best known press line criteria and the sector analysis data results, then the general press-line performance criteria was privatized for the selected company in the automotive industry by using deep and comprehensive interview with the managers. After determining of the press line performance criteria, the most appropriate products' decision-making have been made by using Analytic Hierarchy Process. Analytic Hierarchy Process separates the goal/problem to sub goals/problems and collects each sub-goal/problem's solution in a single conclusion. This method makes decision-making easy by connecting feeling, perceiving, judgment and experience that are factors in forming the decision. In the evaluation made by Analytic Hierarchy Process, decision makers can make comparisons among alternative products by sensitivity analysis.

August, 2012 **Güçlü UÇAK**

SYMBOLS

A **:** Pairwise comparison matrix of the criteria

w **:** Vector of weights

λ **:** Eigenvalue

ABBREVIATIONS

AHP	: Analytic Hierarchy Process
ANP	: Analytic Network Process
BALCOR	: Balkan Conference on Operational Research
BMI	: Business Monitor International Ltd.
CI	: Consistency Index
CR	: Consistency Ratio
MCDM	: Multi Criteria Decision Making
OSD	: Turkish Automotive Producer's Association

FIGURES

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1. INTRODUCTION

Growing rate of change in the economic, political and social environments of business today has lead to growing competitiveness, uncertainities and risks. These circumstances have led to a dramatic increase in attention given to strategic planning of all kinds. Planning of production method has itself received a good deal of attention in recent years. Under such circumstances, a firm would have a better chance of success and survival by a judicious spreads of its resource and investments achieved through production method selection.

In this thesis, multi-attribute decision making methods which are used for many industrial production areas will be examined. Most suitable method will be selected and the implementation of the method to automotive industry is implemented with examples.

To reach the aim of this thesis, first of all challenging industry which needs tool for the best production method should be selected so the automotive industry was selected for the field study because Turkey's automotive industry needs the most efficient production methods. After the selection of the automotive industry, the production method was chosen in the automotive industry to find the most efficient result.

Press lines and welding robots are the main elements of the automotive industrial production. The selection of press lines and welding robots is very important. To make the correct selections at the beginning of the production process helps us to have the most suitable part,

-with the best price,

-with the best timing,

-with the best quality,

as it is aimed for the serial production.

For a sample automotive part, considering multi-attribute decision making methods; we can decide the most suitable press line and welding robot in the shortest time.

Today, automotive industry is open for improvements because of the increasing production volumes and customer expectations. Continuously increasing quality expectations with increasing production volumes have to be satisfied. In addition to all these factors, the newly designed models and the new parts for these new models are added and to have continuous productivity become inevitable for automotive industry.

To enable continuous productivity, the automotive parts have to be produced at the most suitable lines for themselves. For the selection of these production lines, certain methods can be used to find the fastest and most suitable selection. After the design of the part is completed, the selection of the most suitable production line has to be completed in the fastest way and production has to begin without losing time.

To make the most suitable selection at the beginning is very important for automotive industry in which time is as valuable as money. In this study, information about multi-attribute decision making methods will be given which are used for many industrial production areas. Most suitable method will be selected and the implementation of the method to automotive industry is explained with examples.

The aim of this study is to create a model for the selection of the production line using a multi-attribute decision making method.

2. HISTORY AND PRESENT STATE OF TURKISH AUTOMOTIVE INDUSTRY

In this section the informations which are about Turkish automotive industry, automotive industry's history and the information about the automotive production are expressed briefly.

2.1 The Automotive Industry

The automotive industry in Turkey plays an important role in the manufacturing sector of the Turkish economy.

The companies operating in the Turkish automotive sector are mainly located in the Marmara Region.

In 2011 Turkey produced 1.189.000 motor vehicles, ranking 17th largest producer in the world. All production number of the world is nearly 81.000.000. China is the leader of the first league of the automotive producers all of which produced more than 3.500.000 vehicle in 2011. Japan, USA, Germany, South Korea, Brasil and India are in this first league of the world automotive producers. Mexico, France, Spain, Canada, Thailand, Iran, Russia, England, Czech Republic and Turkey can be considered as the second league of the automotive producers which have a production more than 1.000.000 vehicle in 2011.

Turkey has 13 automotive producers. Oyak Renault, Tofaş and Ford Otosan produced nearly 300.000 vehicles for each in 2011 while Toyota and Hyundai produced nearly 100.000 vehicles for each.

For the 100th anniversary of the republic Turkey has a goal to reach 2.000.000 vehicle production. With this production number Turkey can be in the first ten automotive producers around the world and first three in Europe. (Ulasimonline, 2011)

2.1.1 History

In 1959 Otosan factory was established in Istanbul to produce the models of the Ford Motor Company under the licence in Turkey.

In 1961 Devrim was manufactured at the Tülomsaş factory in Eskişehir. It was the first indigenously designed and produced Turkish automobile.

In 1964 Austin and Martin vehicles of the British Motor Corporation began to be producer under licence at the BMC factory in İzmir. The BMC brand was later fully acquired by Turkey's Çukurova Group in 1989, which currently produces all BMC models in the world.

In 1966 Anadol became the first mass-produced Turkish auatomobile brand. All Anadol models were produced by the Otosan factory in Istanbul.

In 1968 Tofaş factory was opened in Bursa for producing Fiat models under licence.

In 1969 Oyak Renault factory was established in Bursa for producing Renault models.

Other global automotive manufacturers such as Toyota, Honda, Opel, Hyundai, Mercedes Benz and MAN AG produce automobiles, vans, buses and trucks in their Turkish factories. There are also a number of Turkish bus and truck brands, such as BMC, Otokar and Temsa.

By 2004 Turkey was exporting 518.000 vehicles a year, mostly to the Europen Union member states. (Goliath, 2005)

In 2006 The European Investment Bank loaned Tofaş €175 million to jointly develop and produce with PSA Peugeot Citroen and Fiat Auto, small commercial vehicles for the European market. The loan, part-financing for total investments estimated at €400 million, was intended to result in an important expansion of the company's production capabilities and create around 5.000 new jobs. The vehicles will be produced at the manufacturing plant of Tofaş in Bursa with an additional, initial, annual capacity of 135.000 cars, due to roll off the assembly line in late 2007. (The EU Bank, 2006)

Like in many countries, the automotive industry has been significantly affected by the global financial crisis. In March 2009 Turkey's Automotive Industry Association (OSD) said the automotive production fell by 63& on the year in the first two months of 2009, as exports dropped by 61,6% in the same period. (Bussinessneweurope, 2009)

2.1.2 Production

Turkey produced 1.024.987 motor vehicles in 2006, (OSD, 2009) ranking as the 7th largest automotive producer in Europe; behind Germany (5.819.614), France (3.174.260), Spain (2.770.435), United Kingdom (1.648.388), Russia (1.508.358) and Italy (1.211.594), respectively (OICA, 2006). In 2008 Turkey produced

1.147.110 motor vehicles, ranking as the 6th largest producer in Europe (behind Unites Kingdom and above Italy) and the 15th largest producer in the world. (Ulasimonline, 2009).

Turkey's automotive sector has been dented by the dramatic slowdown in the sector that began in the autumn of 2008. Early in the year, analysts were predicting total auto sales to fall as much as 20% during the year due to a collapse exports that forced many manufacturers to suspend production. In recent months, however, the market has begun to improve. Domestic sales have been propped up by tax cuts, and while exports are still suffering, they are at least stabilising.

In 2011 Turkey produced 1.189.000 motor vehicles, ranking 17th largest producer in the world.

Based on Dr.Martin Fahlbush's study and BMI Q4 2009 report, SWOT analysis results are achieved as seen at Table 2.1. For the field study, the SWOT analysis result will be very important to determine industry's critical sucess factor.

Table 2.1: SWOT Analysis for Automotive Industry (Fahlbusch, 2005)

STRENGTHS	WEAKNESSES
Apart from Iran, which faces domestic and international constraints on growth, there is no other significant regional producer. This provides Turkey with a clear market advantage.	High taxes and bureaucratic hurdles could hamper plans for increasing foreign investment in the sector.
Turkey's geographic proximity to Europe and Asia makes the country a strong export base.	The rising cost of living is set to dampen sales groth over the short term.
There is a low-cost base and a relatively well-tranined workforce.	
Four of the country's top ten overall exporters are automotive firms, reflecting the importartance of the industry to the economy.	
The tax treaty with the EU reduces tariffs on exports.	

Table 2.1: SWOT Analysis for Automotive Industry (Fahlbusch, 2005)

OPPORTUNITIES	**THREATS**
An increase in the minimum wage will boost consumer spending power.	Much of the recent growth in Turkish auto production is because of its status as a prospective EU member. While membership appears likely, it is not yet assured.
The opening of Iraq’s borders provides Turkey with an opportunity to become a major supplier and increase exports.	The large fiscal overhang in the economy is one area which hinders progress towards EU membership, and tax increase to meet IMF demands could limit sales growth.
The export-oriented nature of the Turkish automotive industry and its geographical concentration provides plenty of opportunities for suppliers.	Preparations to join the EU and bring industry in line with other members could see Turkey lose its competitiveness.
	An increase in the minimum wage would erode Turkey’s advantage of a low-cost labour pool, which currently attracts manufacturers.
	Dependence on EU markets has made Turkey’s automotive industry vulnerable to the economic downturn.

3. A REVIEW OF MANUFACTURING METHODS IN AUTOMOTIVE INDUSTRY

The word manufacturing is derived from the Latin “manu factus”, meaning made by hand. Manufacturing involves making products from raw materials by various processes or operations.

Manufacturing is generally a complex activity, involving people who have a broad range of disciplines and skills and a wide variety of machinery, equipment, and tooling with various levels of automation, including computers, robots, and material-handling equipment. Manufacturing activities must be responsive to several demands and trends:

- A product must fully meet design requirements and specifications.
- A product must be manufactured by the most economical methods in order to minimize costs.
- Quality must be built into the product at each stage, from design to assembly, rather than relying on quality testing after the product is made.
- In a highly competitive environment, production methods must be sufficiently flexible so as to respond to changing market demands, types of products, production rates, production quantities, and on-time delivery to the customer.
- New developments in materials, production methods, and computer integration of both technological and managerial activities in a manufacturing organization must constantly be evaluated with a view to their timely and economic implementation.
- Manufacturing activities must be viewed as a large system, each part of which is interrelated to others. Such systems can be modelled in order to study the effect of factors such as changes in market demands, product design, material and various other costs, and production methods on product quality and cost.

- The manufacturing organization must constantly strive for higher productivity, defined as the optimum use of all its resources: materials, machines, energy, capital, labour and technology. Output per employee per hour in all phases must be maximized.

Many processes are used to produce parts and shapes. There is usually more than one method of manufacturing a part from a given material. The broad categories of processing methods for materials are:

Table 3.1: Manufacturing methods.

Metal Casting	Expendable mold and permanent mold .
Metal Forming & shaping	Rolling, forging, extrusion, drawing, sheet forming, powder metallurgy, and molding .
Plastics Molding & Forming	Blow Molding, CNC Machining, Centrifugal Casting, Continuous Strip Molding, Compression Molding, Profile Extrusion, Continuous Lamination, Injection Molding, Filament Winding, Thermoforming,Vacuum Forming, Pressure Bag Molding, Pressure Forming, Pulshaping, Twin Sheet Forming, Pultrusion, Liquid Resin Molding, Reaction Injection Molding (RIM), Rotational Molding, Resin transfer molding (RTM)
Rapid Prototyping	Stereolithography - SLA or SL, 3D Printing - 3DP, Selective Laser Sintering - SLS, Fused-Deposition Modeling - FDM, Solid-Ground Curing - SGC, Laminated Object Manufacturing - LOM, Multi-Jet Modeling - MJM, Direct Shell Production Casting - DSPC, Polyjet Technology, Laser Engineered Net Shaping - LENS
Joining	Welding, brazing, soldering, diffusion bonding, adhesive bonding, and mechanical joining .
Machining	Turning, boring, drilling, milling, planing, shaping, broaching, grinding, ultrasonic machining, chemical, electrical, and electrochemical machining and high-energy beam machining .
Finishing Operations	Honing, lapping, polishing, burnishing, deburring, surface treating, coating and plating processes.

Many of these manufacturing methods are used at automotive industry. But the most common one is “Metal Forming and Shaping”, because the main material of the automotive industry is sheet metal. And the main sheet metal forming method is “forming at press-lines” which is also called as “stamping”.

3.1 Stamping As Sheet Metal Forming Method

Stamping includes a variety of sheet-metal forming manufacturing processes, such as punching using a machine press or stamping press, blanking, embossing, bending, flanging, and coining. This could be a single stage operation where every stroke of the press produce the desired form on the sheet metal part, or could occur through a series of stages. The process is usually carried out on sheet metal, but can also be used on other materials, such as polystyrene.

Stamping operations can be listed as below.

- Bending
- Blanking
- Coining
- Drawing
- Deep drawing
- Repoussé and chasing (embossing)
- Forming
- Piercing
- Progressive stamping

3.1.1 Simulation

Stamping simulation is a technology that calculates the process of sheet metal stamping, predicting common defects such as splits, wrinkles, springback and material thinning. Also known as forming simulation, the technology is a specific application of non-linear finite element analysis. The technology has many benefits in the manufacturing industry, especially the automotive industry, where lead time to market, cost and lean manufacturing are critical to the success of a company.

Recent research by the Aberdeen research company found that the most effective manufacturers spend more time simulating upfront and reap the rewards towards the end of their projects.

Stamping simulation is used when a sheet metal part designer or toolmaker desires to assess the likelihood of successfully manufacturing a sheet metal part, without the expense of making a physical tool. Stamping simulation allows any sheet metal part forming process to be simulated in the virtual environment of a PC for a fraction of the expense of a physical tryout.

Results from a stamping simulation allow sheet metal part designers to assess alternative designs very quickly to optimize their part for low cost manufacture.

3.2 Stamping Press

A stamping press is a metalworking machine tool used to shape or cut metal by deforming it with a die. A press has a press frame, a bolster plate, and a ram.

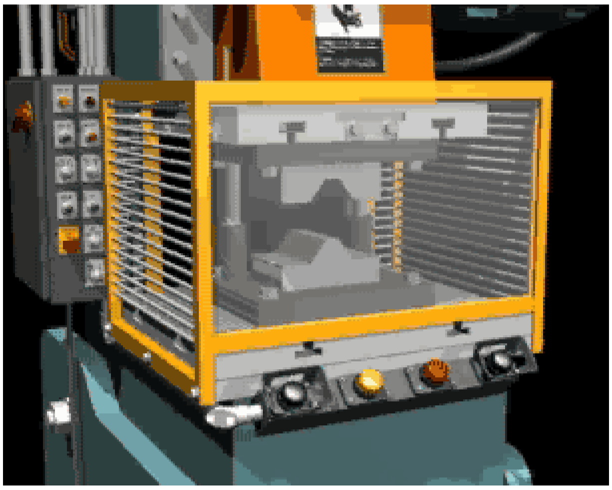


Figure 3.1. Power press with a fixed barrier guard

The bolster plate (or bed) is a large block of metal upon which the bottom portion of a die is clamped; the bolster plate is stationary. Large presses (like the ones used in the automotive industry) have a die cushion integrated in the bolster plate to apply blank holder forces. This is necessary when a single acting press is used for deep drawing. The ram is also a solid piece of metal that is clamped to the top portion of a (progressive) stamping die and provides the stroke (up and down movement). This action causes the die to produce parts from the metal being fed through it.

Stamping presses can be subdivided into mechanically driven presses and hydraulically driven presses.

The most common mechanical presses use an eccentric drive to move the press's ram, whereas hydraulic cylinders are used in hydraulic presses. The nature of drive system determines the force progression during the ram's stroke. The advantage of the hydraulic press is the constant press force during the stroke. Mechanical presses have a press force progression towards the bottom dead center depending on the drive and hinge system. Mechanical presses therefore can reach higher cycles per unit of time and are usually more common in industrial press shops.

Another classification is single-acting presses versus double- (seldom triple) acting presses. Single-acting presses have one single ram. Double-acting presses have a subdivided ram, to manage, for example, blank holding (to avoid wrinkles) with one ram segment and the forming operation with the second ram segment.

Typically, presses are electronically linked (with a programmable logic controller) to an automatic feeder which feeds metal raw material through the die. The raw material is fed into the automatic feeder after it has been unrolled from a coil and put through a straightener. A tonnage monitor may be provided to observe the amount of force used for each stroke.

3.3 Stamping Press Evaluation

The aim of this study is to select the press lines via multi criteria decision making techniques. There are three main criteria to reach the study’s goal: the first main criterion is “general specifications of the press lines”, the second main criterion is “technical specification of the press lines” and the third main criterion is “specification of the supplier”. Also each main criterion is composed of criteria, each criterion may be composed of sub-criteria.

3.3.1 General Specifications of the Press Lines

The first main performance criterion is “General specifications of the press line”. General specifications of the press line consist of six criteria as stated below.

- Capacity of the press line
- Price of the press line
- Quality of the service
- Dimensions of the press line

- Production year
- General image of the press line brand

"Capacity of the press line" is the production capacity of the press line which limits the production quantity.

"Price of the press line" is the first purchasing investment requirement of the mentioned press line.

"Quality of the service" is the service performance of the press line when it needs to be fixed urgently.

"Dimensions of the press line" is the product availability of the press line when it is evaluated with its dimensions.

"Production year" is the model year of the press line which gives when it is produced first time.

"General image of the press line" is the first impression of the press line brand.

3.3.2 Technical Specifications of the Press Lines

The second main performance criterion of this study is "Technical specifications of the press line". Technical specifications of the press line consists of three criteria as stated below.

All three criteria also have their sub-criteria as seen below.

- Efficiency of the press line
  - Main engine power
  - Working pressure
  - Press stroke number per minute
  - Tool dimensions and weight
- Plate specifications
  - Lower plate specifications
  - Upper plate specifications
- Bolster specifications
  - Lower bolster specifications
  - Upper bolster specifications

"Efficiency of the press line" is the production efficiency of the press line which limits the production quantity. It is directly related with the main engine power, working pressure, press stroke number per minute and tool dimensions and weight. All of these four have to be considered to calculate a production program.

“Plate specifications” are the press line’s plate’s dimensions and other details. All calculations have to be related of these specifications. A press line which has not an enough plate for a desired production cannot be used anytime. There are two plates on press lines. Upper and lower ones between them the dies of production will be fixed.

“Bolster specifications" are the specifications of the bolster plates’ of the press lines. The bolster plate is a large block of metal upon which the bottom portion of a die is clamped; the bolster plate is stationary. A press line which has not an enough bolster for a desired production cannot be used anytime as it with insufficient plates.

3.3.3 Specifications of the supplier

The third main performance criterion of this study is “Specifications of the supplier”. Specifications of the supplier consist of three criteria as stated below. Only “Product portfolio of the supplier” criterion has sub-criteria as seen below;

- Financials of the supplier
- Product portfolio of the supplier
    - Current product portfolio of the supplier
    - Target product portfolio of the supplier
- Machine park of the supplier

“Financials of the supplier” is directly related with the supplier and its budget to choose any press line.

“Product portfolio of the supplier” is related with what the supplier produced till today and what they plan to produce after today. Current product portfolio of the supplier is a key to choose the best press line considering the production experinces. Target production portfolio of the supplier is about planning the future capacities.

“Machine park of the supplier” is about to decide if the current press lines are enough or the supplier needs extra investment.

All of these are in our expert survey which can be seen as Appendix at the end of this thesis. It is answered by all suppliers to select the press lines via multi criteria decision making techniques.

4. FIELD STUDY ON FINDING THE BEST PRODUCTION LINE IN AUTOMOTIVE INDUSTRY

The aim of this study is to evaluate press-lines' performance and to find the most appropriate one between some press-line brands. To reach the aim, stamping is chosen as production method at automotive industry. Some of major pressing suppliers are selected in the automotive sector for evaluating press-lines' performances. The study was presented with three phase which are named structuring phase, modelling phase and analysis phase. At the structuring phase, the design of the finding criteria was presented in detailed. At the modelling phase, the method of the study (AHP) and data collection process were presented. At the last phase: analysis phase, the finding of the study was presented.

The approach for the field study step by step was summarized as seen in Figure 4.1 which is called "Design of the study".

As seen in Figure 4.1, the structuring phase consists two steps as called 1., 2., and 3. steps. Modelling phase consists 4. and 5. steps. And analysis phase consists last two steps as 6. and 7. steps.

