# ASSEMBLY LINE BALANCING AND AN IMPLEMENTATION IN COOLER INDUSTRY

by

Şebnem Sevim

September 2010

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# ASSEMBLY LINE BALANCING AND AN IMPLEMENTATION IN COOLER INDUSTRY

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## ABSTRACT

The philosophy of production without waste is the fundamental belief behind lean manufacturing and that should be adopted strongly by the shop floor worker. One of the waste elimination methods is assembly line balancing for lean manufacturing. The assembly line balancing is to assign tasks to the workstations by minimizing the number and time of the workstations to the required values. There should be no workstation with excessively high or low workload, and all workstations must ideally work with balanced workloads. Accordingly, in this study, the axiomatic design method has been applied for assembly line balancing in order to achieve maximum output with the installed capacity. In order to achieve this target, all improvement opportunities have been defined and utilized as an output of the study.

**Keywords**: Lean manufacturing, Axiomatic design, Assembly line balancing.

# MONTAJ HATTI DENGELEME VE SOĞUTMA ENDÜSTRİSİNDE BİR UYGULAMASI

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## ÖZ

Bir ürünü israf olmadan üretmenin felsefesi yalın üretimin arkasındaki temel inançtır ve bu genellikle güçlü bir şekilde üretim çalışanları tarafından benimsenmelidir. Yalın üretim için israf azaltma metotlarından biri de montaj hattı dengelemedir. Montaj hattı dengeleme operasyonları istasyonlara gereken değerlere göre istasyon sayısını ve süresini minimize edecek şekilde atamaktır. Burada hiçbir istasyon aşırı şekilde düşük veya yüksek işyüküne sahip olmamalıdır, tüm istasyonlar dengelenmiş işyüküyle ideal durumda çalışmalıdır. Dolayısıyla bu çalışmada kurulu kapasite ile maksimum çıktıyı alabilmek için axiomatic design metodu montaj hattı dengelemeye uygulanmıştır. Bu hedefi başarmak amacıyla tüm iyileştirme fırsatları değerlendirilip çalışmanın bir çıktısı olarak faydalanılmıştır.

**Anahtar Kelimeler**: Yalın üretim, Aksiyomlarla tasarım, Montaj hattı dengeleme.

**To my family**

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# LIST OF SYMBOLS AND ABBREVIATIONS

**SYMBOL/ ABBREVIATION**

| | |
|---|---|
| AD | : Axiomatic Design |
| DP | : Design Parameter |
| FR | : Functional Requirement |
| SMED | : Single Minute Exchange of Die |
| NEPA | : North East Productivity Alliance |
| WIP | : Work in Process |
| Cs | : Constraints |
| DPs | : Design Parameters |
| FRs | : Functional Requirements |
| [A] | : Matrix that Specify Design |
| Aij | : Relationship between $(i)^{th}$ element of FR vector and $(j)^{th}$ element of DP vector. |
| $p_s$(FRi) | : Probability Density Function |
| Ii | : Information access probability |
| $p_i$ | : Success probability of functional requirement |

# CHAPTER 1

# INTRODUCTION

The change and success achieved by mass production as pioneered in the early 20$^{th}$ Century by Henry Ford had later made its first examples in Japan in the second half of the same century. Lean manufacturing began to spread from the United States of America to Europe towards the end of the 20$^{th}$ Century. However, in the present century of rising international competition and globalization, the key factor is to promote competitiveness. Change and success achieved through lean manufacturing enable revolutionary changes even in multinational companies, thus making the concept of lean manufacturing all the more important.

Now, customer demands are the most important drivers for manufacturers. Customers want to have high-quality, low-cost products. They also want to have products on time and in full. Hence, manufacturing companies need to have enhanced production abilities. They should respond to continuous, variable and unpredictable demands from customers. In the fiercely competitive market, manufacturers need to use flexible, adaptive, active and responsive strategies that meet customer demands at low cost and in short time. One of the strategies is lean manufacturing. The lean manufacturing technique enables manufacturers to eliminate all waste in their operations (Baykasoğlu, 2004).

Lean manufacturing includes many implementations to eliminate waste such as kanban, smed, kaizen, value stream mapping, 5S and visual management. Assembly line balancing is one of the implementation of lean manufacturing that helps reduce overproduction, over stock, motion, handling, scrap, and operators' idle time.

In our study, we applied assembly line balancing by using axiomatic design approach to reduce waste of one product in a cooler manufacturing plant. Supporting subjects of our study such as lean manufacturing, axiomatic design method and assembly line balancing are discussed in Chapter 2. Chapter 3 presents the application method of AD. Chapter 4 presents the details of the implementation, the subject company where the line balancing was implemented, particulars of our application assembly line, how we used axiomatic design and which improvements we achieved through the assembly line balancing. In Chapter 5, we analyze and compare the results obtained, presenting various charts and tables of the line comparing the balanced and imbalanced situations.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 LEAN MANUFACTURING

Lean manufacturing is a production system that first emerged at the Toyota car manufacturing plant in Japan, then spread successfully to other Japanese plants as well as to other firms worldwide. The name of this concept is the Toyota production system. The Toyota production system, discovered by Taichi Ohno and Shingo in Japan, constitutes the basis of lean manufacturing. This system focuses on minimizing waste in all operations. It employs some tools like kaizen, 5S, Poka-yoke etc. to effect improvements (Pavnaskar S.J, 2010).

The Toyota production system imported some parts of the Ford production system by sifting, and combined them with their brilliant ideas. They also used their earlier experiments with other industries. Thus, the Toyota Production System was discovered by genius automobile amateurs (Holweg, 2006).

Here, if we attempt to explain the meaning of lean, to be lean means to get rid of everything that is not really needed. Lean manufacturing is defined as the production system which minimizes such problems as faults, costs, stock, workmanship faults, development process losses, manufacturing space, waste, and customer dissatisfaction (Akçagün, 2001).