First two steps of structuring phase are about finding the performance criteria of the press-lines. Press-lines are investigated as main production method at Turkish automotive industry. And press-line criteria are chosen with the help of experinence, literature review and in depth interview with suppliers. During the literature review a study about AHP applications on machine selection problems is completed and published at BALCOR 2011. (Appendix A.1.) As last step of structuring phase an expert survey (Appendix A.2.) which is prepared to obtain data for to select the press lines via multi criteria decision making techniques.

After finding the criteria of the press lines they are grouped as each main criterion is composed of criteria, each criterion may be composed of sub-criteria. These criteria are determined by Super Decisions program via AHP method.

In this section, three phases which are named structuring, modelling and analysis phase will be explained in detail.

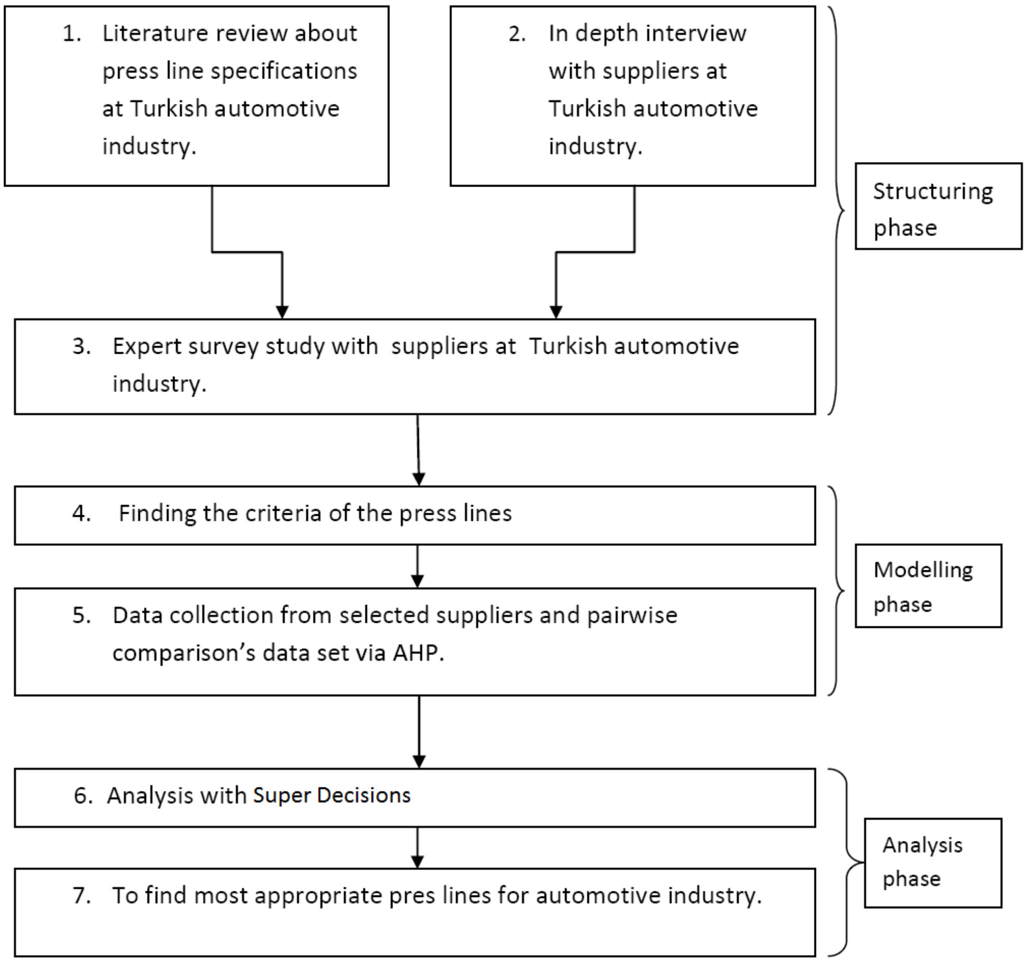


Figure 4.1. Design of the study

4.1 Structuring Phase

To evaluate press-lines' performance and to find the most appropriate one between some press-line brands this study is made with three steps. First step of these three steps is structuring phase.

As seen in figure 4.1, the structuring phase, consists two steps with three studies. First two of these three studies are prepared at same time. First one is "Literature review about press-line specifications at Turkish automotive industry" and second one is "In depth interview with suppliers at Turkish automotive industry". These are prepared simultaneously which are about finding the performance criteria of the press-lines. Press-lines are investigated as main production method at Turkish automotive industry. And press-line criteria are chosen with the help of experinence, literature review and in depth interview with suppliers. During the literature review a study about AHP applications on machine selection problems is completed and published at BALCOR. (Appendix A.1.)

For the first step, the most important thing is to find the most appropriate criteria of the press lines at the automotive industry. Press lines can have many different types, sizes, dimensions, capacities for many different brands. The choice of the most appropriate press line is very important for the most efficient result from the production. Before the decision of the press line selection there is much different information to be known by the supplier of the aforementioned press-line.

First of all, the supplier has to be informed about the cad data of the part which is planned for the production. The Purchasing Department of the main automotive industry is informed by The Product Development Departmant about the newly designed part which is prepared with the help of The Marketing Department. The Marketing Department uses the methods of customer satisfaction while helping The Product Devolopment Department during the design phase. The newly designed part has to fulfill all of the expectations of the customers, because the main idea of all the automotive industries is %100 Customer Satisfaction. The Marketing Department collects information about customer expectations. With the help of this kind of design which needs to study in cooperation; both current customers and customers at target market can be satisfied. After the design is fixed The Product Developement Department prepares the cad data and material specifications (etc. thickness, information about coating, vs.). The Material Planning and Logistics Department also gives the annual volume for the designed part.

After all these informations, cad data, material, annual volume vs. are obtained by all other departments to The Purchasing Department, The Purchasing Department decides the potential suppliers which can produces that part. While choosing these potential suppliers The Purchasing Department first uses the experience and knowledge about the suppliers which have pres lines. While choosing these suppliers as potential suppliers The Purchasing Department considers the size, material and annual volume. For this selection The Purchasing Department knows all supplier's press-lines, material stocks and production capacities. The size of the part is directly engaged with the suppliers' press line dimensions. The material of the part must be easily found by the potential suppliers at their material stocks. And the production capacities of the potential suppliers must be suitable for this newly designed part's annual volume. After deciding the potential suppliers The Purchasing Department sends cad data and all other informations about the part to the choosen potential suppliers. The suppliers prepare their piece price and tooling cost quotations and send to The Purchasing Department. The Purchasing Department receives all of these quotations and prepares a comparison table with them. While preparing this comparison, The Purchasing Department considers both piece price and tooling cost with an amortisation report considering the vehicle's production life. But when choosing the best solution the only criterion is not best piece price and tooling investment. The timing of the supplier for given cad data and also quality are both very important for decision.

After The Purchasing Department has choosen the most appropriate supplier, it is announced to the supplier. Then supplier has to choose the best press line for its newly received part with a Purchase Order with the information of piece price, tooling investment (with tooling equipments details) and timing. This press line decision is very important for the supplier because the production costs and quality is directly engaged to the press line which is chosen by the supplier. For this important decision our study targets to create a model with the help of experience, literature and in depth interview with the suppliers. For his model AHP is chosen as via multi criteria decision making technique.

The literature review is prepared as a study to show AHP's importance as a multi criteria decision making technique for choosing the press lines. The literature review shows that AHP is a commonly used technique for machine selection problems.

In depth interview with the suppliers at Turkish automotive industry for press-line production is the second study for this important decision. At this interview all of the specifications of the press-lines at the suppliers' machine park are considered and classified. These all are presented as the last step of structuring phase.

4.2 Modelling Phase

The modelling phase has two steps. The first one is finding the criteria of the press-lines to prepare the expert survey. And the second one is data collection from the selected suppliers and comparison of the data sets via AHP.

As we mentioned at chapter 3.3., press line specifications are grouped at three main titles. These three main criteria are "general specifications of the press lines", "technical specification of the press lines" and "specification of the supplier". Also each main criterion is composed of criteria, each criterion may be composed of sub-criteria. Then an expert survey (Appendix A.2.) is prepared to obtain data to select the press-lines via multi criteria decision making techniques. This expert survey is sent to all potential suppliers for a chosen part. First of all we assumed a new part for The Purchasing Department with the size of nearly 1.900 mm x 1.800 mm, with the material 0,9 mm thickness and cold rolled and with the annual volume of 100.000 parts/year. The part can be considered as medium difficult when we think its prodution. This means it has not a very deep drawing form. The material specifications of this part can be seen at Material Specification papers (Appendix A.3.). The coil and package informations, thickness tolerance, material specification number, material grade, thickness specification number, thickness type, surface quality all can be seen at these papers. There are four press operations for the production of this part, which means the press line must have at least four press machines as a line. All operation charts take place at these papers to describe the operations detailed. With the help of these informations and the dimensions of the parts, the suppliers decide the most suitable press line. The part is a sheet metal floor panel of a commercial vehicle. The suppliers, which have a press line with 600 – 800 tones having appropriate dimension, can be considered as potential suppliers for this part. The expert survey is examined by all these suppliers and the questiones are answered by the suppliers.

4.2.1 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a powerful and flexible decision-making process to help people set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. By reducing complex decisions to a series of one-on-one comparisons and then synthesizing the results, AHP not only helps decision makers arrive at the best decision, but also provides a clear rationale that it is the best. Designed to reflect the way people actually think, AHP was developed in the 1970's by Dr. Thomas Saaty, while he was a professor at the Wharton School of Business, and continues to be the most highly regarded and widely used decision-making theory. (Liu, Kong, 2005)

The Analytic Hierarchy Process (AHP) is one of the most widely used multi criteria decision making method utilized (www.superdecisions.com) AHP captures priorities from paired comparison judgments of the elements of the decision with respect to each of their parent criteria (Saaty, 1980). Paired comparison judgments can be arranged in a matrix. Priorities are derived from this matrix as its principal eigenvector. Thus, the eigenvector is an intrinsic concept of a correct prioritization process. AHP allows the decision-maker to include intangibles along with tangible numerical data from many sources to make a decision. It also helps decision maker to deal with many factors at the same time as it breaks the problem into parts and then synthesize the parts together in a valid way. AHP provides a transparent framework of analysis leading to rational results and recommendations. On the other hand, stakeholder participation is necessary for large scale problems treated in decision conferences and AHP allows group decision making in a convenient way.

The AHP comprises of six steps (Chung et al., 2005):

(1) Define the unstructured problem. The problem should be stated clearly, and the objective and the outcomes should be included.

(2) Decompose the problem into a hierarchical structure. The AHP decomposes a complex problem into a decision hierarchy, which is much like a decision tree.

(3) Employ pairwise comparisons. Decision elements at each hierarchy level are compared pairwisely, and relative ratings are assigned. Saaty (1980) recommended the use of a nine-point scale to express preferences between options as equally,

moderately, strongly, very strongly, or extremely preferred (with pairwise weights of 1, 3, 5, 7 and 9, respectively) and values of 2, 4, 6 and 8 are the intermediate values. A matrix can be formed to represent the pairwise comparisons as seen below. (Saaty, 1980).

9	7	5	3	**1**	**Importance of elements are equal.** **Decision maker is indifferent between elements.**
9	7	5	**3**	1	**First element is moderately more important than the second one.** **First element is moderately preferred to second one.**
9	7	**5**	3	1	**First element is strongly more important than the second one.** **First element is strongly preferred to second one.**
9	**7**	5	3	1	**First element is very strongly more important than the second one.** **First element is very strongly preferred to second one.**
9	7	5	3	1	**First element is extremely more important than the second one.** **First element is extremely preferred to second one.**

Figure 4.2. AHP Pairwise Weights

(4) Calculate the maximum eigenvalues and eigen vectors. In order to estimate the relative weights of the decision elements in a matrix, the priority of the element is compared by the computation of eigenvalues and eigenvectors with the following formula.

$$A \cdot w = \lambda_{\max} \cdot w$$

(5) Check the consistency property of the matrix. The consistency ratio (CR) is applied to examine the consistency of judgments in the pairwise comparison. The consistency index (CI) and CR are defined as (Saaty, 1980).

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

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}$$

(6) Obtain an overall rating of decision alternatives by aggregating the relative priorities of the decision elements. An overall priority ranking of the decision alternatives can be optained by combining the criterion priorities and priorities of each decision alternative relative to each criterion.

AHP’s first step is that the problem or aim should be stated clearly and the objective/the outcomes should be included. For the study, the aim is decided as “To find the most appropriate pres line for the production”.

Second step of AHP is to decompose the aim/problem into a hierarchical structure like a decision tree. As seen at Chapter 3.3. Press-Line Evaluation the pres-line criteria structure is avaible for AHP hierarchical structure.

Third step of AHP is to employ pairwise comparisons. Decision elements (our each press-line criteria) at each hierarchy level are compared pairwisely and relative ratings are assigned. Saaty (1980) recommended the use of nine point scale to express between options. For collecting pairwise comparison score and product’s ratings with respect to each press line criteria from suppliers, the expert survey was prepared. The data collection process was described in detailed next section.

4.2.2 Data Collection Process

Based on Saaty nine point scale, expert survey was prepared to get pairwise comparison questions for each press line criteria and also to get relative ratings for the press line brands in the portfolio as seen prepared expert survey at Appendix A.2.

The response of the expert survey was collected from the suppliers which have press lines for automotive parts’ productions.

4.3 Analysis Phase

For the study’s data analysis phase, The Super Decisions Software is used. When mentioned super decisions sofware’s structure, The Super Decisions Software can be utilized to trear Analytical Hierarchy Process (AHP) based multi criteria decision problems. The Super Decisions extends the Analytical Hierarchy Process (AHP) that uses the same fundamental prioritization process based on deriving priorities through judgments on pairs of elements or from direct measurements. So, The Super Decisions Software is used for data analysis tool to achieve each product’s priority based on finding of performance criteria.

The Super Decisions software is used for decision-making with dependence and feedback. It implements the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP). Both use the same fundamental prioritization process based on deriving priorities by making judgments on pairs of elements, or obtaining priorities by normalizing direct measurements. In the AHP the decision elements are arranged in a hierarchic decision structure from the goal to the criteria to the alternatives of choice, while in the ANP the decision elements are grouped in clusters, one of which contains the alternatives, which the others contain the criteria, or stakeholders or other decision elements. In the ANP there is not a specific goal element, rather the priorities are determined in a relative framework of influences and the prioritization of the alternatives is implicitly understood to be with respect to whatever the network is about: the decision concern. The clusters are arranged into a network with links among the elements, or sometimes into multiple tiers of elements such as when a problem is decomposed into Benefits, Opportunities, Costs and Risks. Most decision-making methods including the AHP assume independence: between the criteria and the alternatives, or among the criteria or among the alternatives. The ANP is not limited by such assumptions. It allows for all possible and potential dependencies.

The ANP does not limit human understanding and experience to force decision-making into a highly technical model that is unnatural and contrived. It is in essence a formalization of how people usually think, and it helps the decision-maker keep track of the process as the complexity of the problem and the diversity of its factors increase. The best testimony of the power and success of the ANP are those applications that have been done that derived priorities that corresponded with known answers in the real world or that have predicted outcomes. From that perspective it is a reliable and objective approach for making decisions based on priorities and importance with which one has had experience. It is rather different than making guesses about the probabilities of occurrence as some decision-making methods would have you do.

The Analytic Network Process (ANP) is the most comprehensive framework for the analysis of societal, governmental and corporate decisions that is available today to the decision-maker. It allows one to include all the factors and criteria, tangible and intangible that has bearing on making a best decision. The Analytic Network Process allows both interaction and feedback within clusters of elements (inner dependence) and between clusters (outer dependence). Such feedback best captures the complex effects of interplay in human society, especially when risk and uncertainty are involved.

The ANP, developed by Thomas L. Saaty, provides a way to input judgments and measurements to derive ratio scale priorities for the distribution of influence among the factors and groups of factors in the decision. Ratio scales make possible proportionate allocation of resources according to derived priorities. The well-known decision theory, the Analytic Hierarchy Process (AHP) is a special case of the ANP. Both the AHP and the ANP derive ratio scale priorities by making paired comparisons of elements on a common property or criterion. Although many decision problems are best studied through the ANP, one may wish to compare the results obtained with it to those obtained using the AHP or any other decision approach with respect to the time it took to obtain the results, the effort involved in making the judgments, and the relevance and accuracy of the results.

The Super Decisions software uses both AHP and ANP to build the simplest decision model that has a goal, criteria and alternatives, make judgments (paired comparisons), and compute the results to find the best alternative. A hierarchical decision model has a goal, criteria that are evaluated for their importance to the goal, and alternatives that are evaluated for how preferred they are with respect to each criterion. An abstract view of such a hierarchy is shown in Figure. 4.3.

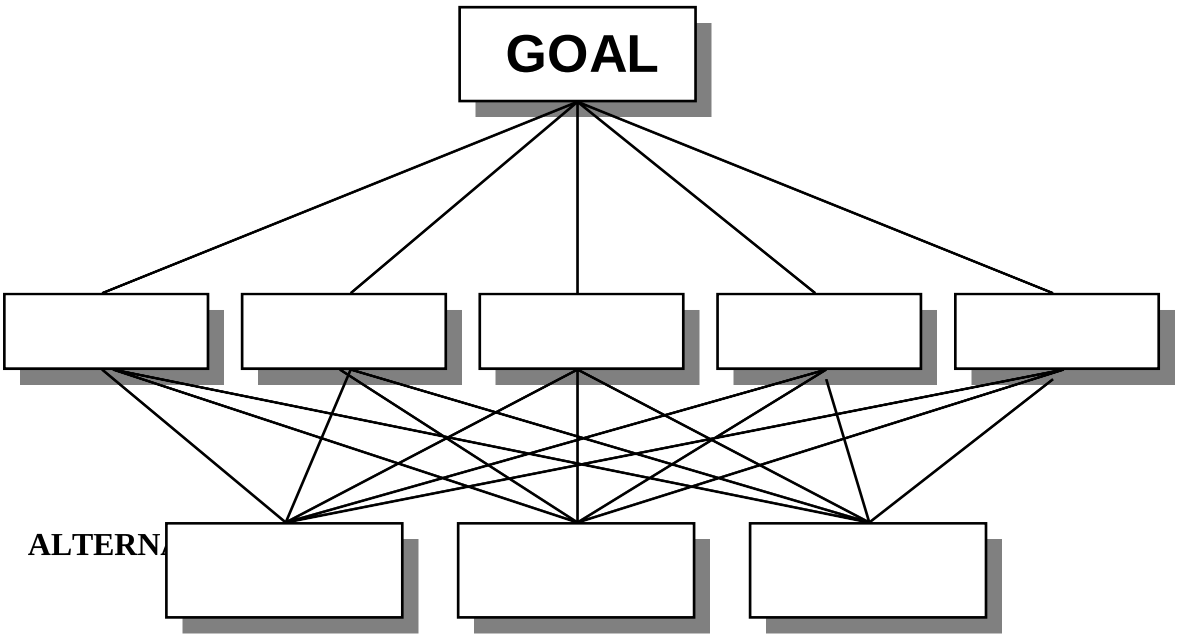


Figure 4.3. Abstract Representation of a Decision Hierarchy

The goal, the criteria and the alternatives are all elements in the decision problem, or nodes in the model. The lines connecting the goal to each criterion means that the criteria must be pairwise compared for their importance with respect to the goal. Similarly, the lines connecting each criterion to the alternatives mean the alternatives are pairwise compared as to which is more preferred for that criterion. Thus in the hierarchy that is shown there are six sets of pairwise comparisons, one for the criteria with respect to the goal and 5 for the alternatives with respect to the 5 criteria.

A SuperDecisions model consists of clusters of elements (or nodes), rather than elements (or nodes) arranged in levels. The simplest hierarchical model has a goal cluster containing the goal element, a criteria cluster containing the criteria elements and an alternatives cluster containing the alternative elements as shown in Figure 4.3. When clusters are connected by a line it means nodes in them are connected. The cluster containing the alternatives of the decision must be named A*lternatives.* Nodes and Clusters are organized alphabetically in the calculations, so an easy way to control the order is to preface the names with numbers.