In order to explain why it is called lean manufacturing, we should note that lean manufacturing is "lean" and, compared to mass production, it uses even fewer resources. Furthermore, it requires even less than half of the stocks needed on site; the number of defective products goes down; it utilizes half of the labor force, half of the production field, half of the time required for the design of products and it produces even more and in ever-increasing diversity.

Labor-craft intensive production is combined with the advantages of mass production in lean manufacturing; thus high costs of the former as well as the rigidity of the latter are avoided. The main strategy of lean manufacturing is to improve quality, cost, and delivery performance while reducing the flow time. Lean manufacturing distinguishes activities that transform or shape materials or knowledge for customer needs and create added value from those activities that use up time and resources but fail to add value onto the products as required by customer needs or create added value at all.

The idea of quality behind lean manufacturing is to fully meet the expectations which the customer hopes exist in particular goods or services and which the customer needs for use when purchasing such goods or services.

Lean manufacturing merges all activities of all involved parties from the top manager to the shop floor employees and related industry actors as a whole to achieve the targets driven by the product market. It requires that further professional abilities should be learnt and implemented within a team atmosphere in a creative way rather than a rigid hierarchy. The primary aim is to spread the responsibility towards persons at the lower levels of the organization. Diversely trained worker teams are employed at each level of the production, and automated machines of high flexibility are used. On the other hand, responsibility is pushed down to the lowest levels of the organizational structure of the company. This responsibility also entails the freedom of employees to control their own work.

In brief, lean manufacturing is the result of the quest of how to realize the cheapest as well as defect-free production with the lowest consumption of resources, with the soonest time in a way which will correspond one-to-one to customer demands without waste or with minimum waste and by utilizing all the production factors in the most flexible way and by fully utilizing its potentials (Baraçlı, 2004).

### 2.1.1 Historical Development of Lean Manufacturing

If we look at the historical development of business and management, first, we see the works produced by human power. Men initially took advantage of the nature to subsist, then invented land tilling (agriculture) to produce food; later when men produced surplus, they started to exchange (barter) products which eventually led to certain product diversity. Finally, upon the invention of money currency, the economy of exchange by money replaced the barter economy.

The agrarian society came into being when human communities were organized around tillable lands to raise food crops using simple implements manufactured at small workshops to improve land tilling.

Agrarian societies evolved into industrial societies through inventions to make life easier and rapidly expanding education leading to mechanized industries in agriculture and almost all aspects of human life. Large factories were erected, and production boosted in the so called industrialization process.

With fast pace production technologies, industrial societies evolved into information societies and knowledge-based economies. Efforts were intensified to produce and implement further information technologies. Such concepts as efficiency, competition, speed, quality emerged. Efficiency entailed best use of materials, labor and all other resources that were to be supported by computerized systems.

Firms, as organizations relying on information technologies, and employees, as agents of organizations, engaged in competition in the market place. In this wave of new technologies and information, firms that wanted to survive relinquished their habits to take up postures that focused on customers, being open to change, getting lean, cooperating with own employees and serving human beings.

Changes in the production systems from the agrarian societies to date almost took place due to failures or shortcomings of existing systems. Most changes were results of technological innovations and associated restructuring. Further, international competition was also as critical to the change as technological innovations.

Today, while manufacturers all over the world try to adopt lean manufacturing, but this proceeds rather slowly. Companies skilled in this art were first concentrated in Japan. While lean manufacturing was deploying to the North America and West Europe under their protection, commercial wars and increased resistance to the foreign capital followed such spread. Intensive efforts have been made over the world to transform to lean manufacturing in the industries since the 1980s. (Womack, Jones and Roos, 1990).

### 2.1.2 Principles of Lean Manufacturing

Lean manufacturing has most effective tools and methods in order to improve supply chain processes (purchasing, production, shipping and customer relations).

Employees of all levels build and guarantee “their own future” by the “Lean Manufacturing System” through the loop of creating added value, setting up the system to create added value and understanding the system.

To give some details on component breakdown: 80% of the lean manufacturing system is waste elimination, 15% is the production system, and the remaining 5% is Kanban. From this point of view, it could be said that it is a philosophy rather a production system. Tools used for the implementation of the lean manufacturing system include lean strategies, lean management rules, continuous organization, intensive training and Kaizen, team work, free dress code, company shirts, choosing the best ones versus the worst ones, profit sharing among stakeholders, different wage scales, visual control, employee satisfaction surveys, communication management, reward systems, proposal system, involvement of white-collar in production, forming company values, making conditions of dismissal as well as employment difficult and transparency and honesty at anytime and anywhere (Shingo, 1989).

Lean thinking leads also one way to do a satisfying job by providing an immediate feedback towards the efforts of transforming waste into value. Lean manufacturing in a sense represents a new age with regard to production systems. The system proposes a prominent, different production model and the work force features their creative characteristics in a free environment in contrast to the mass production in the lean manufacturing system (Womack, 2003).