The model in Figure 4.4., Car Hierarchy model is included with the sample models for the SuperDecisions software. (http: //www.superdecisions.com)

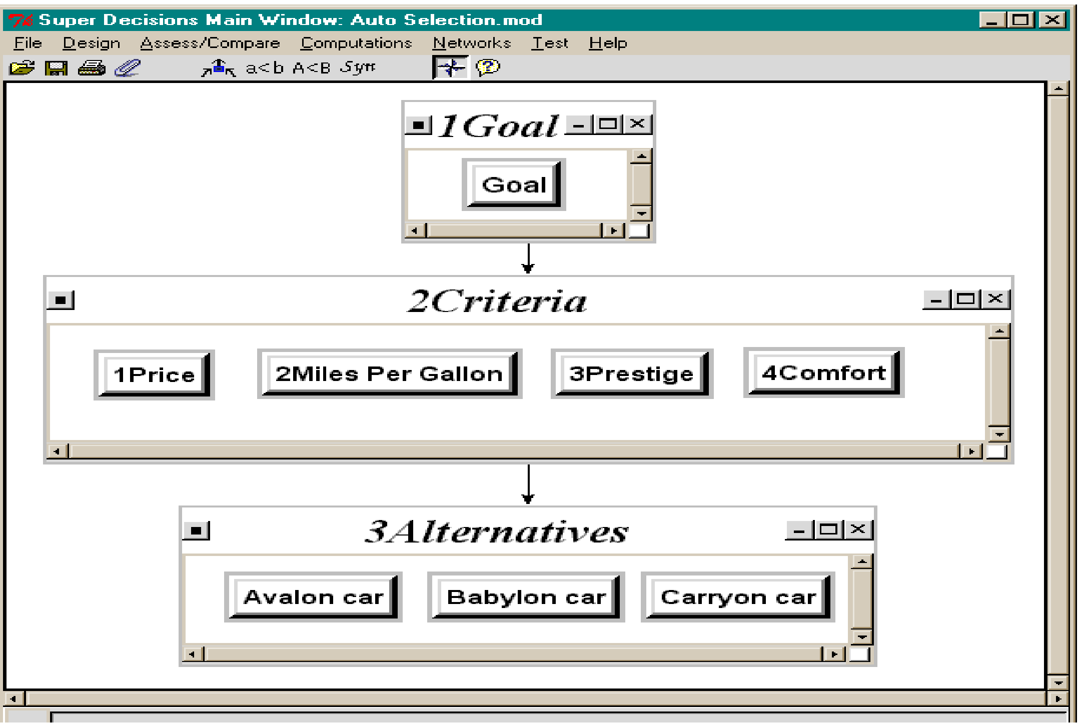


Figure 4.4. Super Decisions Hierarchical Model for Selecting a Car.

(http: //www.superdecisions.com)

Each criterion node is also connected to the alternatives. In a hierarchical Super Decisions model clusters are connected by arrows going in one direction from top to bottom. In network models, clusters may be connected with arrows going both ways and also may be connected to themselves with a loop.

In a hierarchical structure like that shown in Figure 4.5., each comparison set is made up of a parent node and the nodes it connects to in the cluster below. There are five sets of pairwise comparisons to do for this model: the criteria with respect to the goal, and the alternatives with respect to each of the four criteria.

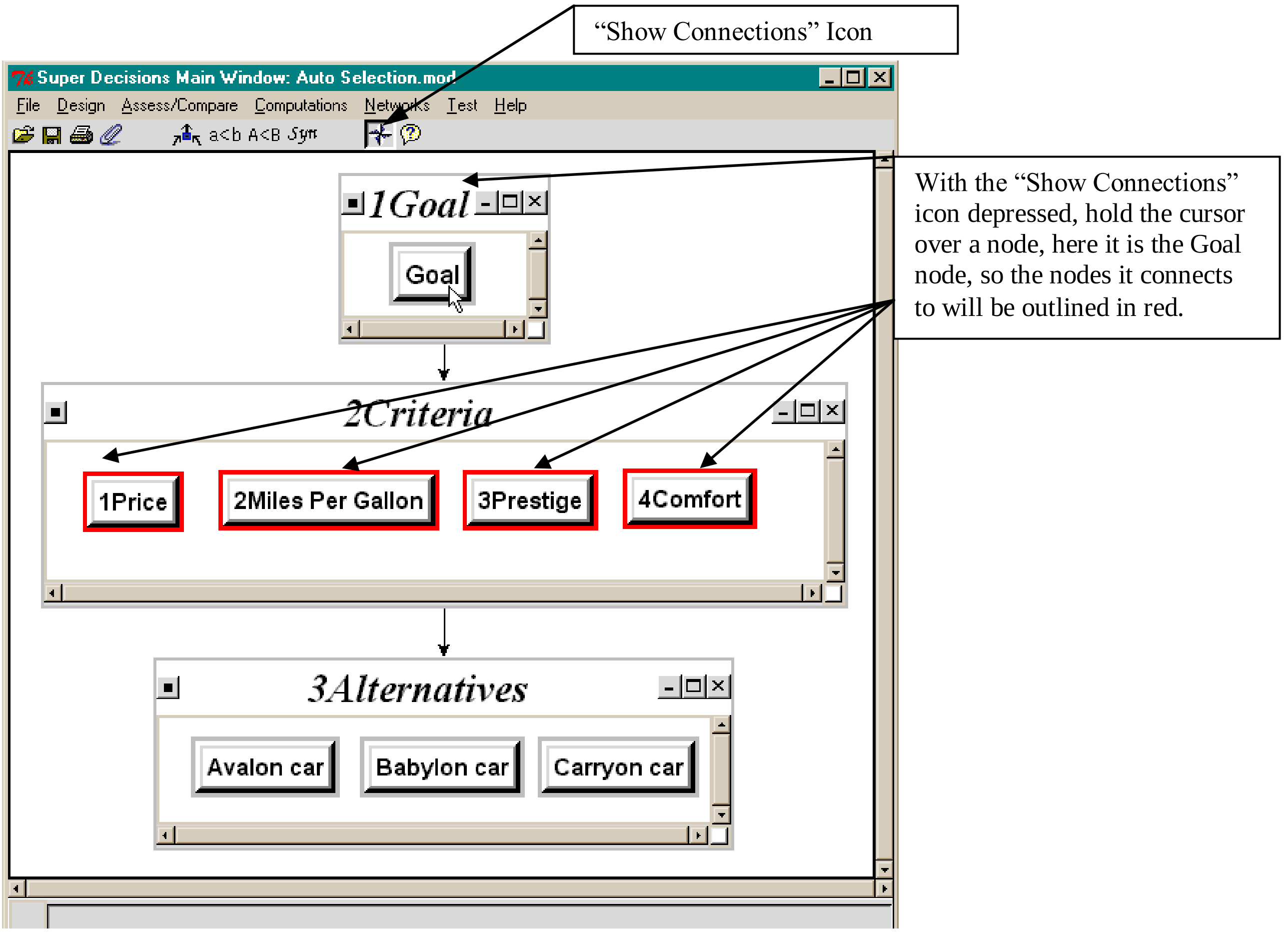


Figure 4.5. Turn on "Show Connections" Icon to see Element Connections. (http: //www.superdecisions.com)

Then the Pairwise Comparisons for the Criteria with respect to the Goal can be seen in this Figure 4.6. in which the pairwise comparisons have already been completed.

Figure 4.6. The Questionnaire Comparison Screen (http: //www.superdecisions.com)

With the matrix button equivalent Matrix comparison screen can be seen in Figure 4.7. A number in the matrix is a dominance judgment. Blue indicates the element listed at the left is dominant (more important, more preferred,…) than the element listed at the top. Red indicates that the element listed at the top is dominant. A judgment of 1.0 means they are equal, a judgment of 3.0 means moderately or three times as much (if you are dealing with measureables), and 9.0 means nine times as much. You should group your elements into homogeneous clusters so that it is not necessary to use a number larger than 9. The Fundamental Scale for judgments is shown in Table 4.1.

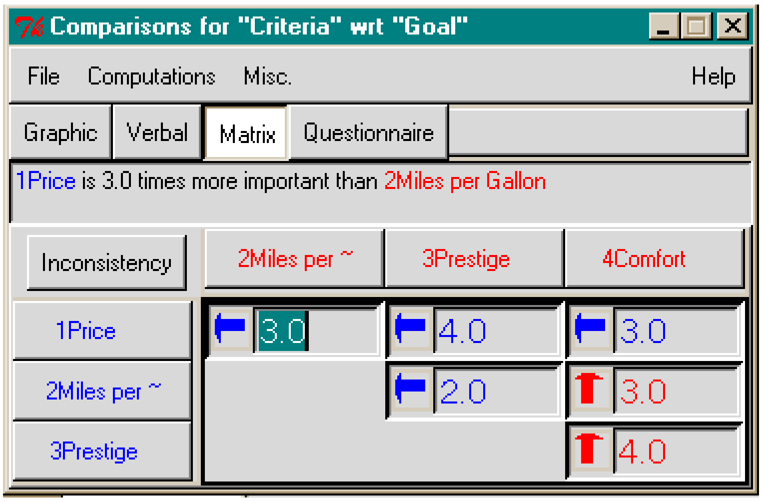


Figure 4.7. The Matrix Pairwise Comparison Screen
(http: //www.superdecisions.com)

Table 4.1: The Fundamental Scale for Making Judgments

1	Equal
2	Between Equal and Moderate
3	Moderate
4	Between Moderate and Strong
5	Strong
6	Between Strong and Very Strong
7	Very Strong
8	Between Very Strong and Extreme
9	Extreme
	Decimal judgments, such as 3.5, are allowed for fine tuning, and judgments greater than 9 may be entered, though it is suggested that they be avoided.

When a number greater than 9 is suggested by the inconsistency checking, this means that the elements you have grouped together are too disparate. You may input a number greater than 9, but perhaps you should re-organize your structure so that such a comparison is not required. It will do no great damage to allow numbers up to 12 or 13, but you should not go much beyond that.

With a click on the Computations, Show New Priorities command to see the results of this pairwise comparison shown in Figure 4.8.

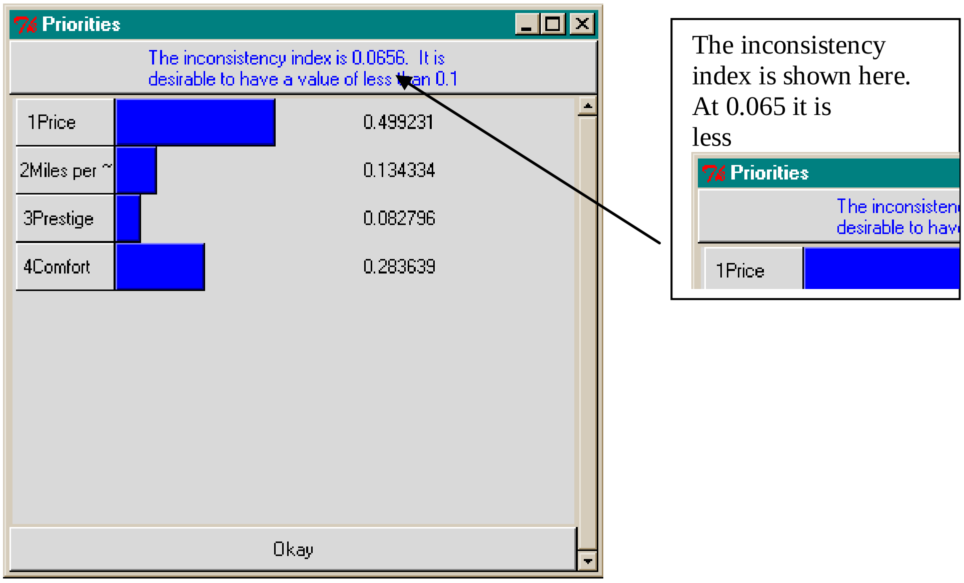


Figure 4.8. The Results of the Pairwise Comparisons (http: //www.superdecisions.com)

In Figure 4.8. the inconsistency is 0.0656, so it is not necessary to correct any judgments.

Building a hierarchy is as much an art as it is a science. Following are some guidelines:

Guideline 1: Try not to include more than seven to nine elements in any cluster or grouping of elements because experiments have shown that it is cognitively challenging for human beings to deal with more than nine factors at one time and this can result in less accurate priorities.

Guideline 2: Try to cluster elements so that they include elements that are "comparable", or do not differ by orders of magnitude. In other words, try not to include items of very small significance in the same cluster as items of greater significance. The purpose of a hierarchy is to cluster the more important elements together and the less important elements together.

By keeping these two simple guidelines in mind, you will be able to model complex decisions correctly and efficiently.

Often the words criteria and objectives are used interchangeably. A criterion is a principle or a standard that things are judged by while an objective is something that is sought or aimed for. The elements in a cluster may be thought of as objectives, or as criteria, depending on the model you are creating.

5. ANALYSIS OF THE SAMPLE PART

5.1 Specifications and Operations of Production of the Sample Part

The sample part which we assumed for our study is a sheet metal floor panel part for a commercial vehicle (Figure 5.1.). The part's dimensions are nearly 1.900 mm x 1.800 mm which are directly related to the first main performance criterion of our expert survey "General specifications of the press line". As we mentioned before "General specifications of the press line" consist of six criteria and "Dimensions of the press line" is the one which is related to the dimensions of our sample part.

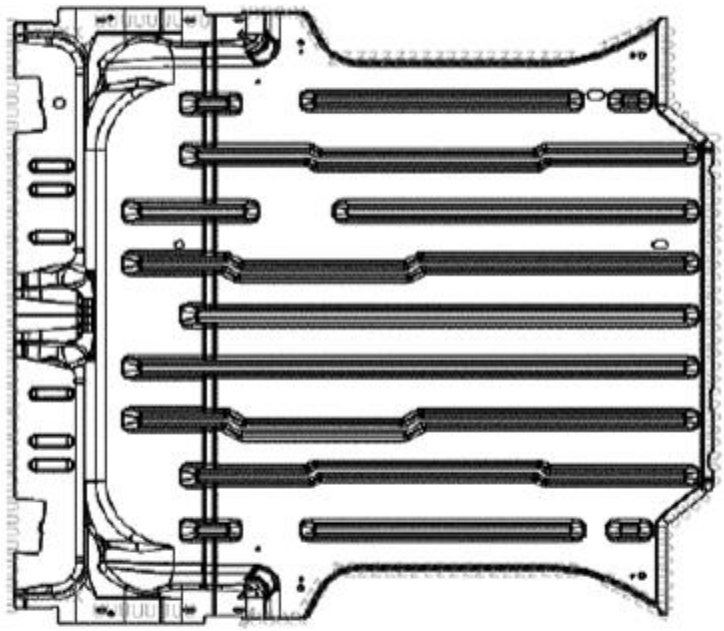


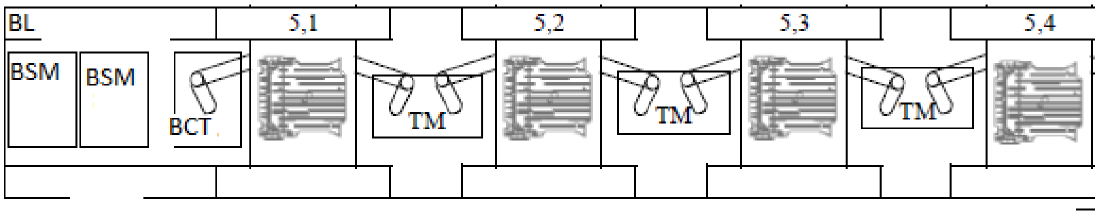
Figure 5.1. The sample part

The material of the sample part has 0,9 mm thickness and it is a cold rolled material. Its thickness tolerance is +0,06 mm. The material specification is WSS-M1A341-A4 and the material grade is BH210. These specifications give us mechanical properties of the material which gives idea about press-line selection according to the "Technical specifications of the press line". As we mentioned before "Technical specifications of the press line" consists of three criteria and "Efficiency of the press line" is the one which is related to the mechanical properties of our sample part. The mentioned material has 220-280 N/mm^2 Yield Strength, 320-400 N/mm^2 Tensile Strength and 32% (min.) Elongation. The coating specification is

WSS-M1P94-A and the coating type is 60G60G HD which gives the coating details and coating thickness. The surface quality is Class 2. All sheet metals used at press-lines for automotive industry are Class 2 except the appearance parts.

The annual volume of 100.000 parts/year. This information is very important for the press-line selection. It is related to “Capacity of the press line”, “Press stroke number per minute” and “Specifications of the supplier”. The annual volume info is very important for capacity planning of the supplier.

The part has simple forms on it as a floor panel which are not deep drawing. We can see those forms from the cad data of the sample part. There are four press-line operations which can be seen also at the operation charts also. The sample part can be considered as medium difficult when we think its prodution steps with four operations (Figure 5.2.). These four operations can give us information about the difficulty level of our sample part which means it has not a very deep drawing form. There are four press operations for the production of this part, which means the press line must have at least four press machines as a line. All operation charts take place at these papers to describe the operations detailed. With the help of these informations and the dimensions of the parts, the suppliers decide the most suitable press line which is 600 – 800 tones. The suppliers which have a press line with such a press-line having appropriate dimensions, can be considered as potential suppliers for this part. The expert survey is examined by all these suppliers and the questiones are answered by the suppliers considering our sample part and 600 – 800 tones press-line.



BL:BLANK LOADING
BSM:BLANK SHEET METALS
BCT:BLANK CENTERING TABLE
TM:TRANSFER MECHANİSM
5,1:DRAWING
5,2:TRIMMING AND PIERCING
5,3:PIERCING WITH CAM MECHANİSM
5,4:FLANGE FORMING AND LAST FORMING

Figure 5.2. The operations of the sample part

These operations are explained for the press-line operators who will work for production of our sample part. Each of them has an operation chart at “Material Specifications and Operation Charts of The Sample Part” (Appendix 3).

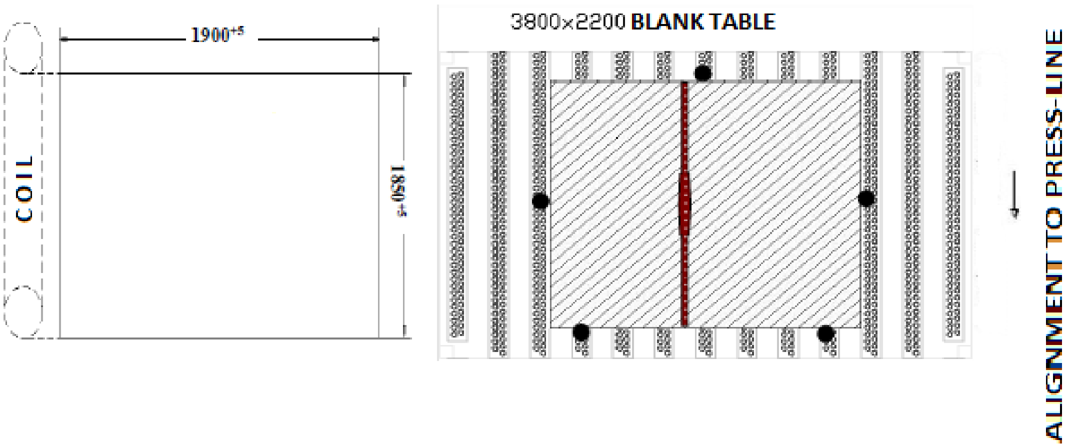


Figure 5.3. The sample part’s blank

The coil of our sample part’s blank has a width 1850 mm. The blanks which are cutted by a guillotine had 1900 mm length. The cutted blanks are placed on a blank table before the first press-line operation. (Figure 5.3.)