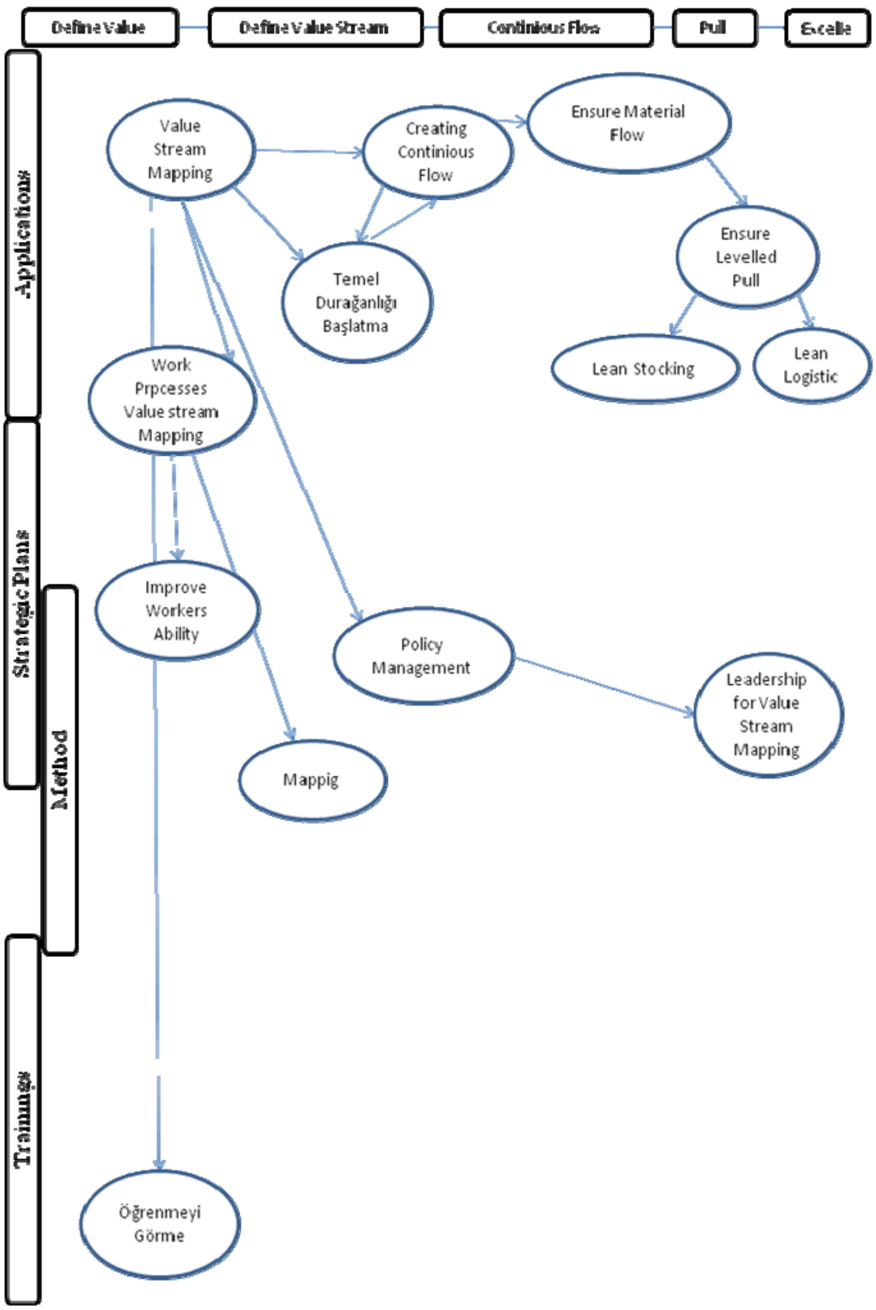



**Figure** 2.1 Lean road map

#### 2.1.2.1 Value

The critical starting point of lean thinking is value, and value can only be defined by the final customer. Producers who create value cannot usually define value properly (Shingo, 1988). To provide a meaningful definition of value, customer requirements should be expressed in a specific product type (goods, services or frequently composition of the two) corresponding to a specific price at a specific time. Value is created by the producer. From the standpoint of the customer, this is the reason of existence of the producers. However, a number of reasons hinder the customers from defining value properly (Womack, 2003).

After defining the product, the most important task in defining value is to identify a target cost based on the quantity of resources and labor required when all visible waste in the process is eliminated in order to manufacture the product having the pre-determined specifications and capabilities. This stage will play a critical role in preventing waste (Akçagün, 2006).

#### 2.1.2.2 Value Flow

Value flow indicates all the specific steps to be taken required for a particular product (goods, services or frequently composition of the two) to be subjected to three critical management function in the enterprise: the problem-solving function including the process starting from the conceptual dimension, from the detailed design and engineering studies to the commencement of production; the information management function starting from receiving orders, including detailed scheduling studies as well as making the delivery and physical transformation function reaching from the raw-material to the customer including the transformation of the finished product. The next stage of the lean thinking is to be defined by the totality of the value flow for each product (or for each product group in some cases) (Womack, 2003).

Another principle of the lean thinking is to arrange the value adding stages as a consecutive flow after eliminating all the waste in the value flow; this is also a stage with significant potential for savings. By means of the value flow analysis, losses on the flow route are identified by the method of mapping value flow routes in order to eliminate losses. The following processes need to be considered at this stage:

* Process development stage (design, production…)

* Information management process (order, planning…)

* Physical transformation process (raw-material, product…)

When value flows are examined, it is seen that activities that do not create value most of the time and resources. Eliminating such losses will bring radical improvements for time and cost dimensions (Çağlar, 2006).

**2.1.2.3 Continuous Flow**

When the value flow is defined, then the next stage of the lean thinking in the lean management, which prepares a value flow map for a specific product and eliminates stages that lead to losses on the flow, could be commenced; hence, the remaining one is enabling the value-creating stages to remain in the flow (Womack and Jones, 2007).

It was Henry Ford and his partners who first saw the potential in the flow principle. The effort required to manufacture T-model cars in 1913 was reduced by about 90% by implementing a continuous flow at the final assembly line. However, this approach was limited by special conditions because the sustained manufacture in quite large quantities of the same model for nineteen years could only be possible under the market conditions of the time. In today's manufacturing environment of small lots where demand is only for tens or hundreds of a product, as opposed to millions , it is required to implement the continuous flow for all product types and adapt it to the fluctuations in customer demand. Serious boosts in productivity as well as quality could be obtained at the enterprises that managed it (Akçagün, 2006).