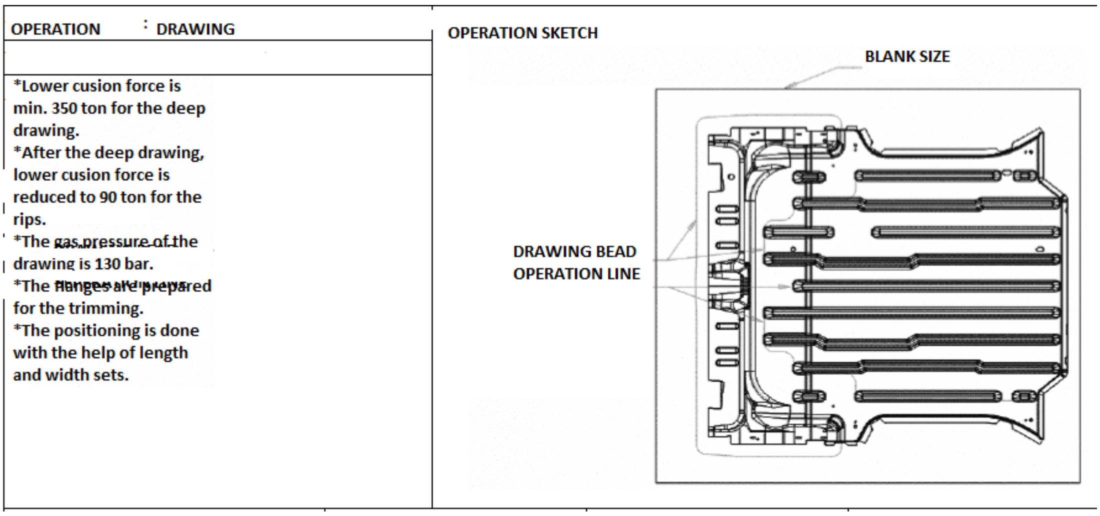


Figure 5.4. Operation 1: Drawing

The first operation of the blank is Drawing. (Figure 5.4.) At this operation the lower cusion force of the press is minimum 350 ton for the deep drawing form of the part. After this deep drawing the lower cusion force is reduced to 90 ton for the rims on the sample part. During these operations the flanges are prepared for the next operation trimming. The sample part’s positioning on the tools is done with the help of length and width sets.

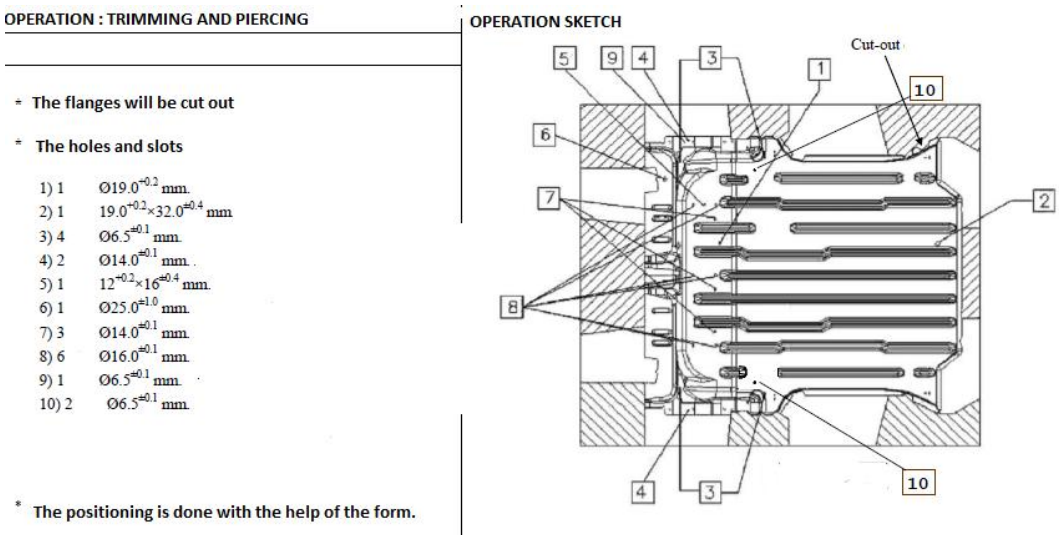


Figure 5.5. Operation 2: Trimming and Piercing

The second operation of the blank is Trimming and Piercing (Figure 5.5. & Figure 5.6.). At this operation the flanges are cutted out like they are shown in the sketch. And the holes and slots are done with the piercing tool. The sample part’s positioning on the tools is done with the help of the form of the part.

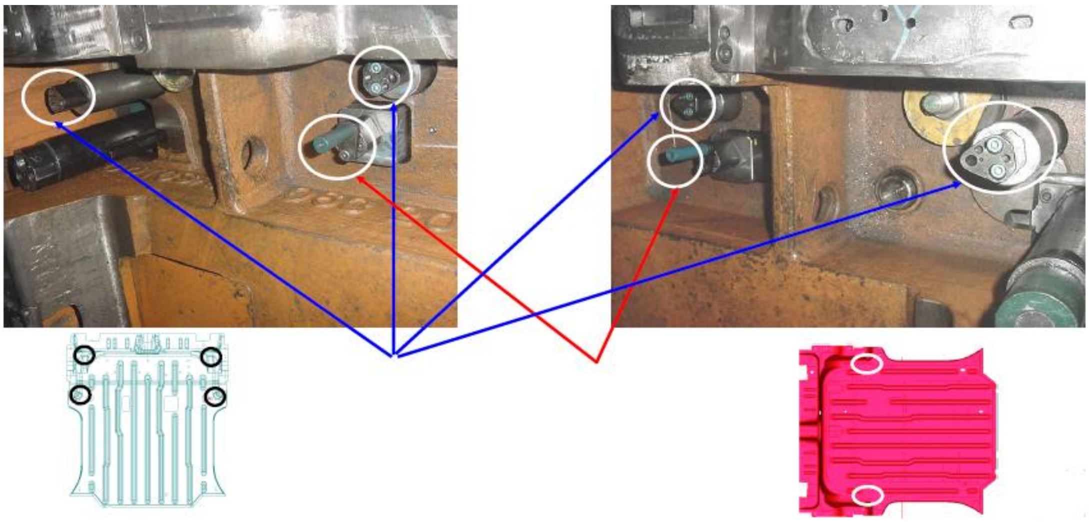


Figure 5.6. Operation 2: Trimming and Piercing

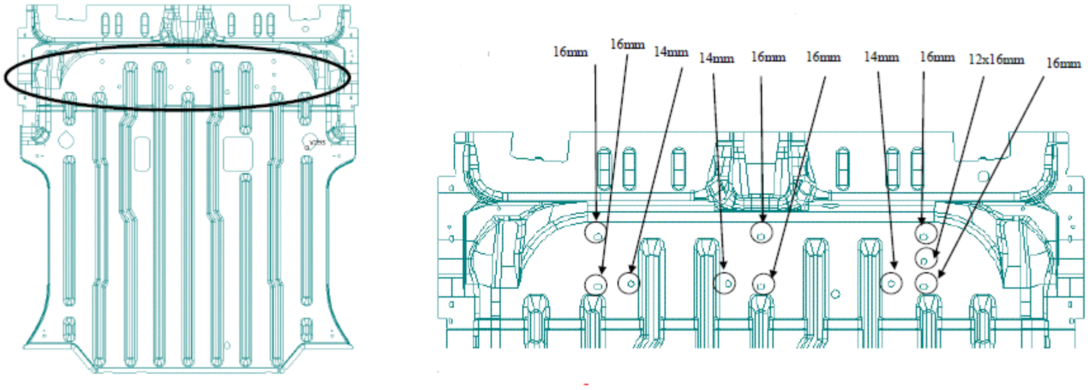


Figure 5.7. Operation 2: Trimming and Piercing (For some special vehicle models)

At the second operation of the sample part some special vehicle models also can be produced with extra piercing punches. (Figure 5.7.)

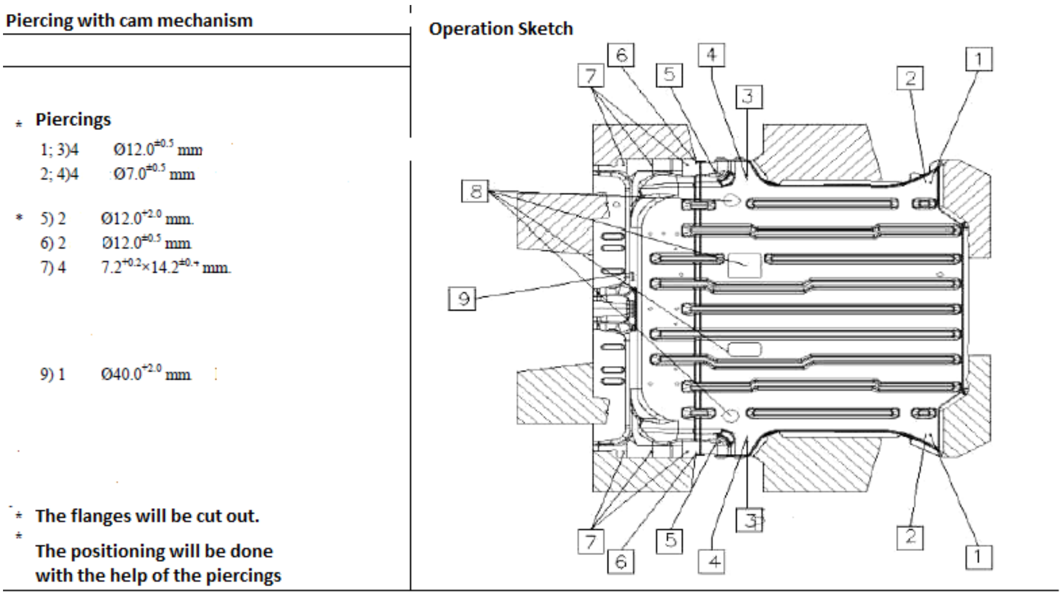


Figure 5.8. Operation 3: Piercing with Cam Mechanism

The third operation of the blank is Piercing with Cam Mechanism (Figure 5.8. & Figure 5.9.). At this operation the flanges are cutted out like they are shown in the sketch. And the holes and slots are done with the piercing tool. The sample part's positioning on the tools is done with the help of the piercings on the sample part.

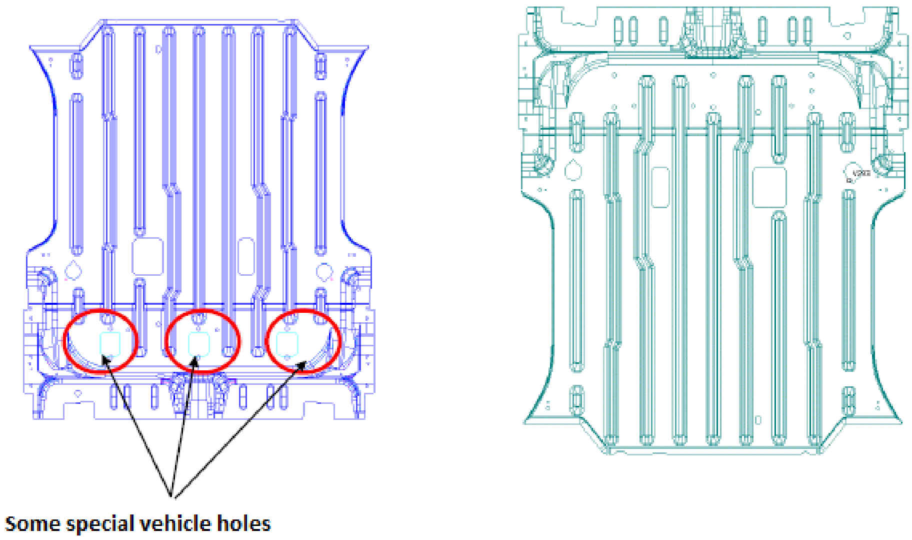


Figure 5.9. Operation 3: Piercing with Cam Mechanism(For some special vehicle models)

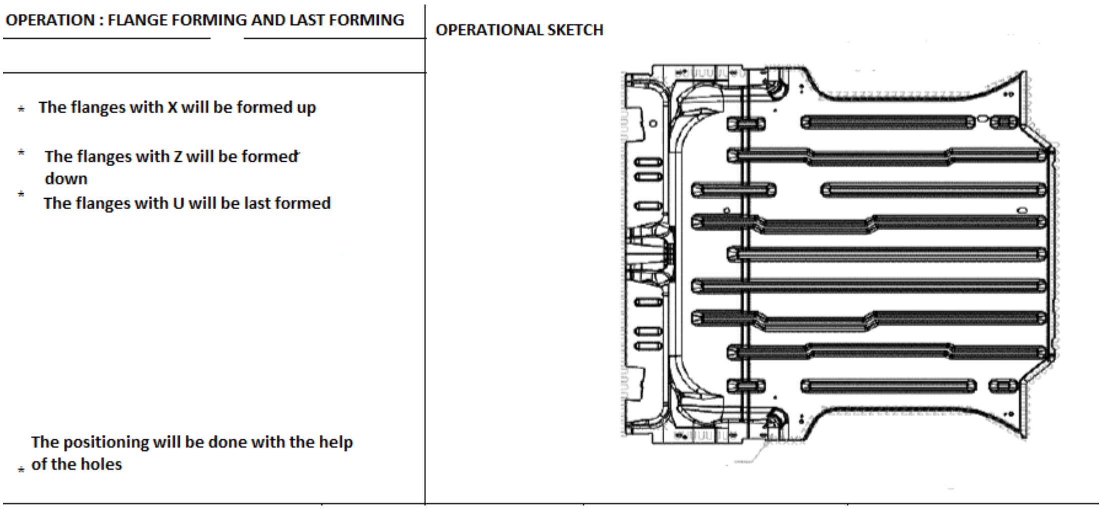


Figure 5.10. Operation 4: Flange Forming and Last Forming

The fourth and last operation of the blank is Flange Forming and Last Forming (Figure 5.10.). At this operation the flanges are cutted out like they are shown in the sketch. The flanges with X mark will be formed up. The flanges with Z mark will be formed down. The flanges with U mark will be formed as last operation. The sample part's positioning on the tools is done with the help of the piercings on the sample part.

5.2. Sample Part's Analysis Phase

For the study's data analysis phase, super decisions software is used. When mentioned super decisions sofware's structure, The Super Decisions software can be utilized to treat AHP based multi criteria decision problems. Super Decisions extends the Analytic Hierarchy Process (AHP) that uses the same fundamental prioritization process based on deriving priorities through judgments on pairs of elements or from direct measurements. So, the super decisions software is used for data analysis tool to achieve each product's priority based on finding of performance criteria. As can be seen hierarchic decision structure via superdecision programs for the study in Figure 5.11.

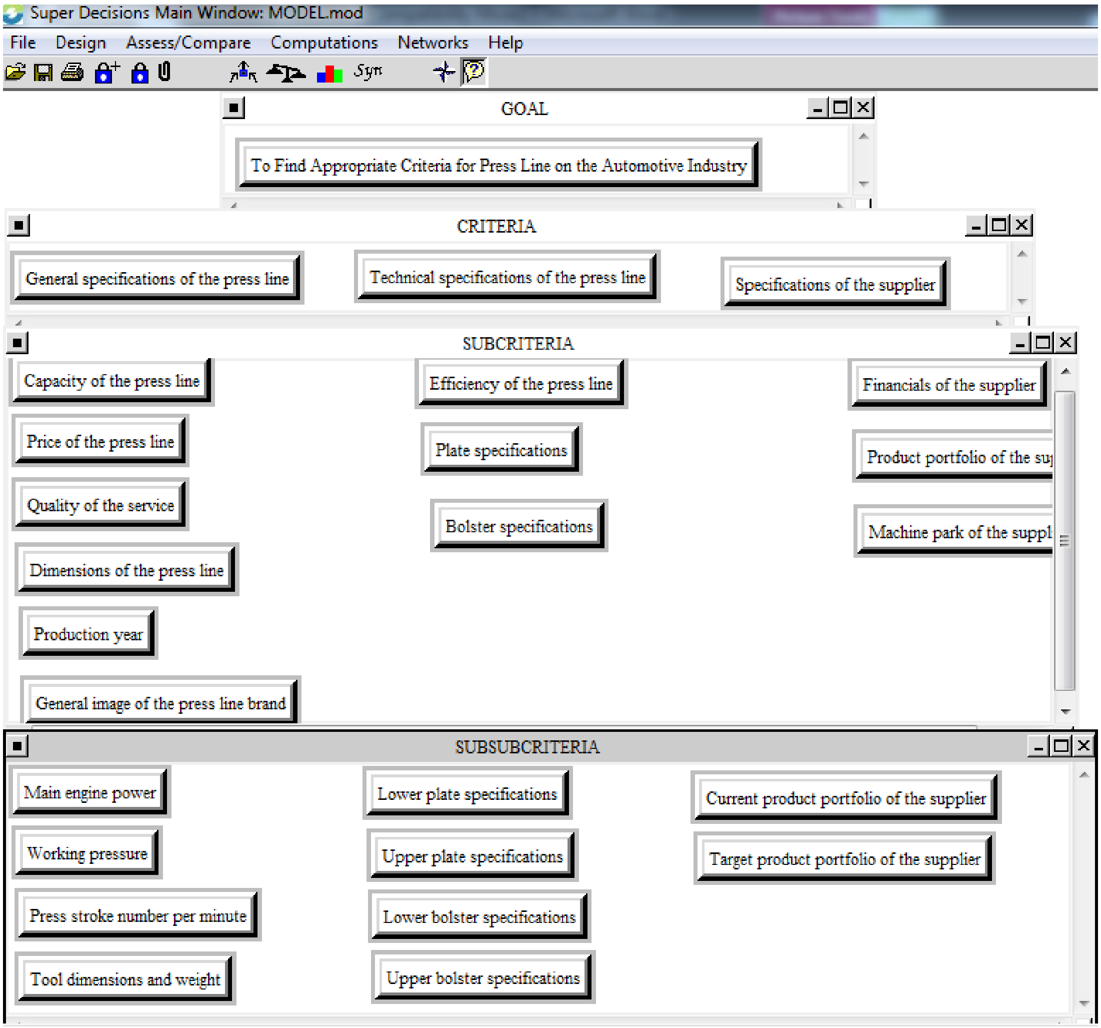


Figure 5.11 Super Decisions Program's Decision-Making Structure

After the in-depth interview with suppliers the performance criteria were achieved to find the most appropriate press-line. There are three main criteria to reach the goal. First main criterion is the "general specifications of the press lines", the second main criterion is “technical specifications of the press lines” and the third main criterion is “specification of the supplier”. Also each main criterion is composed of criteria and sub-criteria.

The first main performance criterion is “General specifications of the press line”. General specifications of the press line consist of six criteria as stated below.

“Capacity of the press line” is the production capacity of the press line which limits the production quantity.

“Price of the press line” is the first purchasing investment requirement of the mentioned press line.

“Quality of the service” is the service performance of the press line when it needs to be fixed urgently.

“Dimensions of the press line” is the product availability of the press line when it is evaluated with its dimensions.

“Production year” is the model year of the press line which gives when it is produced first time.

“General image of the press line” is the first impression of the press line brand.

The second main performance criterion of this study is “Technical specifications of the press line”. Technical specifications of the press-line consist of three criteria as stated below. All these three criteria also have their sub-criteria as seen below too.

“Efficiency of the press line” is the production efficiency of the press line which limits the production quantity. It is directly related with the main engine power, working pressure, press stroke number per minute and tool dimensions and weight. All of these four have to be considered to calculate a production program.

“Plate specifications” are the press line’s plate’s dimensions and other details. All calculations have to be related of these specifications. A press line which has not an enough plate for a desired production cannot be used anytime. There are two plates on press lines. Upper and lower ones between them the dies of production will be fixed.

“Bolster specifications" are the specifications of the bolster plates’ of the press lines. The bolster plate is a large block of metal upon which the bottom portion of a die is clamped; the bolster plate is stationary. A press line which has not an enough bolster for a desired production cannot be used anytime as it with insufficient plates.

The third main performance criterion of this study is “Specifications of the supplier”. Specifications of the supplier consist of three criteria as stated below. Only “Product portfolio of the supplier” criterion has sub-criteria as seen below;

“Financials of the supplier” is directly related with the supplier and its budget to choose any press line.

“Product portfolio of the supplier” is related with what the supplier produced till today and what they plan to produce after today. Current product portfolio of the supplier is a key to choose the best press line considering the production experinces. Target production portfolio of the supplier is about planning the future capacities.

“Machine park of the supplier” is about to decide if the current press lines are enough or the supplier needs extra investment.

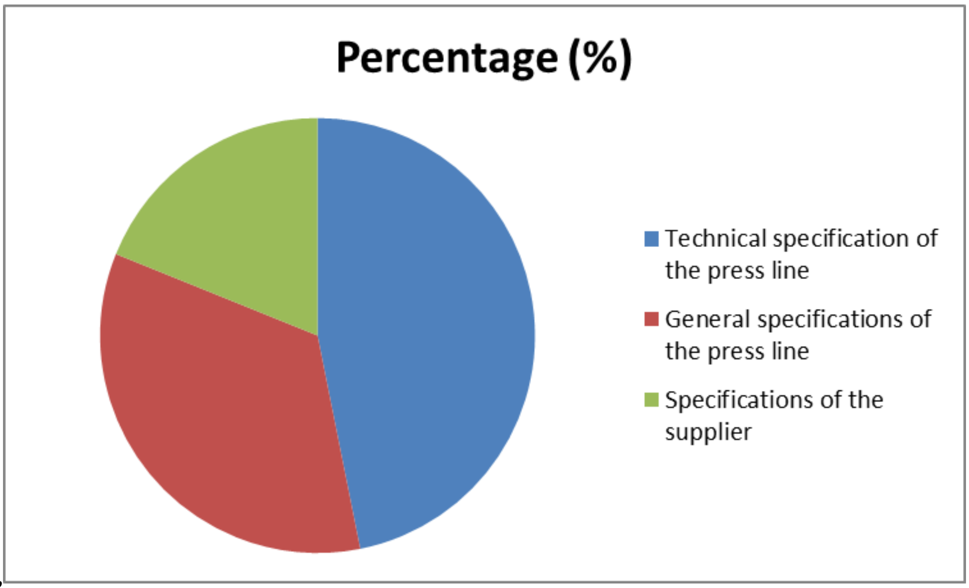
After the determination of the criteria for evaluating press-lines in the portfolio, the expert survey was prepeared as seen appendix A.2 to get priorities for each criterion in goal and also to get each products ranking result with respect to criteria.

5.2.1 Importance of Criteria of the Press-Lines

Sheet metal part producer suppliers having press-lines answered survey's pairwise comparison questions and ranking questions for each brand with respect to each criterion. In according to survey results, the technical specifications of the press line are more important than the general specifications of the press line and the general specifications of the press line are more important than the specifications of the supplier as seen table 5.1.

Table 5.1: The Importance of The Criteria of the Press-lines

	Priority Grade	Percentage (%)
Technical specification of the press line	1	46,85%
General specifications of the press line	2	34,26%
Specifications of the supplier	3	18,89%
		100,00%



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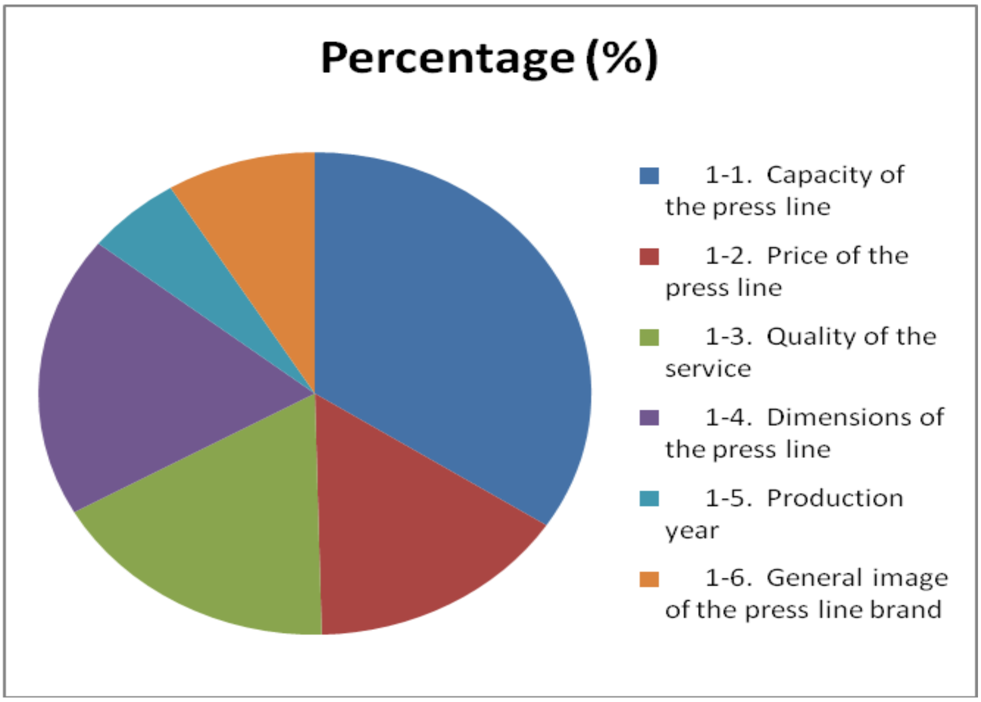
In according to table 5.1, the importance percentage for Technical specifications of the press line is 46,85% and also the importance percentage for General specifications of the press line is 34,26% and lastly the importance percentage for Specifications of the supplier is 18,89%. The sum of these three percentages is 100% as the total importance percentage.

In according to survey results as seen in table 5.2, the most important subcriterion among the six subcriteria of the general specifications of the press line is the capacity of the press line. The second important subcriterion of the general specifications of the press line is the dimensions of the press line. The third one is quality of the service. The fourth one is price of the press line. The fifth one is general image of the press line brand. And the sixth and the last one is production year of the press line.

Table 5.2: The Importance of The Sub-Criteria of the General Specifications of the Press-lines

	Priority Grade	Percentage (%)
1-1. Capacity of the press line	1	34,20%
1-2. Price of the press line	4	15,41%
1-3. Quality of the service	3	17,21%
1-4. Dimensions of the press line	2	18,87%
1-5. Production year	6	5,58%
1-6. General image of the press line brand	5	8,74%



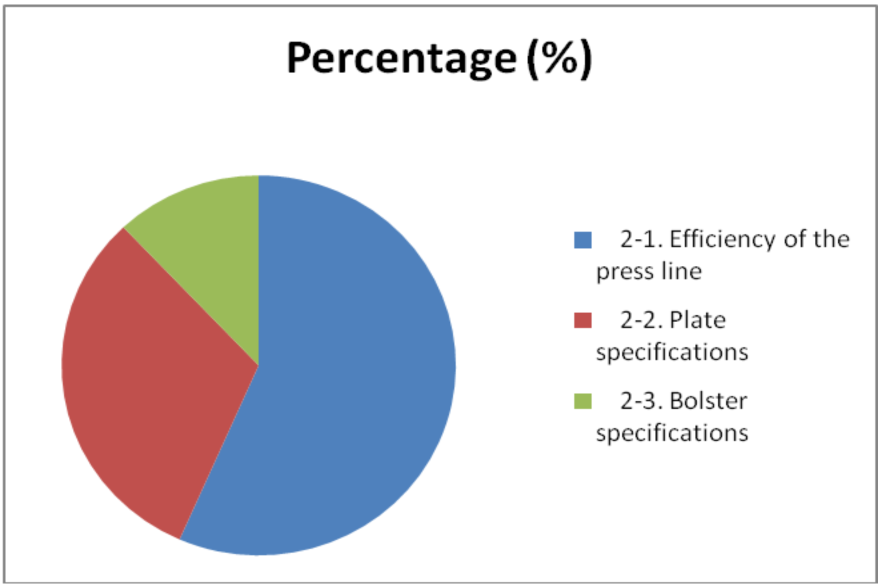
In according to table 5.2, the importance percentage for capacity of the press line is 34,20%, for the dimensions of the press line is 18,87%, for the quality of the service is 17,21%, for the price of the press line is 15,41%, for the general image of the press line brand is 8,74% and for the production year of the press line is 5,58%. The sum of these six percentages is 100% as the total importance percentage.

As a result for the general specifications of the press line as the second main important criteria of our survey, the most important subcriterion is the capacity of the press line.

In table 5.3, the most important subcriterion among the three subcriteria of the technical specifications of the press line is the efficiency of the press line. The second important subcriterion of the technical specifications of the press line is the plate specifications. The third one is the bolster specifications.

Table 5.3: The Importance of The Sub-Criteria of the Technical Specifications of the Press-lines

	Priority Grade	Percentage (%)
2-1. Efficiency of the press line	1	56,57%
2-2. Plate specifications	2	31,39%
2-3. Bolster specifications	3	12,04%

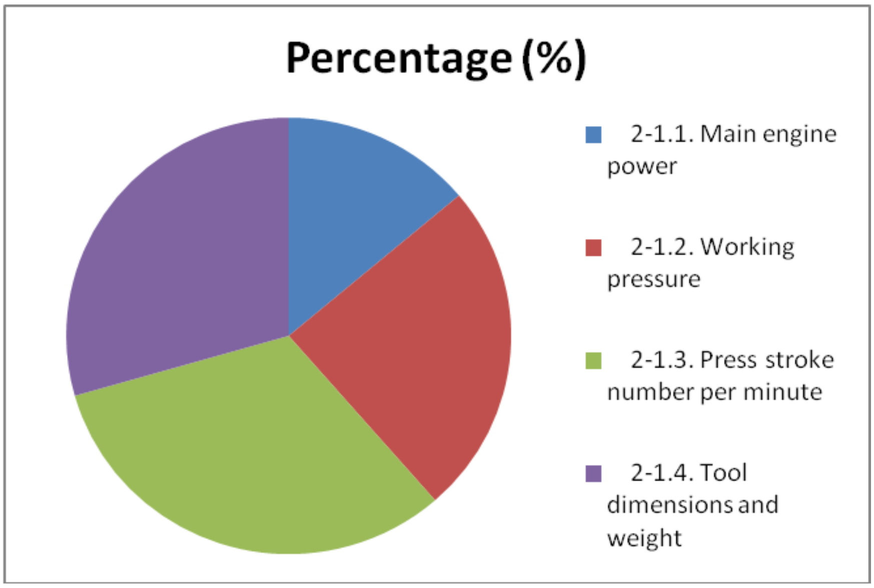


The importance percentage for the efficiency of the press line is 56,57%, for the plate specifications is 31,39% and for the bolster specifications is 12,04%. The sum of these three percentages is 100% as the total importance percentage.

The technical specifications of the press line have three subcriteria which we compared above at table 5.3. The efficiency of the press line as the most important subcriteria has four sub-subcriteria which we will compare at table 5.4. The most important sub-subcriterion among the four sub-subcriteria of the efficiency of the press line is the press stroke number per minute. The second important sub-subcriterion is the tool dimensions and weight. The third one is working pressure and the fourth and the last one is the main engine power.

Table 5.4: The Importance of The Sub-Subcriteria of the Efficiency of the Press-lines

	Priority Grade	Percentage (%)
2-1.1. Main engine power	4	13,87%
2-1.2. Working pressure	3	24,71%
2-1.3. Press stroke number per minute	1	32,00%
2-1.4. Tool dimensions and weight	2	29,43%

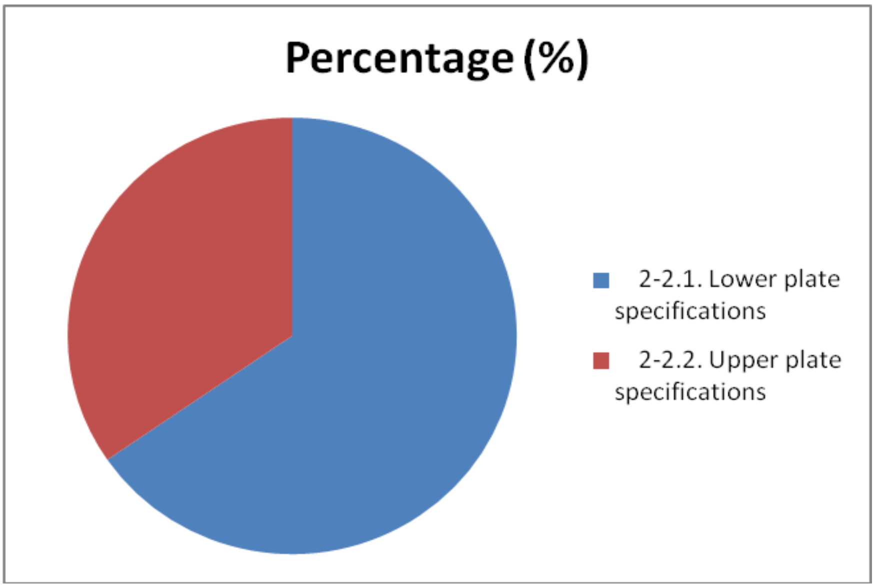


In according to table 5.4, the importance percentage for the main engine power is 13,87%, for the working pressure is 24,71%, for the press stroke number per minute is 21,00% and for the tool dimensions and weight is 29,43%. The sum of these four percentages is 100% as the total importance percentage.

The plate specifications of the press line as the second important subcriterion of the efficiency of the press line has two sub-subcriteria which we will compare at table 5.5. The lower plate specifications are more important then the upper plate specifications.

Table 5.5: The Importance of The Sub-Subcriteria of the Plate Specifications of the Press-lines

	Priority Grade	Percentage (%)
2-2.1. Lower plate specifications	1	65,40%
2-2.2. Upper plate specifications	2	34,60%

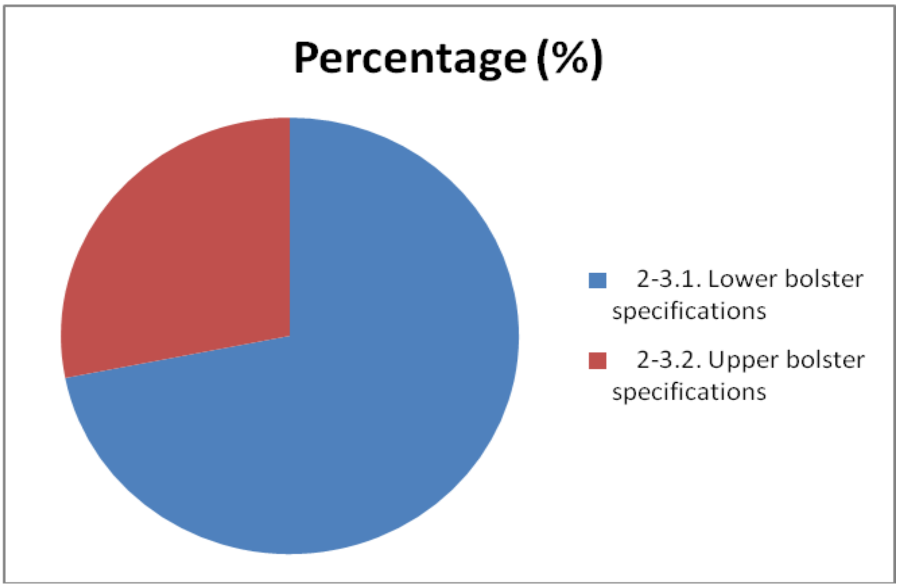


In according to table 5.5, the importance percentage for the lower plate specifications is 65,40% and for the upper plate specifications is 34,40%. The sum of these two percentages is 100% as the total importance percentage.

The bolster specifications of the press line as the third important subcriterion of the efficiency of the press line has two sub-subcriteria which we will compare at table 5.6. The lower bolster specifications are more important then the upper bolster specifications.

Table 5.6: The Importance of The Sub-Subcriteria of the Bolster Specifications of the Press-lines

	Priority Grade	Percentage (%)
2-3.1. Lower bolster specifications	1	71,91%
2-3.2. Upper bolster specifications	2	28,09%



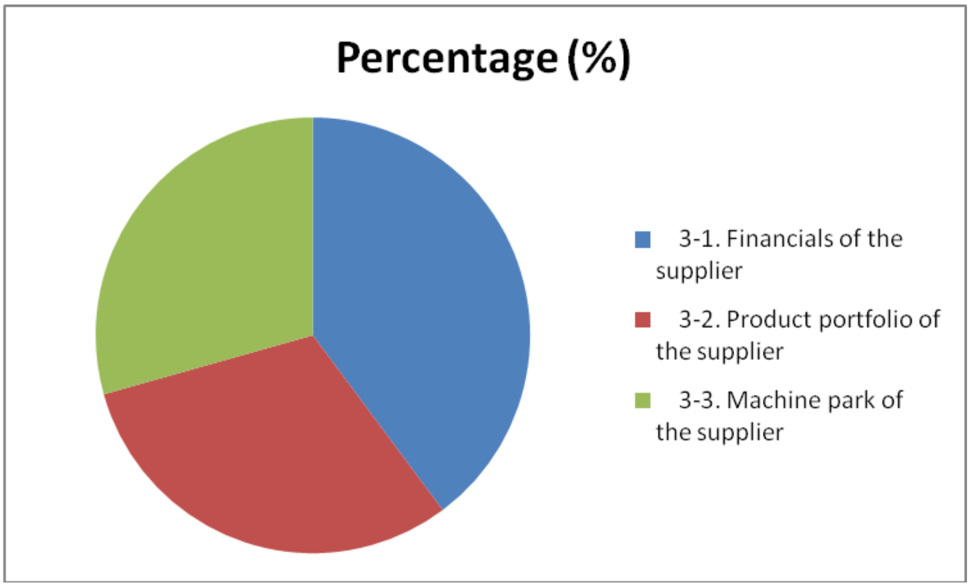
In according to table 5.6, the importance percentage for the lower bolster specifications is 71,91% and for the upper bolster specifications is 28,09%. The sum of these two percentages is 100% as the total importance percentage.

As a result for the technical specifications of the press line as the most important main criteria of our survey, the most important subcriteria is the efficiency of the press line.

The third and the last main criterion of our survey, is the specifications of the supplier. The specifications of the supplier have three subcriteria. Financials of the supplier is the most important subcriterion of the specifications of the supplier. The second important subcriterion is the product portfolio of the supplier. The third and the last important subcriterion of the specifications of the supplier is the machine park of the supplier.

Table 5.7: The Importance of The Subcriteria of the Specifications of the Suppplier

	Priority Grade	Percentage (%)
3-1. Financials of the supplier	1	39,82%
3-2. Product portfolio of the supplier	2	30,80%
3-3. Machine park of the supplier	3	29,38%

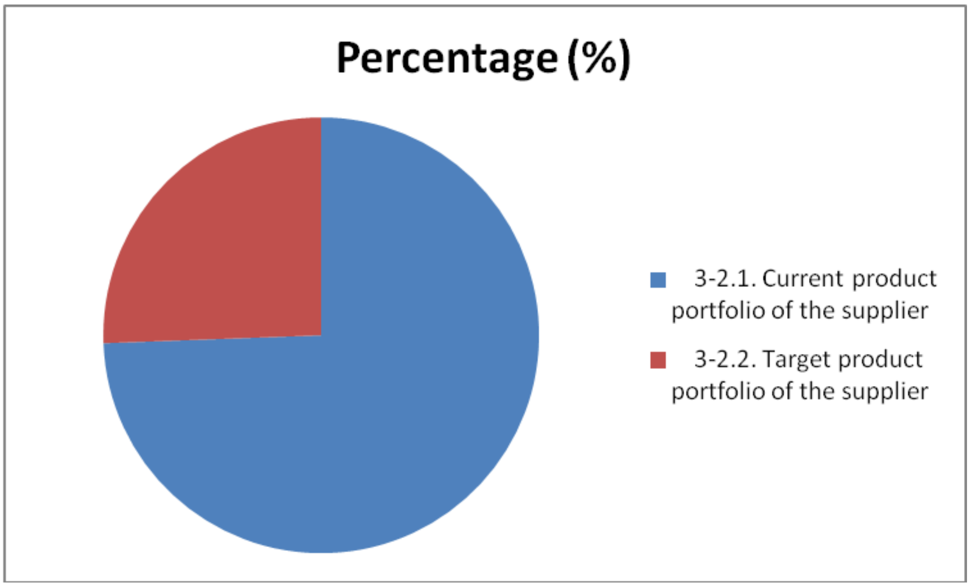


In according to table 5.7, the importance percentage for the financials of the supplier is 39,82%, for the product portfolio of the supplier is 30,80% and for the machine park of the supplier is 29,38%. The sum of these four percentages is 100% as the total importance percentage.

The product portfolio of the supplier as the subcriterion of the specifications of the supplier has two sub-subcriteria. The current product portfolio of the supplier is more important than the target product portfolio of the supplier.

Table 5.8: The Importance of The Sub-Subcriteria of the Product Portfolio of the Suppplier

	Priority Grade	Percentage (%)
3-2.1. Current product portfolio of the supplier	1	74,43%
3-2.2. Target product portfolio of the supplier	2	25,58%



In according to table 5.8, the importance percentage for the current product portfolio of the supplier is 74,43% and the for the target product portfolio of the supplier is 25,58%.

As a result for the specifications of the supplier as the third important main criteria of our survey, the most important subcriteria is the financials of the supplier.