Instead of forcing the products that customers do not ask for, enabling the customer to draw the product when he so wants demand will eliminate many sources of waste. When the continuous flow is applied, product development, order taking, physical production procedures shall become accomplishable on short notice. Since this enables the customer to design the things that s/he really desires at the time that suits his/her will and provides the opportunity to plan as well as to generate, it will become possible to forecast sales, use sophisticated planning software, eliminate the need to launch campaigns to liquidate stocks, and allow focusing on better production of the things demanded. To this end, focus will be placed on the flowing product, and all impediments introduced by job descriptions, procedures, instructions, functions and departments will be eliminated. Establishing specific work systems will prevent formation of losses on flow routes (halt, return, scrap etc.) (Rother and Shook, 1999).

**2.1.2.4 Pull**

The "pull" principle of the lean thinking implies the drawing of value from its source by the customer. By its simple, definition, "pull" implies that without the demand of the customer at the next stages, no product or service shall be produced at the previous stages. However, the implementation of this rule in practice is accomplished in a complicated way. The best way to understand the logic behind the pull thinking (and in a sense the difficulty) is to start the work with the demand intended by the customer on a specific product and examine all the stages backwards until the product to be reached by the customer (Kemal, 2004).

When pull is applied, there is no need for the stocks; scraps and waste caused by undesirable production are prevented; there is no need to do any scheduling for each bench; occurrence of demand fluctuations prior to the process is prevented; it is possible to manufacture all products in any combination; and it is further possible to comply with changes in demand instantaneously. Demand becomes stable since customers are sure that their expectations will be met on time; and since there is no need to organize campaigns for disposing of the products piled in stocks. The significance of the pull system increases when it is applied to the value flow between companies. When organizations begin to define value properly; when they question each step in the entire value flow; when they ensure the continuous flow of the product through value driving stages and when they enable customers to draw value from the enterprise, then they begin to see that there is no lower limit with regard to time, cost and failures. No matter how the improvement activity is repeated, employees will find new ways to reduce losses each time. The final principle of the lean thinking expresses that excellence is not a dream (Akçagün, 2006).

**2.1.2.5 Excellence**

The notion of excellence in lean manufacturing implies that there are indefinite opportunities for the development of the utilization of each type of assets. Reducing losses systematically will reduce operating costs of the enterprise and ensure the highest customer satisfaction at the lowest price.

When organizations begin to define value properly and identify the value flow thoroughly, ensure continuous flow of the stages contributing to value at product base and enable the customers to draw value from the enterprise, then strange things start to happen. When this point is achieved, then employees begin to see that there is no end to the processes of approximating the products to the real needs of customers on one hand and workloads, time, costs and reducing failures on the other. Since the first four principles of the lean thinking integrate through a cycle, the flow rate of value increases and thus waste remains hidden at value flow is sure to come out. If you pull more strongly, obstacles before the flow become apparent and then eliminated (Womack and Jones, 1996).When the lean approach is applied, radical improvements will be observed concerning all the parameters such as labor force efficiency, timing of the accomplishment of the work, stocks, defective product that the customers have together with waste ratio, duration of presenting the product to the market; product range could be increased by minor additional costs and those could be achieved in a few years time with negative capital investment by selling some existing equipment without the need for new technological investments. Experience of the companies that implement lean manufacturing demonstrate 90% reduction in production flow duration, 100% increase at productivity, 80% decrease in stocks, quadruple acceleration at product development duration and 30% increase in capacity. Savings ratios that could be achieved by lean manufacturing are demonstrated in Figure 2.2 (Rother and Shook, 1999).

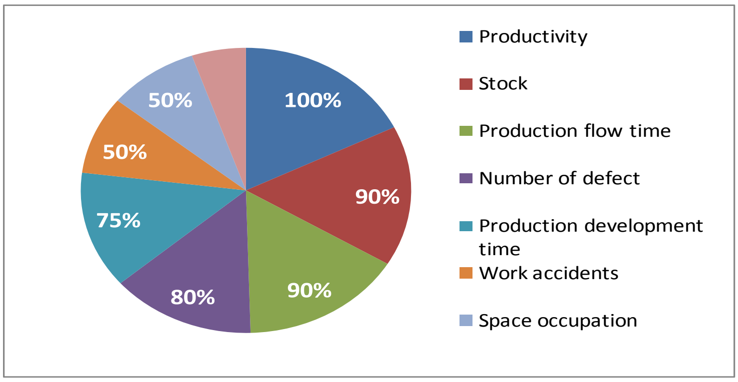



**Figure 2.2** Savings achieved through lean manufacturing

### 2.1.3 General Features of Lean Manufacturing

Lean manufacturing decisively targets “perfection”. Targets such as continuously reducing costs, production with zero-defect (poka-yoke), just-in-time production and infinite product range are the sub-targets of the “perfection” target. Lean manufacturers are consistently in search of perfection to achieve this target.

The key principles of lean manufacturing approach to this end are (Cesur, 1997);

- Designing and manufacturing products in accordance with customers demands,
- Determining product groups according to changing demand fluctuations and manufacturing basis,
- Building good relationships with suppliers to deliver the product on time.

Success factors that characterize lean manufacturing (Akçagün, 2001) are;

- Project manager,
- Team work,
- Information culture,
- Integration with suppliers,
- Concurrent engineering and
- Consumer orientation.

Project manager, team work and supplier integration distinguish lean manufacturing concept from Tayloristic production (Karlson and Ahlstrom, 1996).

Underlying these six success factors is the Total Quality Control, which aims to develop quality together with the system implemented all over the personnel and companies. Therefore, lean manufacturing achieves its goal by manufacturing the quality product right at the first time flawlessly.. Figure 2.3 shows success factors of lean manufacturing.