Table 5.9: The Importance of All Criteria, Subcriteria and Sub-Subcriteria of the Expert Survey of the Press-Line

1- General specifications of the press line	**34,26%**
1-1. Capacity of the press line	34,20%
1-2. Price of the press line	15,41%
1-3. Quality of the service	17,21%
1-4. Dimensions of the press line	18,87%
1-5. Production year	5,58%
1-6. General image of the press line brand	8,74%
2- Technical specification of the press line	**46,85%**
2-1. Efficiency of the press line	56,57%
2-1.1. Main engine power	13,87%
2-1.2. Working pressure	24,71%
2-1.3. Press stroke number per minute	32,00%
2-1.4. Tool dimensions and weight	29,43%
2-2. Plate specifications	31,39%
2-2.1. Lower plate specifications	65,40%
2-2.2. Upper plate specifications	34,60%
2-3. Bolster specifications	12,04%
2-3.1. Lower bolster specifications	71,91%
2-3.2. Upper bolster specifications	28,09%
3- Specifications of the supplier	**18,89%**
3-1. Financials of the supplier	39,82%
3-2. Product portfolio of the supplier	30,80%
3-2.1. Current product portfolio of the supplier	74,43%
3-2.2. Target product portfolio of the supplier	25,58%
3-3. Machine park of the supplier	29,38%

In table 5.9, all of the importance percentages can be seen which are explained at the previous tables detailed. Table 5.9 is useful to see all of these percentages at one table. After this step we can calculate the importance level of each criteria's, subcriteria's or sub-subcriterias. For this calculation the percentages are multiplied by eachother as seen at table 5.10.

Table 5.10: The Importance Level of All Criteria, Subcriteria and Sub-Subcriteria of the Expert Survey of the Press-Line

1- General specifications of the press line

1-1. Capacity of the press line	0,1172	(1) x (1-1.)
1-2. Price of the press line	0,0528	(1) x (1-2.)
1-3. Quality of the service	0,0589	(1) x (1-3.)
1-4. Dimensions of the press line	0,0647	(1) x (1-4.)
1-5. Production year	0,0191	(1) x (1-5.)
1-6. General image of the press line brand	0,0299	(1) x (1-6.)

2- Technical specification of the press line

2-1.1. Main engine power	0,0368	(2) x (2-1.) x (2-1.1.)
2-1.2. Working pressure	0,0655	(2) x (2-1.) x (2-1.2.)
2-1.3. Press stroke number per minute	0,0848	(2) x (2-1.) x (2-1.3.)
2-1.4. Tool dimensions and weight	0,0780	(2) x (2-1.) x (2-1.4.)
2-2.1. Lower plate specifications	0,0962	(2) x (2-2.) x (2-2.1.)
2-2.2. Upper plate specifications	0,0509	(2) x (2-2.) x (2-2.2.)
2-3.1. Lower bolster specifications	0,0406	(2) x (2-3.) x (2-3.1.)
2-3.2. Upper bolster specifications	0,0158	(2) x (2-3.) x (2-3.2.)

3- Specifications of the supplier

3-1. Financials of the supplier	0,0752	(3) x (3-1.)
3-2.1. Current product portfolio of the supplier	0,0433	(3) x (3-2.) x (3-2.1.)
3-2.2. Target product portfolio of the supplier	0,0149	(3) x (3-2.) x (3-2.2.)
3-3. Machine park of the supplier	0,0555	(3) x (3-3.)

The sum of these all percentages is 100% as the total importance percentage. These importance levels will be used to calculate the press-line brands' comparison markings. Sheet metal part producer suppliers having press-lines answered survey's pairwise comparison questions and ranking questions for each brand with respect to these criterias. In according to survey results, the importance levels are calculated at table 5.10.

Table 5.11: The Importance Level of All Criteria, Subcriteria and Sub-Subcriteria of the Expert Survey of the Press-Line and the Average Marking of the Press-Line Brands with respect to these criterias

	0,1172	0,0528	0,0589	0,0647	0,0191	0,0299	0,0368	0,0655	0,0848	0,0780	0,0962	0,0509	0,0406	0,0158	0,0752	0,0433	0,0149	0,0555
	1-1. Capacity of the press line	1-2. Price of the press line	1-3. Quality of the service	1-4. Dimensions of the press line	1-5. Production year	1-6. General image of the press line brand	2-1.1. Main engine power	2-1.2. Working pressure	2-1.3. Press stroke number per minute	2-1.4. Tool dimensions and weight	2-2.1. Lower plate specifications	2-2.2. Upper plate specifications	2-3.1. Lower bolster specifications	2-3.2. Upper bolster specifications	3-1. Financials of the supplier	3-2.1. Current product portfolio of the supplier	3-2.2. Target product portfolio of the supplier	3-3. Machine park of the supplier
Schuler	7,38	5,00	7,50	7,63	4,88	8,00	6,63	6,00	7,00	6,00	6,00	5,75	5,88	5,88	6,88	6,50	6,75	6,00
Fagor	6,13	5,13	6,63	6,63	4,25	6,75	6,13	5,75	6,13	5,13	5,38	5,13	5,00	4,88	6,13	5,75	6,50	5,63
SMC	3,80	4,40	3,40	4,00	2,40	3,80	4,60	5,40	5,00	4,40	3,40	3,00	3,20	3,00	3,00	3,40	3,40	3,60
SMG	4,33	4,67	4,50	4,17	2,33	4,33	5,33	5,17	5,17	2,67	3,83	3,50	3,33	3,17	3,33	4,00	3,67	5,33
Komatsu	5,40	4,80	5,80	5,60	3,80	5,60	5,60	6,40	6,60	4,60	5,60	5,20	5,80	5,60	5,20	5,60	5,20	5,80
Benelli	2,80	5,60	3,80	4,40	2,00	3,80	3,40	4,20	4,40	3,60	4,80	5,60	6,20	4,80	2,80	3,20	3,20	4,20
Mossini	5,25	5,63	5,38	5,75	3,88	5,63	5,50	5,38	6,00	4,88	5,38	5,13	5,63	5,50	4,88	4,88	5,13	5,50
Dirinler(From Local Market)	4,00	4,17	3,67	2,83	3,50	3,67	4,17	4,50	5,50	3,50	4,67	4,33	3,67	3,67	3,00	3,83	3,67	4,67
Ales Pres(From Local Market)	3,40	5,00	4,40	2,20	1,80	2,60	4,20	4,60	5,00	2,20	3,60	3,20	2,40	2,40	1,60	2,20	2,00	4,20

The suppliers answered each question at our expert survey considering the pres-line brands. The answers are calculated as the average of the sum of these answers. According to table 5.11, the press-line brands are on the left line. The Criteria, Subcriteria and Sub-Subcriteria of the Expert Survey of the Press-Line are written on the top line. Above them we can see the importance levels of them which are calculated at table 5.10. The average of the answers about press-line brands are the main subject of this table.

In this table, the chosen press-line brands are the ones which are also decided by the interviews with the suppliers. These brands don't represent all of the press-line brands. And these markings and ratings are limited with only the answer of some suppliers so they only give an idea about a limited part of all suppliers in Turkey. This expert survey is answered by the suppliers only to get their ideas and it is a subjective study.

After the calculation at table 5.11, each importance levels written at the above of each column and the average answers about press-line brands are calculated one by one to get the results at table. Each result in each cell at table 5.12, represent the grade of that brand related with The Criteria, Subcriteria and Sub-Subcriteria of the Expert Survey of the Press-Line which are written on the top line of each column.

Table 5.12: The Scores of the Press-Line Brands for the Criteria, Subcriteria and Sub-Subcriteria of the Expert Survey

	1-1. Capacity of the press line	1-2. Price of the press line	1-3. Quality of the service	1-4. Dimensions of the press line	1-5. Production year	1-6. General image of the press line brand	2-1.1. Main engine power	2-1.2. Working pressure	2-1.3. Press stroke number per minute	2-1.4. Tool dimensions and weight	2-2.1. Lower plate specifications	2-2.2. Upper plate specifications	2-3.1. Lower bolster specifications	2-3.2. Upper bolster specifications	3-1. Financials of the supplier	3-2.1. Current product portfolio of the supplier	3-2.2. Target product portfolio of the supplier	3-3. Machine park of the supplier
Schuler	0,86	0,26	0,44	0,49	0,09	0,24	0,24	0,39	0,59	0,47	0,58	0,29	0,24	0,09	0,52	0,28	0,10	0,33
Fagor	0,72	0,27	0,39	0,43	0,08	0,20	0,23	0,38	0,52	0,40	0,52	0,26	0,20	0,08	0,46	0,25	0,10	0,31
SMC	0,45	0,23	0,20	0,26	0,05	0,11	0,17	0,35	0,42	0,34	0,33	0,15	0,13	0,05	0,23	0,15	0,05	0,20
SMG	0,51	0,25	0,27	0,27	0,04	0,13	0,20	0,34	0,44	0,21	0,37	0,18	0,14	0,05	0,25	0,17	0,05	0,30
Komatsu	0,63	0,25	0,34	0,36	0,07	0,17	0,21	0,42	0,56	0,36	0,54	0,26	0,24	0,09	0,39	0,24	0,08	0,32
Benelli	0,33	0,30	0,22	0,28	0,04	0,11	0,12	0,28	0,37	0,28	0,46	0,28	0,25	0,08	0,21	0,14	0,05	0,23
Mossini	0,62	0,30	0,32	0,37	0,07	0,17	0,20	0,35	0,51	0,38	0,52	0,26	0,23	0,09	0,37	0,21	0,08	0,31
Dirinler(From Local Market)	0,47	0,22	0,22	0,18	0,07	0,11	0,15	0,29	0,47	0,27	0,45	0,22	0,15	0,06	0,23	0,17	0,05	0,26
Ales Pres(From Local Market)	0,40	0,26	0,26	0,14	0,03	0,08	0,15	0,30	0,42	0,17	0,35	0,16	0,10	0,04	0,12	0,10	0,03	0,23

In according to table 5.12, the press-line brands have their own grades about each column with the average Marks of the expert survey answers. After getting the results at this table we can calculate the sum of every press-line brand as a sum of each line. Finally in table 5.13, in according to the survey results which are related to all answers the scores can be seen. These scores are calculated over ten maximum score. Schuler as press-line brand has the best score with 6,53 (over 10 as maximum score). (These scores are calculated with a subjective expert survey)

Table 5.13: The Total Scores of the Press-Line Brands

Schuler	**6,53**
Fagor	**5,79**
SMC	**3,87**
SMG	**4,15**
Komatsu	**5,53**
Benelli	**4,04**
Mossini	**5,34**
Dirinler(From Local Market)	**4,03**
Ales Pres(From Local Market)	**3,35**

5.3. Welding Robot Evaluation

To evaluate welding robots' performance and to find the most appropriate one among some welding robot brands, we made another in-depth interview with the suppliers. The criteria hierarchy can be in Table 5.14.

Table 5.14: The Importance of All Criteria, Subcriteria and Sub-Subcriteria of the Expert Survey of the Welding Robots

1- General specifications of the welding robot	**35,88%**
1-1. The quality of the welding equipment of the robot.	29,85%
1-2. Quality of the service	22,32%
1-3. Availability of the spare parts	14,42%
1-4. The price of the welding robot.	18,86%
1-5. General image of the welding robot brand	14,55%
2- Technical specification of the welding robot	**46,25%**
2-1. The weight of the welding gun	20,64%
2-2. The power of the transformer	41,36%
2-3. The range of the robotic weld arm	38,00%
3- Specifications of the supplier	**17,87%**
3-1. Financials of the supplier	15,72%
3-2. Product portfolio of the supplier	31,46%
3-2.1. Current product portfolio of the supplier	76,94%
3-2.2. Target product portfolio of the supplier	23,06%
3-3. Machine park of the supplier (for the current welding robots)	28,64%
3-4. The current chilling (cooling) system of the supplier (water or air cooling)	24,18%

With the help of this table, we can also evaluate the welding robot brands.

6. CONCLUSIONS AND RECOMMENDATIONS

The major aim of this thesis is to create a model for the selection of the production line using a multi-attribute decision making method. This study is done to evaluate press-lines' performance and to find the most appropriate one between some press-line brands. The performance criteria for evaluating press-line brands in the portfolio were obtained through the field study and the most appropriate products for the portfolio were determined with respect to these performance criteria.

Based on the literature review for this study AHP is the most suitable method for the machine selection problems. With the help of this literature review an expert survey is prepared with in-depth interview with the suppliers. This expert survey has three main criteria to reach the study's goal: the first main criterion is "general specifications of the press lines", the second main criterion is "technical specification of the press lines" and the third main criterion is "specification of the supplier". Based on this study, technical specifications of the press lines is more important than the other ones.

The press-line brands Schuler, Fagor and Komatsu have the best three scores according to our expert survey results. These three brands have the best scores for all three main criteria also. This shows that the suppliers prefer brands which can supply the best products for the needs of the automotive suppliers. Only the cheap one or the one having best service is not enough for the sheet metal suppliers.

When each press-line brand's situation is checked with respect to each performance criterion, the brand's strong and weak features could be revealed. One of the main contributions of this study is to enable to see brands' weak features and focus on improvements for the future success.

After this study about press-line selection an expert survey about welding robot selection is prepared as a further study too. During our literature review we investigated that such studies are not present till today. Although there are many studies with AHP for many kinds of machine selections; there is not any one with an expert survey. Our study is mostly based on the expectations and experiences of the suppliers. The suppliers are doing such decisions and studies everyday but they do it as a way of their daily works. This study helps us to understand what they think when do their decisions about the press-lines. This study is a beginning to combine the know-how and the experience of the suppliers and the AHP as a decision method. It is also possible to use Fuzzy AHP for further studies. Fuzzy AHP can help us to obtain the results with a different range than the AHP. The comparison of these two methods can give an idea to the supplier for their selections.

The study includes also some limitations. All survey results depend on suppliers' opinions although they are the chosen and best supliers of Turkish automotive industry. So the findings might be different if other suppliers were integrated in the study. The study could not be generalized for all automotive industry; its findings reflect the situation only for the selected suppliers.

As further studies, new criterion for the press-line selection for the automotive industry may be investigated with their subcriteria. Also, the relationship between suppliers' opinions and current brands' situations may be investigated.

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Url-3<http://www.eib.or/projects/press/2006/2006-070-turkey-car-industry-in-perpetual-motion.htm> accessed at February 2012 (The EU Bank, 2006)

Url-4<http://businessneweurope.eu/story1527/Car_industry_turns_into_a Turkey> accessed at February 2012 (Bussinessneweurope, 2009)

Url-5<http://www.osd.org.tr/tskb.pdf> accessed at February 2012 (OSD, 2009)

Url-6<http://oica.net/wp-content/uploads/2007/06/worldprod_country-revised.pdf> accessed at February 2012 (OICA, 2006)

Url7<http://www.ulasimonline.com/news_details.php?id=8052&uniq_id=1246562801> accessed at February 2012 (Ulasimonline, 2009)

Url-8<http: //www.superdecisions.com>, February 2012

APPENDICES

APPENDIX A.1. : LITERATURE REVIEW (published at BALCOR 2011)

APPENDIX A.2. : EXPERT SURVEY

APPENDIX A.3. : MATERIAL SPECIFICATIONS AND OPERATION CHARTS OF THE SIMPLE PART

APPENDIX A.4. : EXPERT SURVEY

APPENDIX A.1.

AHP Applications on Machine Selection Problems

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Abstract

This study has concerned the works on application of AHP to the Machine Selection Problems. AHP is the most common method for the Machine Selection Problems. AHP method is also one of the well-known MCDM methods, because the AHP consists of a systematic approach based on breaking the decision problem into a hierarchy of interrelated elements. The evaluation of selection attributes is done using a scaling system showing that each criterion is related with another. This scaling process is then converted to priority values to compare alternatives. It is a very useful tool to define the problem structure. The main advantages of AHP are the relative ease in handling multiple criteria and the fact that it can effectively handle both qualitative and quantitative data. The selection process of a machine has been a critical issue for companies throughout years, because the improper selection of a machine might cause various problems having a negative effect on productivity, precision, flexibility and the company's responsive manufacturing capabilities. It also causes the waste of time, investment and labor. In this study it is aimed to classify and compare AHP applications on the Machine Selection Problems. It is believed that it will help researchers on this area to find out which topics are more popular to study and to where they are applied as there is no such an overview in literature.

KEYWORDS

AHP, Machine Selection.

1. INTRODUCTION

Making decisions is a part of our daily lives. The major concern is that almost all decision problems have multiple, usually conflicting criteria. Research on how to solve such problems has been enormous. Methodologies (AHP, TOPSIS, PROMETHEE etc.), as well as their applications, appear in professional journals of different disciplines. Several authors have prepared literature reviews about applications (Alias et.al., 2008, Mansouri et.al., 2000).

The Analytic Hierarchy Process (AHP) method is one of the well-known Multi Criteria Decision Making (MCDM) methods, because the AHP consists of a systematic approach based on breaking the decision problem into a hierarchy of interrelated elements. The evaluation of selection attributes is done using a scaling system showing that each criterion is related with another. This scaling process is then converted to priority values to compare alternatives. It is a very useful tool to define the problem structure. The main advantages of AHP are the relative ease in handling multiple criteria and the fact that it can effectively handle both qualitative and quantitative data.

AHP, developed by Saaty (1980), has been studied extensively and used in almost all the applications related with decision making in the last 30 years. The wide applicability is due to its simplicity, ease of use, and great flexibility. It can be integrated with other techniques, for instance, mathematical programming in order to consider not only both qualitative and quantitative factors, but also some real-world resource limitations. This approach, regarded as the integrated AHP, can definitely make a more realistic and promising decision than the stand-alone AHP. More focus, therefore, has been confined to the integrated AHPs recently. Ho (2008) prepared a literature review about integrated analytic hierarchy process and its applications.

AHP is also the most common method for the machine selection problems. This study has concerned only the works on application of AHP to these problems. In this study, studies found in open literature are classified and compared. It is believed that it will help researchers on this area to figure out which topics have already been studied and which topics should be studied as further.

2. MACHINE SELECTION

Machine selection problem is a problem where you choose one of the alternatives having best attributes considering comparison criteria. The studies on machine selection problems are broadly classified into six categories: (1) Product Design (2) Manufacturing Process (3) Flexible Manufacturing System (4) Machine Tool (5) Material Handling System and (6) Robotic.

Product design: Most common attributes are material, shape, size, appearance, delivery and most common criteria are time, cost, quality.

Manufacturing Process: Most common attributes are material, weight, surface roughness, production rate, lead time and most common criteria are quality, cost.

Flexible Manufacturing System: Most common attributes are total costs involved, floor space requirement, quality of results, ease of use, competitiveness, expandability and most common criteria are cost, productivity.

Machine Tool: Most common attributes are spindle speed, power, cutting feed, rotary table, number of tools, repeatability, dimension accuracy, shape accuracy and most common criteria are cost, performance.

Material Handling System: Most common attributes are speed, load capacity, accuracy, efficiency, repeatability, flexibility, load diversity, technological risk, spare part supply and most common criteria are performance, technical aspect, cost, strategic aspect.

Robotic: Most common attributes are velocity, repeatability, accuracy, load capacity and most common criteria are performance, cost and quality.

3. AHP APPLICATIONS

AHP has been adopted in education, engineering, government, industry, management, manufacturing, personal, political, social, and sports (Ho, 2008). More areas to study can be found in literature but decisions on selecting machine and equipment used in facilities are critical to companies due to the fact that an improperly selected machine can have a negative effect on the overall performance of the company. Thus, this topic is concerned in this study. 60 studies are found in literature.

All studies mentioned above are summarized in the following table. First column in table represents the authors of the articles/proceedings. Second column represents the publication year. Third column represents the MCDM technique(s) used in the study. Last column represents the objective of the problem. Repeated phrases in table are abbreviated as follows to adjust the text layout:

SIDP: To improve the design process
SAMT: To select best advanced manufacturing technology
SCIM: To select best computer integrated manufacturing system
SCP: To select best casting process
SEC: To select best equipment for construction
SFMS: To select best flexible manufacturing system
SLH: To select best loading-hauling system
SMC: To select best machining center
SMHD: To select best material handling device
SMT: To select best machine tool
SNM: To select best nontraditional machining
SPDA: To select the best product design alternative
SR: To select best robot
SRTP: To select best rapid tooling process
SSME: To select ship main engine
SWSM: To select best wafer slicing machine

Table 1. Studies on machine selection using AHP

Authors	Year	Hybrid	Task
Park	1996	No	SMHD
Goh	1997	No	SR

Table 1. Studies on machine selection using AHP (continued)

Authors	Year	Hybrid	Task

Herişçakar	1999	SMART	SSME
Akarte et.al.	2000	No	SCP
Chan et.al.	2000	No	SFMS
Lee et.al.	2001	Fuzzy	SPDA
Braglia et.al.	2001	No	SMHD
Chan et.al.	2001	No	SMHD
Tiwari et.al.	2001	No	SCP
Monitto et.al.	2002	Fuzzy	SCIM
Chan	2002	No	SMHD
Su et.al.	2003	No	SIDP
Bozdağ et.al.	2003	Fuzzy	SCIM
Shamsuzzaman et.al.	2003	Fuzzy	SFMS
Başçetin	2003	No	SLH
Yurdakul et.al.	2003	TOPSIS	SNM
Febransyah et.al.	2004	Fuzzy	SPDA
Manassero et.al.	2004	No	SPDA
Yurdakul	2004	No	SCIM
Abdi et.al.	2004	No	SFMS
Yurdakul	2004	ANP	SMT
Bhattacharya et al.	2005	QFD	SR
Kapoor & Tak	2005	Fuzzy	SR
Yang et.al.	2005	No	SAMT
Shapira et.al.	2005	No	SEC
Rao	2005	TOPSIS	SFMS
Chen et.al.	2005	No	SMT
Hanumaiah et.al.	2006	QFD	SRTP
Gao et. al.	2006	Fuzzy	SMT
Ayağ et.al.	2006	Fuzzy	SMT
Vijayaram	2006	No	SMHD
Chakraborty et.al.	2006	No	SMHD
Chang et. al.	2007	No	SWSM
Ayağ	2007	No	SMT
Yurdakul et.al.	2007	No	SMT
Çimren et.al.	2007	No	SMT
Al-Ahmari	2008	Fuzzy	SAMT
Chang et. al.	2008	Fuzzy	SWSM
Rao	2008	TOPSIS	SFMS
Rao et.al.	2008	No	SFMS
Önüt et. al.	2008	Fuzzy, TOPSIS	SMC
Yurdakul et.al.	2008	Fuzzy, TOPSIS	SMT
Yurdakul et.al.	2008	Fuzzy, TOPSIS	SMC
Duran et.al.	2008	Fuzzy	SAMT
Dağdeviren	2008	PROMETHEE	SMT
Sun et. al.	2008	Grey relation	SMT
Abraham et. al.	2008	Fuzzy, QFD	SR
Anand et.al.	2008	Fuzzy	SR
Iç et.al.	2009	Fuzzy	SMC
Guan et.al.	2009	No	SMT
Zhou et.al.	2010	Fuzzy	SRTP
Lokesh et. al.	2010	No	SRTP
Macias et.al.	2010		SAMT
Maniya et.al.	2010	No	SPDA
Yanwei et.al.	2010	Fuzzy	SAMT
Tuzkaya et.al.	2010	Fuzzy, PROMETHEE	SMHD
Tsai et.al.	2010	No	SMT
Wang et.al.	2010	Fuzzy	SMC
Qi	2010	Fuzzy	SMT
Ayağ et.al.	2011	Fuzzy	SMT

4. OBSERVATIONS

This study has focused on machine selection problems. The results have given a clear idea that AHP has particularly applied to the selection of machines (approximately 2/3 of problems) related with manufacturing. Figure 1 shows the number of related literature in which it could be noticed that machine tool selection is the most popular.

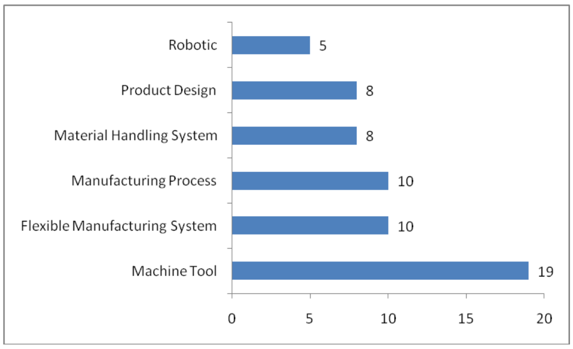

Figure 1: Number of articles on related topics.

When reviewing the relevant literature, it becomes evident that only limited attention has been devoted on machine selection problems. However, it became much popular nowadays and many studies have been carried out particularly, in the last three years (approximately 1/3 of all publications related to machine selection). Figure 2 shows the number of publications. We found one publication in 2011 because the studies have not published thoroughly yet in this year.

Another important fact that first study applied AHP to machine selection problem is published 16 years later than AHP has introduced.

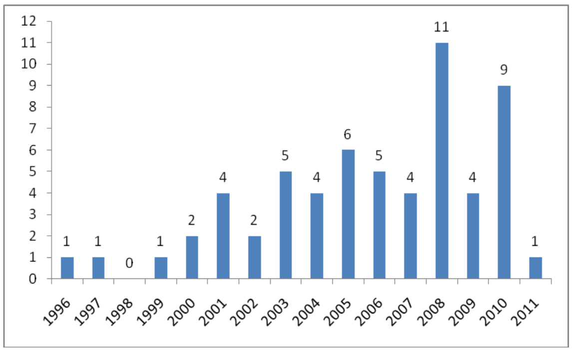

Figure 2: Frequency of publications.

The results suggest that more than half of the studies have employed AHP technique standalone. Secondly, fuzzy AHP has been widely used. The rest of the studies have been carried out by using integrated AHP techniques/comparing with other MCDM techniques. Figure 3 shows the number of articles as percentage considering techniques used in studies. Table 1 shows the number of studies described as “Others” in Figure 3, in detail.

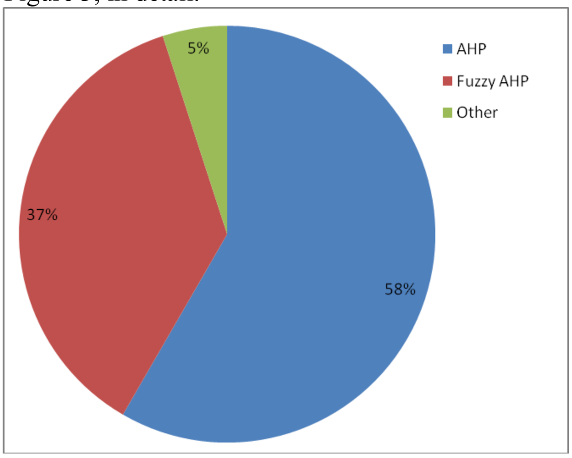

Figure 3: Percentage of the studies using different techniques.

Table 1: MCDM techniques used in the studies.

Approaches	Number of Articles
AHP, PROMETHEE	1
AHP, TOPSIS	2
AHP, Fuzzy AHP	1
Fuzzy AHP	15
Fuzzy AHP, Fuzzy TOPSIS	6

5. CONCLUSIONS

This study has examined literature on AHP application to machine selection problem in which revealed that AHP application to machine selection problem has increased in recent years. Also, integrating fuzzy logic with AHP has gained popularity. On the other hand, only two MCDM techniques (TOPSIS and PROMETHEE) have been applied/compared with AHP. It is recommended to the researchers to use other MCDM techniques (VIKOR, ELECTRE etc.) with AHP.

Considering AHP application area, it is noticed that AHP applications to machine selection problems can be classified into six categories (product design, manufacturing process, material handling system, machine tool, flexible manufacturing system and robotic). Future studies should be conducted on application to other areas in which machine selection is vital.

This study is a preliminary work. It is planned to implement AHP to machines selection problem in automotive industry. Press lines and welding robots are the main elements of the automotive industrial production. As a further study, we will select the most suitable press line and welding robot for a sample automotive part by using AHP.

ACKNOWLEDGEMENT

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APPENDIX A.2.

EXPERT SURVEY

The attached survey is prepared to obtain data for a graduate thesis at Marmara University Mechanical Engineering Program.

IMPORTANT NOTE:

For the accuracy and reliability of the data, please firstly read carefully the given information on filling the survey questionnaire and then answer the questions.

Thanks in advance for your kindness and assistance.

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We would like you to answer all the questions for in the attached questionnaire. The information about how you answer the questions is given under the title of “evaluation method”.

The aim of this study is to select the press lines via multi criteria decision making techniques. There are three main criteria to reach the study’s goal: the first main criterion is “general specifications of the press lines”, the second main criterion is “technical specification of the press lines” and the third main criterion is “specification of the supplier”. Also each main criterion is composed of criteria, each criterion may be composed of sub-criteria as seen below in the list.

TO FIND THE MOST APPROPRIATE PRESS LINE IN THE PORTFOLIO

1- General specifications of the press line
1-1. Capacity of the press line
1-2. Price of the press line
1-3. Quality of the service
1-4. Dimensions of the press line
1-5. Production year
1-6. General image of the press line brand

2- Technical specification of the press line
2-1. Efficiency of the press line
2-1.1. Main engine power
2-1.2. Working pressure
2-1.3. Press stroke number per minute
2-1.4. Tool dimensions and weight
2-2. Plate specifications
2-2.1. Lower plate specifications
2-2.2. Upper plate specifications
2-3. Bolster specifications
2-3.1. Lower bolster specifications
2-3.2. Upper bolster specifications

3- Specifications of the supplier
3-1. Financials of the supplier
3-2. Product portfolio of the supplier
3-2.1. Current product portfolio of the supplier
3-2.2. Target product portfolio of the supplier
3-3. Machine park of the supplier

THE EXPLANATION OF THE CRITERIA

To reach this study's goal, three main performance criteria are revealed during in-depth interviews with Turkey's biggest automotive sheet metal suppliers in order to evaluate press line brands in the portfolio.

1- General specifications of the press line: The first main performance criterion is "General specifications of the press line". General specifications of the press line consist of six criteria as stated below.

Criteria of General specifications of the press line

1-1. Capacity of the press line
1-2. Price of the press line
1-3. Quality of the service
1-4. Dimensions of the press line
1-5. Production year
1-6. General image of the press line brand

2- Technical specifications of the press line: The second main performance criterion of this study is "Technical specifications of the press line". Technical specifications of the press line consists of three criteria as stated below.
All three criteria also have their sub-criteria as seen below.

Criteria of Technical specifications of the press line

2-1. Efficiency of the press line
2-1.1. Main engine power
2-1.2. Working pressure
2-1.3. Press stroke number per minute
2-1.4. Tool dimensions and weight

2-2. Plate specifications
2-2.1. Lower plate specifications
2-2.2. Upper plate specifications

2-3. Bolster specifications
2-3.1. Lower bolster specifications
2-3.2. Upper bolster specifications

3-Specifications of the supplier: The third main performance criterion of this study is "Specifications of the supplier". Specifications of the supplier consist of three criteria as stated below. Only "Product portfolio of the supplier" criterion has sub-criteria as seen below

3-1. Financials of the supplier
3-2. Product portfolio of the supplier
3-2.1 Current product portfolio of the supplier
3-2.2 Target product portfolio of the supplier
3-3. Machine park of the supplier

THE EVALUATION METHOD OF THE SURVEY

In answering the survey questionnaire, we would like you to compare the relative importance of the sub factors given as pairs with respect to the factor indicated. Please put an “X” in the suitable box of a number in the 1-9 scale.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

9 7 5 3 1 Importance of elements are equal. Decision maker is indifferent between elements.

9 7 5 3 1 First element is moderately more important than second one. First element is moderately preferred to second one.

9 7 5 3 1 First element is strongly more important than second one. First element is strongly preferred to second one.

9 7 5 3 1 First element is very strongly more important than second one. First element is very strongly preferred to second one.

9 7 5 3 1 First element is extremely more important than second one. First element is extremely preferred to second one.

Example Question 1: Compare the relative importance of the given criteria pairs with respect to “general specifications of the press line” main criterion using the following scale. Please put “X” on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Capacity of the press line	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Price of the press line

Example Evaluation 1 : If you think that, with respect to “general specifications of the press line”, “Capacity of the press line” and “Price of the press line” are equally important, then please put an “X” to number 1.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Capacity of the press line	9	8	7	6	5	4	3	2	**X**	2	3	4	5	6	7	8	9	Price of the press line

Example Evaluation 2 : If you think that, with respect to “general specifications of the press line”, “Capacity of the press line” is very strongly more important than “Price of the press line”, then please put an “X” to number 7 close to “Capacity of the press line”.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Capacity of the press line	9	8	**X**	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Price of the press line

Example Evaluation 3 : If you think that, with respect to “general specifications of the press line”, “Price of the press line” is moderately to strongly more important than “Capacity of the press line”, then please put an “X” to number 4 close to “Price of the press line”.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Capacity of the press line	9	8	7	6	5	4	3	2	1	2	3	**X**	5	6	7	8	9	Price of the press line

SURVEY QUESTIONNARE

Question 1: Compare the relative importance of the given criteria pairs with respect "to find the most appropriate criteria on selecting of press line" using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

General spec.of the pressline	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Technical spec.of the pressline
Technical spec.of the press line	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Specifications of the supplier
Specifications of the supplier	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	General spec.of the press line

Question 2: Compare the relative importance of the given criteria pairs with respect to "general specifications of the press line" main criterion using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Capacity of the press line	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Price of the press line
Price of the press line	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Quality of the service
Quality of the service	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Dimensions of the press line
Dimensions of the press line	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Production year
Production year	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	General image of the press line brand
General image of the pressline brand	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Capacityofthe pressline

Question 3: Compare the relative importance of the given criteria pairs with respect to "technical specifications of the press line" main criterion using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Efficiency of the press line	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Plate specifications
Plate specifications	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Bolster specifications
Bolster specifications	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Efficiency of the press line

Question 4: Compare the relative importance of the given sub criteria pairs with respect to "efficiency of the press line" criterion using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Main engine power	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Working pressure
Working pressure	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Press stroke number per minute
Press stroke number per minute	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Tool dimensions and weight
Tool dimensions and weight	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Main engine power

Question 5: Compare the relative importance of the given sub criteria pairs with respect to "plate specifications" criterion using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Lower plate specifications	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Upper plate specifications

Question 6: Compare the relative importance of the given sub criteria pairs with respect to "bolster specifications" criterion using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Lower bolster specifications	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Upper bolster specifications

Question 7: Compare the relative importance of the given criteria pairs with respect to "specifications of the supplier" main criterion using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Financials of the supplier	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Product portfolio of the supplier

Product portfolio of the supplier	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Machine park of the supplier
Machine park of the supplier	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Financials of the supplier

Question 8: Compare the relative importance of the given sub criteria pairs with respect to "product portfolio of the supplier" criterion using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Current product portfolio of the supplier	98765432123456789	Target product portfolio of the supplier

Question 9: Please rate the given products with respect to each "general specifications of the press-line" factors.

BRANDS \ CRITERIA	Capacity of the press line	Price of the press line	Quality of the service	Dimensions of the press line	Production year	General image of the press line brand
Schuler						
Fagor						
SMC						
SMG						
Komatsu						
Benelli						
Mossini						
Dirinler(From Local Market)						
Ales Pres(From Local Market)						

Question 10: Please rate the given products with respect to each "technical specifications of the press line" factors.

CRITERIA / BRANDS	Main engine power	Working pressure	Press stroke number per minute	Tool dimensions and weight	Lower plate specifications	Upper plate specifications	Lower bolster specifications	Upper bolster specifications
Schuler								
Fagor								
SMC								
SMG								
Komatsu								
Benelli								
Mossini								
Dirinler(From Local Market)								
Ales Pres(From Local Market)								

Question 11: Please rate the given products with respect to each "specifications of the supplier" factors.

CRITERIA / BRANDS	Financials of the supplier	Current product portfolio of the supplier	Target product portfolio of the supplier	Machine park of the supplier
Schuler				
Fagor				
SMC				
SMG				
Komatsu				
Benelli				
Mossini				
Dirinler(From Local Market)				
Ales Pres(From Local Market)				

APPENDIX A.3.

MATERIAL SPECIFICATIONS AND OPERATION CHARTS OF THE SAMPLE PART

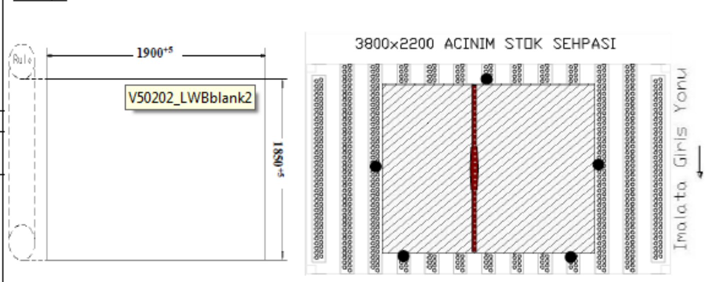
MALZEME SPESİFİKASYONLARI

Otosan Kodu	:
Rulo/Paket Boyutları	: 0.9x1850R
Kalınlık Toleransı	: +0.06
Malzeme Spek No	: WSS-M1A341-A4
Malzeme Grade	: BH 210
Kaplama Spek No	: WSS-M1P94-A
Kaplama Tipi	: 60G60G HD
Yüzey Kalitesi	: Class 2
Standart Spek No	:
Kesme Makinası	: U1/U2 (Açınım hattı)
Açınım Kalıbı No	:
Pres No	:
Tabaka Ağırlığı (kg)	:
Band Ağırlığı (kg)	: 26,08
Tabaka veya Bandan Çıkan Parça Sayısı:	1
Brüt Parça Ağırlığı (kg)	: 26,08
Net Parça Ağırlığı (kg)	:
Sacın Temin Kaynağı	:
Artık Sac Kullanımı	:

Model Kullanımı (Adet/Ünite)

H1	H2	H3	H4	H5	H6	H7	H8					

SKEÇ :

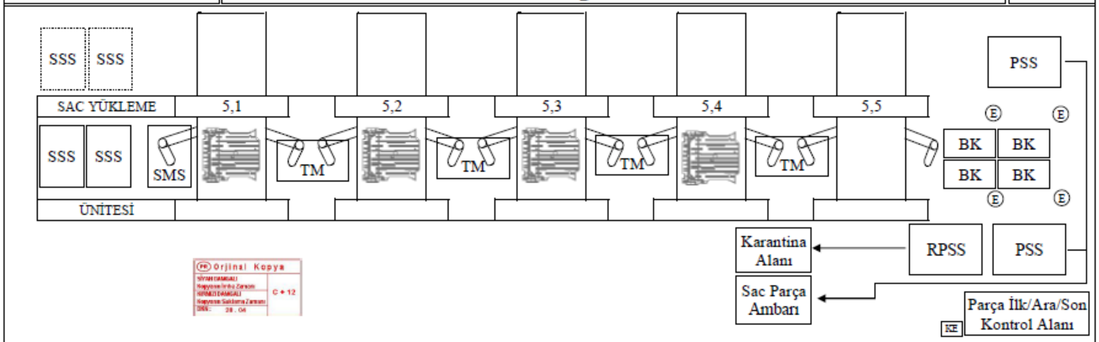


NOT: * Çember atılacak

Program No:	47
Kalıp Stroğu(mm):	900
Adım (mm):	1900
İstif Şekli:	Tek 1/1
Çapak Sand. Ağırlık Ayarı(kg):	-

Revizyon Tarihi: 28.01.2008
Revizyon No: 08/01
Parça Adı :
ARKA TABAN PANELİ SWB

HAT YERLEŞTİRME FORMU



Op. No.	Kalıp No.	Operasyon Adı	Pres No	Yük. IRB-	Boş. IRB-	KALIP OTOMASYONU Y	K	PS	ÇDK	AKY				
											Y	Yastık	BK	Band Konveyör
											K	Kaldırıcı	TM	Transfer Mekiği
10	062.203	Çekme	5,1	51Y	51B	Alt	X	X			PS	Parça Sensörü	DK	Demir Kol
20	063.203	Kesme & Delme	5,2	52Y	52B	Üst	X	X	X		ÇDK	Çapak Düşürme Kanalı	ÇS	Çapak Sandığı
30	066.204	Kamlı Delme	5,3	53Y	53B	Üst	X	X	X		AKY	Alt Kalıp Yüksekliği	SMS	Sac Merkezleme Sehpası
40	064.203	Flanş Bükme & Ütüleme	5,4	54Y	54B	Üst	X	X			ETC	Elle Ters Çevir	R	Robot
											SSS	Sac Stok Sehpası	RTC	Robotla/Mekikle Ters Çevir
											PSS	Parça Stok Sehpası	Ⓔ	Eleman
											RPSS	Red Parça Stok Sehpası	ⓎⒺ	Yağlama Elemeanı
											ÇF	Çevirme Fikstürü	KE	Kontrol Elemanı

			Set Bağlama		Ok. Alma		Hazırlayan :	Tarih : 16.04.2000	
Adet	Saat	Eleman	Süre	Eleman	Süre	Eleman	Parça Adı :	Parça No :	Line :
									5

OPERASYON AÇIKLAMA SAYFASI

Operasyon Adı : **Çekme**

Kalıp No : **3TKH0-062.203**

Açıklama :

* Alt yastık kuvveti min. 350 ton olarak ayarlanarak, öndeki derin bölgenin çekmesi alt yastık kullanılarak yapılacak.