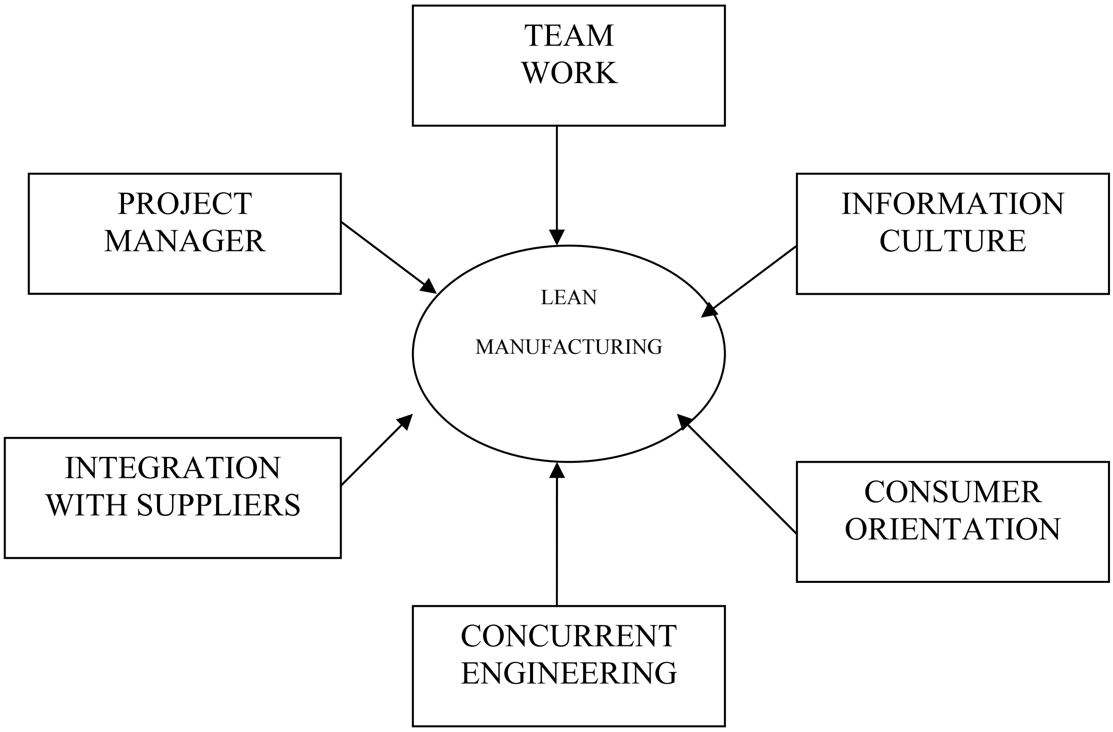



**Figure 2.3** Success factors of lean manufacturing

The critical starting point of the lean thinking is value. However, it is quite difficult to define value which can only be defined by the customer. There are two factors that help the customer to perceive as well as explain value. The first is quality and the other is price. Customers consider the minimum-maximum relationship between price and value which imply that they desire the price at minimum whereas quality at maximum. They decide accordingly on the value of the product or the service and thus they could define them. Furthermore, in order to make the definition of value meaningful, customer needs must be expressed as a specific product time at a definite time. Lean manufacturing provides a satisfactory job by providing immediate feedback on the efforts to transform waste into value. Further, it gives guidance on making the work more efficient instead of obliterating the existing works as suggested by reengineering.

Lean is a tool to present value to the customer because of providing flow of value without waste. The Lean Enterprise Research Center (Lerc, 2004) obtained the following results for value for most production operations: %5 of activities add value, %35 of activities are necessary non-value activities, %60 add no value et all. (Melton, 2005). If we define customer needs, we can distinguish process steps as value adding and non-value adding. Non-value adding activities are called waste. Here, in order to eliminate waste, value and waste should be defined, information management be improved and continuous improvement be applied by the participation of managerial employees. The lean leaders must demonstrate the financial, cultural and organizational benefits of continuous improvements by examples. So, that concept will be learned by them. (Melton, 2005).

By using lean manufacturing tools and techniques, you reduce waste, waiting times, inventories, and improve productivity. They sometimes directly contribute to better quality (Joosten, 2009).

Lean manufacturing isn't a singular concept, and it cannot be equated solely with waste elimination or continuous improvement. Lean manufacturing highlights mechanisms needed to achieve the central objective of waste elimination (Rachna, 2007).

Here we may refer to a paper which is about lean manufacturing practices and a transfer of innovations, demonstrates the increase in value through lean manufacturing. The said transfer of innovations involved NEPA (firms that implemented lean manufacturing in Northeast England, North East Productivity Alliance) processes being applied to 15 companies, and engineers were trained by a rotation among companies. The North East Productivity Alliance (NEPA) has improved the performance of manufacturing companies through the transfer of knowledge from the Japanese automotive industry. At the end of the research they showed the NEPA programme enabled companies to significantly improve their performance and competitiveness so their savings increased too. (Herron and Hicks, 2008).

In short, if we consider the system by lean thinking, it demonstrates ways to define value, classify the steps that constitute value in a best and truest form and ensure carrying out those steps without fail and realize them through efficiency as well as efficacy. Hence, it is lean because it produces with minimum labor, energy, equipment and space in shorter time gets closer to actual desires of the customers. If we consider them in a different standpoint, we could classify the factors that lead to success as follows (Alkan, 2003).

**Participation of the Management / Employee**

- Visionary leadership and spirited persons,
- “New Culture” objectives and thinking,
- Long-term strategic plan and orientation,
- Employee participation and human resource development,
- Integrative, sacred goals,
- Measurement against target / rewarding,
- Organizational systems that are product and customer oriented,
- Good communication systems and practices,
- Promotion / research and training support

**Quality**

- Customer oriented product development and marketing,
- Product development / cross functional groups for production,
- Personal responsibility and continuous quality improvement,
- Statistical process control of key product characteristics,
- Focusing on innovations and experiences,
- Partnership relations with the sellers having quality certificate

**Production Operations**

- Continuous flow process/cellular production,
- Process which is demand-based, not capacity-based,
- Rapid change of the procedures/small lot sizes,
- Emphasis on standardization/simplification before automation,
- Preventive maintenance programmes/maintenance programmes that take preventive actions

### 2.1.4 Sources of Waste

When waste in the system is continuously reduced by the implementation of lean thinking and resources are oriented towards creating further value, not only profitability and competitiveness of the companies increase but also customers receive more appropriate, higher quality, cheaper products and services (Genç, 2007).

The lean manufacturing system aims to produce in shorter time than the traditional production system by eliminating waste. Figure 2.4 displays lean manufacturing philosophy that shortens the duration between customer order and product delivery.

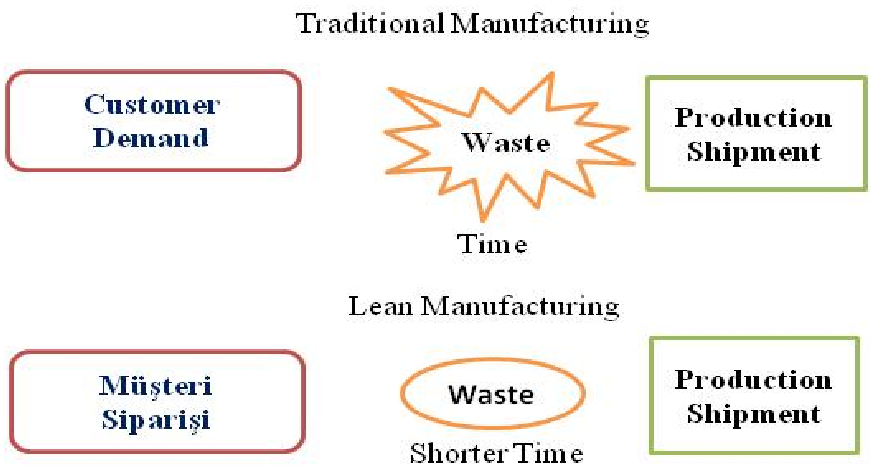



**Figure 2.4** Importance of waste elimination for lean manufacturing

When this chain spreads over all sectors and activity areas, it contributes to the increase of wealth in the society. Product quality is now measured with one in a million defect level and it is usually specified by international arrangements. Those strict quality criteria shall not be met by the control and remedy method. Starting from the design, it is necessary to turn the whole system into one that will produce properly for the first time (Özçelikel, 1994).

Taichi Ohno, the pioneer and developer of lean manufacturing implementations, enumerates seven categories of waste occurring during production as follows:

1. Overproduction
2. Waiting

3. Transportation
4. Extra Processing Steps
5. Inventory
6. Activities that are not oriented to production, unnecessary actions.
7. Defective products and remedial operations (Çetinkaya, 2000).

**2.1.4.1 Over Production**

The most important reason of overproduction is to produce more than the requirements of the next process. Under such circumstances partial stocks are formed at production lines. Those unnecessary stocks formed between production blocks influence the harmony of production and harm the whole system (Emre, 1995).

To meet the product required by the customer or the next production step instantly, instant production is necessary. However, enterprises usually keep some security stocks to necessarily meet the demand by taking likely problems into consideration. Thus, they prevent the production line from stopping. Those are the reasons of waste and when waste starts somewhere, it emerges somehow in each function of the enterprise (Güre, 2006).

**2.1.4.2 Waiting**

The waiting of the machinery and labor force at the production line is defined as waste of time. Therefore, it means lost product and waste. It is difficult to quantify the waiting time since this time is hidden during the production process by the workers. However, the efficient utilization of the machinery and labor force is necessary for the increase of efficiency (Güre, 2006).

**2.1.4.3 Transportation**

It is the activity that does not add any value to the carrying product and it is a significant source of waste. Transportation is accomplished under the circumstances where two or three operations are required over the product or between storage points located different spots. Transportation requires additional labor, storage areas and additional cost. During facility settlement arrangement studies, the amount and repetition of the transportations may be reduced by further approximating the processes.

Making arrangements by transport methods and arranging facility settlement in a way to reduce transportations will eliminate a significant source of waste(Güre, 2006).

#### 2.1.4.4 Extra Processing Steps

The process itself could be considered as a source of waste. By some of the improvements on the process, it is possible to shorten the processing time and increase product quality. Reducing the processing amount is the most important step for the prevention of waste (Güre, 2006).

#### 2.1.4.5 Working with Over Stock (WIP)

The stocks in enterprises are usually used for concealing production problems such as equipment failures, long set-up time, great production volumes and missing coordination between the processes. When the stocks are sufficient, those problems do not occur. However, acting as if there were no problem by means of keeping over stock, increases production costs. Instead of this, it is required to find out the problems by reducing stocks and to tend towards their solution. Acting with lean manufacturing logic by taking the required measures with regard to procurement, production and coordination shall prevent the formation of stock (Güre, 2006).

#### 2.1.4.6 Activities not Oriented to Production

Some of the activities that are not oriented to production but used at the production line and unnecessary actions done are regarded as waste. For example, unnecessary search, walking, arm and hand movements are unnecessary actions that do not add value to the product. Simplifications of the work and method studies are effective methods that may be used to reduce those types of motion waste (Güre, 2006).

#### 2.1.4.7 Defective Products

It is really difficult to calculate the real cost of defective products considered as source of waste. Those costs include scrap, material and labor cost. It is usually more than estimated. The reasons of those costs must be investigated and analyzed. Furthermore, problems such as problems arising at the production system, delays and failure to carry out distribution on time constitute additional costs (Güre, 2006).