* Derin bölgenin çekmesi bitince alt yastık kuvveti 90 tona düşürülerek kaburgaların çekmesi yapılacaktır.

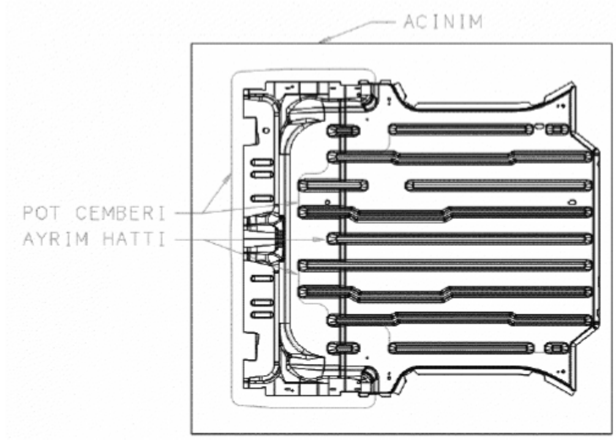
* Ön tarafta gas basıncı ile yapılan çekmede, gas basınç değerleri 130 barda tutulacaktır.

* Flanşlar kesme için geliştirilecek.

* Derinlik zımbası konulacak.

* Konumlama en/boy dayama ile yapılacak.

OPERASYON SKECI :



Parça Konumu :

Çevirme Noktası: Açı:

X = 4250

Y = 0

Z = 300

Hazırlayan :	**Kalıbı Tasarlayan :**	**Geliştiren :**

Parça Adı :	**Parça No :**	**Oper. No :**
		10

OPERASYON AÇIKLAMA SAYFASI

Sayfa No :

Operasyon Adı : **Kesme & Delme**

Kalıp No : **3TKH0-063.203**

Açıklama :

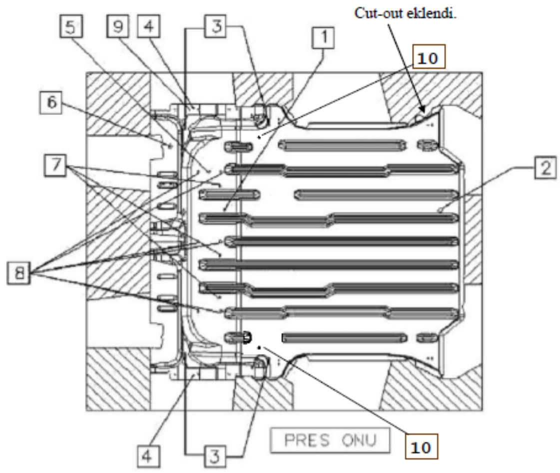
* Çevrede bölgesel kesme yapılacak.

* Delme:

1) 1 adet Ø$19.0^{+0.2}$ mm.lik delik,
2) 1 adet $19.0^{+0.2}\times32.0^{\pm0.4}$ mm.lik slot,
3) 4 adet Ø$6.5^{\pm0.1}$ mm. Lik delik (sadece kombilerde).
4) 2 adet Ø$14.0^{\pm0.1}$ mm. Lik delik .
5) 1 adet $12^{+0.2}\times16^{\pm0.4}$ mm.lik slot delinecektir.(sadece kombilerde)
6) 1 adet Ø$25.0^{\pm1.0}$ mm. Lik delik delinecektir.
7) 3 adet Ø$14.0^{\pm0.1}$ mm. Lik delik (sadece kombilerde). .
8) 6 adet Ø$16.0^{\pm0.1}$ mm. Lik delik (sadece kombilerde). .
9) 1 adet Ø$6.5^{\pm0.1}$ mm.lik delik sağ tarafa delinecektir.
10) 2 adet Ø$6.5^{\pm0.1}$ mm. Lik delik (sadece vanlarda).

* Konumlama parça formundan yapılacak.

OPERASYON SKECI :



Parça Konumu :

Çevirme Noktası: Açı:

X = 4250

Y = 0

Z = 300

Hazırlayan :	**Kalıbı Tasarlayan :**	**Geliştiren :**

Parça Adı :	**Parça No :**	**Oper. No :**

	OPERASYON AÇIKLAMA SAYFASI	Sayfa No :

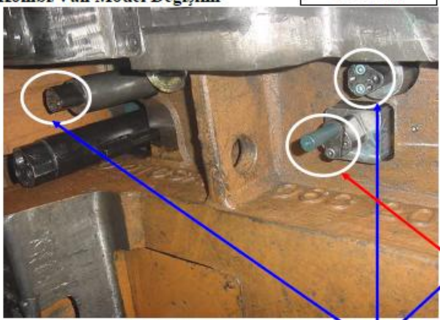
Kalıp Detay Fotoğrafları:

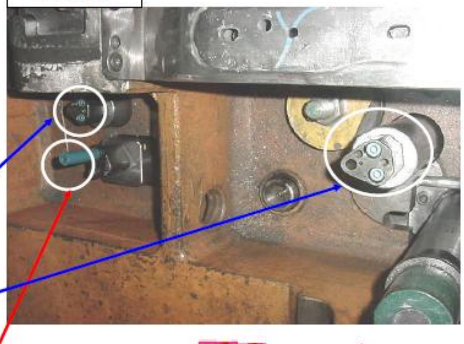
Kombi/Van Model Değişimi

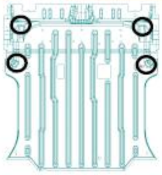
SOL YAN

Koç yüksekliği değerleri:
Van: 1103,2
Kombi:1097,5

SAĞ YAN

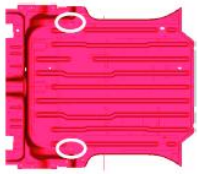






Sadece kombi modeli için 4 adet sağ + sol ön yan Ø6.5 mm lik delik delinecek, Van modelinde shutheight (strok) ayarı ile delinmeyecek.

Sadece van modeli için 2 adet sağ yan ve sol yan Ø6.5 mm lik zımba takılacak, kombi modelinde sökülecek

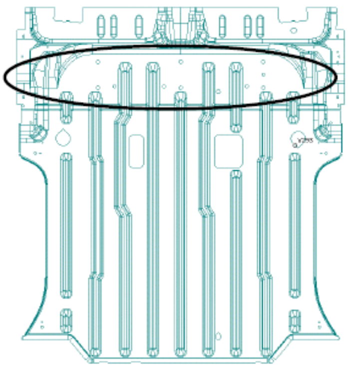


20	063. 203	Kesme& Delme	5.2	Hazırlayan :	
				Parça Adı :	Parça No :
Op. No.	3TKHO- Kalıp No.	Operasyon Adı	Pres No	ARKA TABAN PANELİ (SWB)	

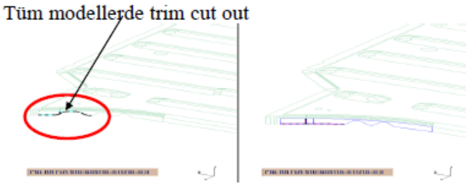
	OPERASYON AÇIKLAMA SAYFASI	Sayfa No :

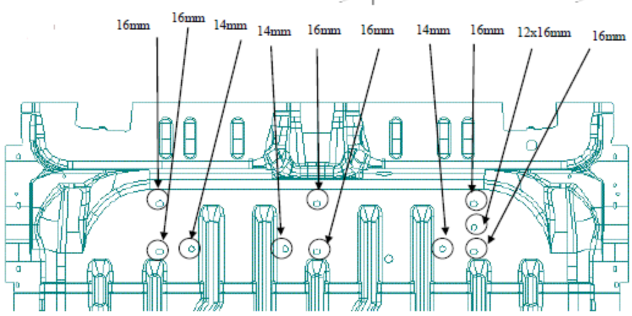
Space Car Modeli

Koç yüksekliği değerleri:
Van: 1103,2
Kombi:1097,5
Kombi Plus:1097,5



Tüm modellerde trim cut out





20	063. 203	Kesme& Delme	42	Hazırlayan :	
				Parça Adı :	Parça No :
Op. No.	3TKHO- Kalıp No.	Operasyon Adı	Pres No	ARKA TABAN PANELİ (SWB)	

	OPERASYON AÇIKLAMA SAYFASI	Sayfa No :

Operasyon Adı : **Delme & Kesme**

Kalıp No : **3TKH0-066.204**

Açıklama

- Delme:
  1; 3)4 adet Ø$12.0^{\pm0.5}$ mm.lik delik, (em. kemeri/tie down)
  2; 4)4 adet Ø$7.0^{\pm0.5}$ mm.lik delik, (antirotasyon)

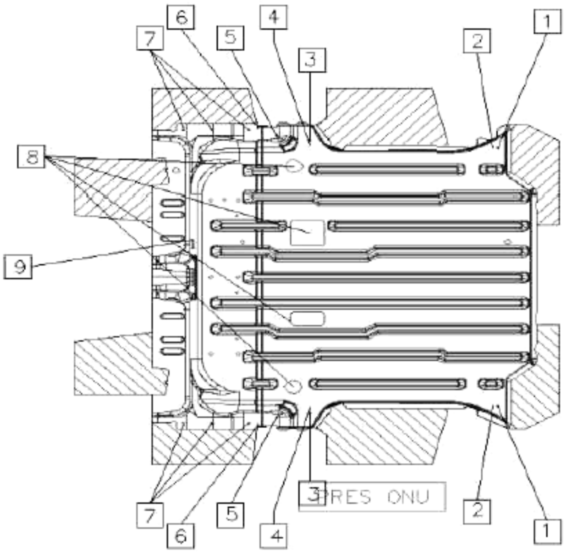
- 5) 2 adet Ø$12.0^{+2.0}$ mm.lik delik, (boya drenaj)
  6) 2 adet Ø$12.0^{\pm0.5}$ mm.lik delik,
  7) 4 adet $7.2^{+0.2}\times14.2^{\pm0.4}$ mm.lik slot delinecektir.

- 8) 4 adet şekilli boşaltma, (Yalnızca Kombilerde - yani 5T16-K11218-DB)

  9) 1 adet Ø$40.0^{+2.0}$ mm.lik kamlı delik.

- Yalnızca Van ve yalnızca Kombilerde bulunan delikler farklı kalıplarda (op.20 ve op.30'da) delinerek shutheight ayarı ile ayarlanabilir.
- Çevresel kesme tamamlanacak.
- Konumlama MC deliklerindem yapılacak.

OPERASYON SKECI :

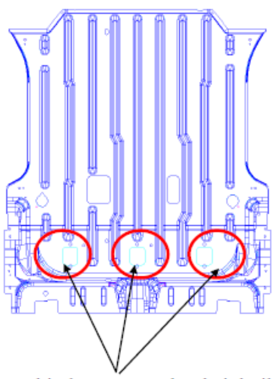


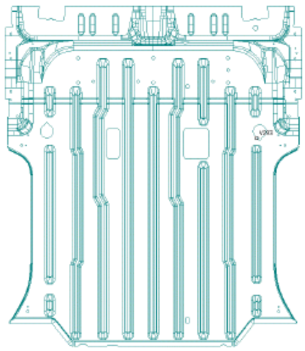
Parça Konumu : Çevirme Noktası: Açı: X = 4250 Y = 0 Z = 300	**Hazırlayan :**	**Kalıbı Tasarlayan :**	**Geliştiren :**
	Parça Adı :	**Parça No :**	**Oper. No :** 30

	OPERASYON AÇIKLAMA SAYFASI	Sayfa No :

Kalıp Detay Fotoğrafları:
Space Car/Kombi/Van Model Değişimi

Koç yüksekliği değerleri:
Van: 1103
Kombi:1095,5
Kombi Plus:1099





Kombi plus 1098,5 shut height ile boşaltmalar iptal olacak(3 adet)

30	066. 204	Kesme& Delme	53	Hazırlayan :	
				Parça Adı : ARKA TABAN PANELİ (SWB)	Parça No :
Op. No.	3TKHO- Kalıp No.	Operasyon Adı	Pres No		

OPERASYON AÇIKLAMA SAYFASI

Sayfa No :

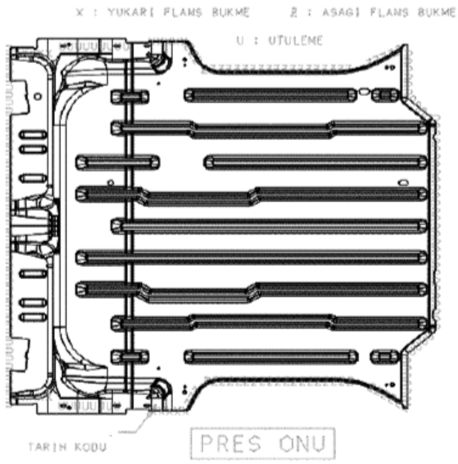
Operasyon Adı : **Flanş Bükme & Form**

Kalıp No : **3TKH0-064.203**

Açıklama

- Gösterilen bölgelerde flanşlar aşağı ve yukarı bükülecek.
- Panelin yan tarafındaki flanşa son form verilecek.
- Birleşme yüzeyleri ütülenecek.
- Konumlama MC deliklerindem yapılacak.

OPERASYON SKECI :



Parça Konumu :

Çevirme Noktası: Açı:

X = 4250
Y = 0
Z = 300

Hazırlayan :	**Kalıbı Tasarlayan :**	**Geliştiren :**
Parça Adı :	**Parça No :**	**Oper. No :** 40

APPENDIX A.4.

EXPERT SURVEY

The attached survey is prepared to obtain data for a graduate thesis at Marmara University Mechanical Engineering Program.

IMPORTANT NOTE:

For the accuracy and reliability of the data, please firstly read carefully the given information on filling the survey questionnaire and then answer the questions.

Thanks in advance for your kindness and assistance.

Güçlü Uçak
Marmara Faculty of Engineering
Mechanical Engineering M.Sc.
e-mail: gucak@ford.com.tr

Aykut Kentli
Marmara Faculty of Engineering
Mechanical Engineering
e-mail: akentli@marmara.edu.tr

We would like you to answer all the questions for in the attached questionnaire. The information about how you answer the questions is given under the title of “evaluation method”.

The aim of this study is to select the welding robots via multi criteria decision making techniques. There are three main criteria to reach the study’s goal: the first main criterion is “general specifications of the welding robots”, the second main criterion is “technical specification of the welding robots” and the third main criterion is “specification of the supplier”. Also each main criterion is composed of criteria, each criterion may be composed of sub-criteria as seen below in the list.

TO FIND THE MOST APPROPRIATE WELDING ROBOT IN THE PORTFOLIO

1- General specifications of the welding robot
    1-1. The quality of the welding equipment of the robot.
    1-2. Quality of the service
    1-3. Availability of the spare parts
    1-4. The price of the welding robot.
    1-5. General image of the welding robot brand

2- Technical specification of the welding robot
    2-1. The weight of the welding gun
    2-2. The power of the transformer
    2-3. The range of the robotic weld arm

3- Specifications of the supplier
    3-1. Financials of the supplier
    3-2. Product portfolio of the supplier
        3-2.1. Current product portfolio of the supplier
        3-2.2. Target product portfolio of the supplier
    3-3. Machine park of the supplier (for the current welding robots)
    3-4. The current chilling (cooling) system of the supplier (water or air cooling)

THE EXPLANATION OF THE CRITERIA

To reach this study's goal, three main performance criteria are revealed during in-depth interviews with Turkey's biggest automotive sheet metal suppliers in order to evaluate welding robot brands in the portfolio.

1- General specifications of the welding robot: The first main performance criterion is "General specifications of the welding robot". General specifications of the welding robot consist of five criteria as stated below.

<u>Criteria of General specifications of the welding robot</u>

1-1. The quality of the welding equipment of the robot.
1-2. Quality of the service
1-3. Availability of the spare parts
1-4. The price of the welding robot
1-5. General image of the welding robot brand

2- Technical specifications of the welding robot: The second main performance criterion of this study is "Technical specifications of the welding robot". Technical specifications of the welding robot consist of three criteria as stated below.

<u>Criteria of Technical specifications of the welding robot</u>

2-1. The weight of the welding gun
2-2. The power of the transformer
2-3. The range of the robotic weld arm

3-Specifications of the supplier: The third main performance criterion of this study is "Specifications of the supplier". Specifications of the supplier consist of four criteria as stated below. Only "Product portfolio of the supplier" criterion has sub-criteria as seen below

3-1. Financials of the supplier
3-2. Product portfolio of the supplier
3-2.1. Current product portfolio of the supplier
3-2.2. Target product portfolio of the supplier
3-3. Machine park of the supplier (for the current welding robots)
3-4. The current chilling (cooling) system of the supplier (water or air cooling)

THE EVALUATION METHOD OF THE SURVEY

In answering the survey questionnaire, we would like you to compare the relative importance of the sub factors given as pairs with respect to the factor indicated. Please put an "X" in the suitable box of a number in the 1-9 scale.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

9 7 5 3 1 Importance of elements are equal. Decision maker is indifferent between elements.

9 7 5 3 1 First element is moderately more important than second one. First element is moderately preferred to second one.

9 7 5 3 1 First element is strongly more important than second one. First element is strongly preferred to second one.

9 7 5 3 1 First element is very strongly more important than second one. First element is very strongly preferred to second one.

9 7 5 3 1 First element is extremely more important than second one. First element is extremely preferred to second one.

Example Question 1: Compare the relative importance of the given criteria pairs with respect to "general specifications of the press line" main criterion using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Capacity of the press line	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Price of the press line

Example Evaluation 1 : If you think that, with respect to "general specifications of the press line", "Capacity of the press line" and "Price of the press line" are equally important, then please put an "X" to number 1.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Capacity of the press line	9	8	7	6	5	4	3	2	**X**	2	3	4	5	6	7	8	9	Price of the press line

Example Evaluation 2 : If you think that, with respect to "general specifications of the press line", "Capacity of the press line" is very strongly more important than "Price of the press line", then please put an "X" to number 7 close to "Capacity of the press line".

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Capacity of the press line	9	8	**X**	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Price of the press line

Example Evaluation 3 : If you think that, with respect to "general specifications of the press line", "Price of the press line" is moderately to strongly more important than "Capacity of the press line", then please put an "X" to number 4 close to "Price of the press line".

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Capacity of the press line	9	8	7	6	5	4	3	2	1	2	3	**X**	5	6	7	8	9	Price of the press line

SURVEY QUESTIONNARE

Question 1: Compare the relative importance of the given criteria pairs with respect "to find the most appropriate criteria on selecting of welding robot" using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

General spec. of the weld.robot 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Technical spec. of the weld.robot
Technical spec. of the weld.robot 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Specifications of the supplier
Specifications of the supplier 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 General spec. of the weld.robot

Question 2: Compare the relative importance of the given criteria pairs with respect to "general specifications of the welding robot" main criterion using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

The quality of the weld.eq.of the robot 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Quality of the service
Quality of the service 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Availability of the spare parts
Availability of the spare parts 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 The price of the welding robot
The price of the weld.robot 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 General image of the weld.robot brand
Gen.image of theweld.robot brand 9 8 7 6 5 4 3 212 3 4 5 6 789 The quality of theweld.eq.of the robot

Question 3: Compare the relative importance of the given criteria pairs with respect to "technical specifications of the welding robot" main criterion using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

The weight of the welding gun 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 The power of the transformer
The power of the transformer 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 The range of the robotic weld arm
The range of the robotic weld arm 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 The weight of the welding gun

Question 4: Compare the relative importance of the given criteria pairs with respect to "specifications of the supplier" main criterion using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Financials of the supplier 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Product portfolio of the supplier
Product portfolio of the supplier 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Machine park of the supplier
Machine park of the sup. 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 The current chilling system of the sup.
The current chilling system of the supp.9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Financials of the supp.

Question 5: Compare the relative importance of the given sub criteria pairs with respect to "product portfolio of the supplier" criterion using the following scale. Please put "X" on the number of your choice.

1=Equal 3=Moderately 5=Strongly 7=Very Strongly 9=Extremely

Current product portfolio of the supp.98765 4 3 2 1 2 3 4 5 6 789 Target product portfolio of the supp.

CURRICULUM VITAE

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