### 2.1.5 Comparing Lean Manufacturing with Mass Production

Lean manufacturing is a philosophy. The main characteristic that distinguishes this philosophy from the other classical ones is that instead of overlooking the problems at production environment and removing the adverse effects that have come into being; it encourages continuous efforts to analyze the root cause of the problem. Various problems arise from ambiguity at the production site and this ambiguous effect leads to the disruption of production. The basic fault experienced to date is to obscure the ambiguity by keeping high levels of stocks instead of eliminating sources that lead to ambiguity. Lean manufacturing focuses on eliminating sources of ambiguity.

If we review the history of production systems, it is argued that the new technologies influence production and organization models, and Fordist and Taylorist approaches began to lose their significance. As already known, the Fordist production implies the production based on mass production based on standardization and price competition through the machinery particularly set up for specific products by means of the moving assembly line. The moving assembly line in the Fordist production prominently affects business organization and industrial organization. Accordingly, industries of mass production tended to cover larger and multiple areas and further integrate vertically (an enterprise embodying all functions from the preparation of raw materials to production and marketing stage). Furthermore, the assembly line underlined advanced technical division of labor. Works at the Fordist production were all shaped according to the scientific management approach developed by Taylor. A plan that covers all stages of the production process is based on this model. The work is systematically divided into subcomponents in this plan and those subcomponents are all defined in detail. The activities of workers that are subject to a strict division of labor in the plan were limited in a way that maximizes the efficiency and are calculated in detail by timing. Thus, mass production gave rise to differentiation of the hierarchical structuring (vertical division of labor) on the highest degree that covers functions such as duties and positions (horizontal division of labor) together with planning and control. The division of labor and specialization allow the work to be accomplished by unskilled and semi-skilled labor and thus the dependency on the skilled labor decreased. The moving assembly line in which a steady relationship between the unskilled worker and the machine is established in the Fordist production allow the output to be standardized by coordinating different rhythms and different operations providing technical conditions for mass production. Therefore, enterprises manufacturing on a large scale form the basic units. The detailed division of labor and standardization of produced goods aimed to increase productivity per worker at the Fordist manufacturing. Efforts were made to reinforce the efficiency increase through organizational structuring based on vertical communication and central control. Thereby the decision making was completely removed out of the shop floor and the worker's control on production was eliminated. The idea and implementation of detailed division of labor encompassing simple, repetitive actions by workers and the intention to increase speed and efficiency and reduce the worker's control on the production process eventually made possible that the work could be done by unskilled workers. Although attempts were made later to compensate for the alienation of the worker from the work as a whole and the decision making process by better pay, the decline in workers' motivation could not be prevented.

Implementing the new technologies in the production process gave rise to the flexibility of the production process. Flexible production is the production style of small and medium size enterprises that compete with each other but exchange expertise and production information. In flexible production, product differentiation could be accomplished with general purpose machines by using modular production and it is possible to comply with the changing demands by different products with the same machines. Quality rather than price comes to the forefront in competition.

The traditional Taylorist-Fordist organization model experiences significant changes against such working systems as synchronous engineering, just-in-time production, total quality control, continuous development, team work, integration of the supply chain and cooperation peculiar to lean manufacturing.. Within this framework, new organization models based on creativity and participatory relations were developed. These models where efforts are made to combine flexibility and efficiency involve such arrangements as establishing a horizontal organization, minimizing hierarchical levels, and setting up multi-directional connections between units.

## 2.2 AXIOMATIC DESIGN

The axiomatic design process begins by defining the largest scope goal of the production system and then dividing it into the smaller scope requirements systematically (Cochran, 1999).

Axiomatic design ensures a design principle which makes the process more efficient. We can ensure efficiency by improving the requirements. According to Suh (Suh, 1990), the axiomatic design rules also enable us to check why we followed this way. It also informs us on the other design methods (Werneman, Kielberg and Adman, 2000).

The Axiomatic Design is now visibly applied outside traditional engineering problems. For example, if used for learning organizations, there exist 5 rules here: systems thinking, building a shared vision, personal unknowns, mental models and learning teams. These 5 principles help learning organizations to implement the Axiomatic Design. Indeed, human beings may learn several points at a time. Ultimately, we may argue that the Axiomatic Design rules give human beings and computers the chance to address more difficult problems and reach correct results (Senge, 1990).

Design is an activity based on designer's experiences; the axiomatic design ensures a theoretical base for the experimental actions. AD ensures a framework to designers to see design target, the relation between functional requirements and design parameters and the clarification why to select the design. The design axioms give certain type of information which shows effective estimation methods for the designer (Chen et al, 2001).

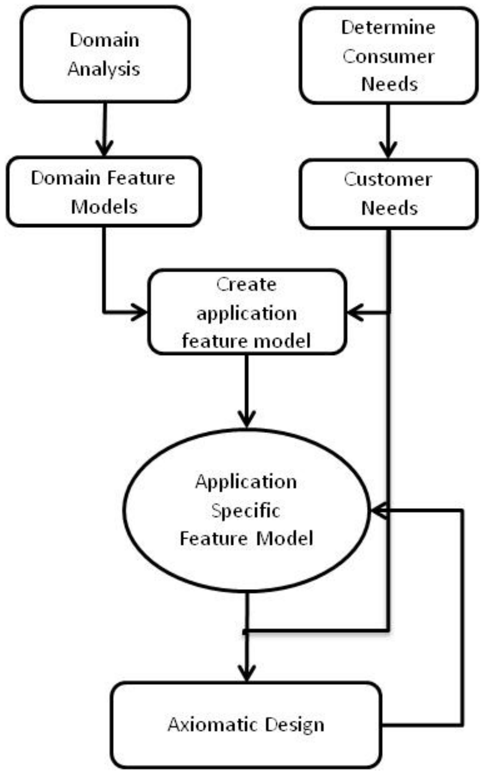



**Figure 2.5** Proposed approach for requirements analysis

### 2.2.1 Axiomatic Design Framework

The underlying hypothesis of axiomatic design is that there exist fundamental principles that govern good design practice. It is a general theory of design, which provides a scientific basis for designers to make design decisions. Axiomatic design theory can be applied recursively throughout the design hierarchy. Design problems are stated; solutions are proposed and analyzed; and decisions are made. The components that distinguish axiomatic design from other design theories are domains, hierarchies, zigzagging, and the two design axioms: independence and information (Martin and Kar, 2002).

#### 2.2.1.1 The Concept of Domains

The axiomatic design can be used to find solutions to design problem, offer a suggestion to the design, make design decisions; it's composed of four domains: customer, functional, physical and process domains (Hou and Wen, 2007). In Figure, the domain on the left relative to the domain on the right represents “what we want to achieve”, whereas the domain on the right represents the design solution of “how we propose to satisfy the requirements specified in the left domain”.

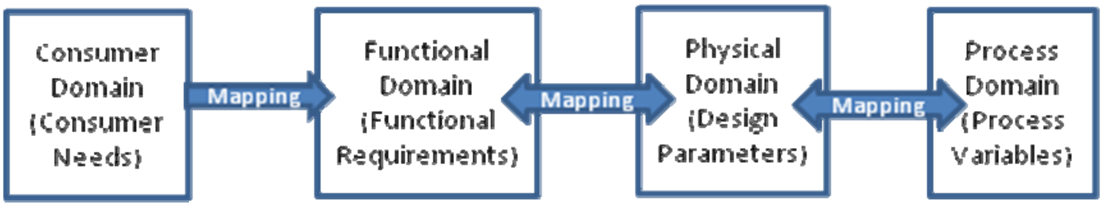



**Figure 2.6** Axiomatic design domains

The definitions of the key expressions in the concept of domains are as follows (Martin and Kar, 2002):

**Functional requirements (FRs):** FRs are a minimum set of independent requirements that completely characterizes the functional needs of the product (or software, organizations, systems, etc.) in the functional domain.

**Constraints (Cs):** Cs are bounds on acceptable solutions. There are two kinds of constraints. Input constraints are imposed as part of the design specifications. System constraints are constraints imposed by the system in which the design solution must function.

**Design parameters (DPs):** DPs are the key physical (or other equivalent terms in the case of other fields) variables in the physical domain that characterize the design that satisfies the specified FRs.

**Process variables (PVs):** PVs are the key variables (or other equivalent terms in the case of other fields) in the process domain that characterizes the process that can generate the specified DPs.

The customer domain is characterized by customer needs (or the attributes) the customer is looking for in a product, process or system. In the functional domain, the customer needs are specified in terms of functional requirements (FRs) and constraints

(Cs). In order to satisfy the specified FRs, we conceive a design described by design parameters (DPs) in the physical domain. Finally, to produce the design product specified in terms of DPs, we develop a process that is characterized by process variables (PVs) in the process domain (Suh, 2001).

#### 2.2.1.2 The Design Axioms

There is a suitable DP for every FR which shows how to achieve the FR. We can use the axiomatic design in designing, evaluating and controlling manufacturing systems. Moreover, axiomatic design can be used to define potential areas for improvements (Cochran, Tapia and Oropeza, 2001).

The primary objective of the design method by axioms is to form a scientific basis for designs and to develop design activities by supporting the designer with rational thinking processes and tools (Suh, 2001). Design approach by axioms ensures a systematic search at the design space with a view to realize this objective. Systematic search process minimizes random search and facilitates to choose the best one among alternative design solutions. The most important concept in design with axioms is the existence of design axioms. The first axiom among those is called as "independence axiom" and the second is "information axiom". Those are (Suh, 1990) ;

**Axiom 1.** *Independence Axiom:* Ensures independence between functional requirements.

**Axiom 2.** *Information Axiom:* Minimizes information content of design.

The relationship between functional requirements and design parameters is mathematically specified below:

**{FR} = [A] {DP}** (2.1)

Here,

**{FR} :** Functional requirements vector,

**{DP} :** Design parameters vector and

**[A] :** Matrix that specify design,

Each Aij at [A] matrix demonstrate the relationship between $(i)^{th}$ element of FR vector and $(j)^{th}$ element of DP vector.

**Axiom 1: Independence Axiom**

The independence axiom defines the independence relation between functional requirements (FRi) and design parameters (DPi). Every FRi must be related with only one DP without effect of other design parameters (DPi) (Durmuşoğlu and Kulak, 2008).

At the equation, {FR} and {DP} is a n*1 column matrix and [A] is a n*n matrix Aij=∂FRi/∂DPj, will describe relation between FR's and DP's. The requirement of the independence axiom design matrix [A] must be "diagonal" and "triangular". So, the relation between FR and DP will have necessary specification to design with the AD method. The type of the design that is taken into consideration is defined by the structure of [A] matrix. The condition that ensures all elements of [A] matrix which are not diagonal as zero assure *discrete* design matrix. It is quite difficult to achieve such design in real life. The condition where [A] matrix is triangular and which implies that the elements above all diagonal elements ensure a *separated* design matrix. It is the design condition that is most encountered in the real world. If [A] matrix does not have a special structure, or in other words, if the condition where there are non-zero elements at the diagonal is in question, then the matrix is called as *coupled* design matrix. To ensure a design to correspond to the independence axiom, [A] matrix should be discrete or separated design (Durmuşoğlu and Kulak, 2008).

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ : \\ : \\ FR_i \end{Bmatrix} \begin{pmatrix} A_{11} & A_{12} \ldots\ldots & A_{1j} \\ A_{21} & A_{22} \ldots\ldots & A_{2j} \\ : & & \\ : & & \\ A_{i1} & A_{i2} \ldots\ldots & A_{ij} \end{pmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ : \\ : \\ DP_i \end{Bmatrix} \quad \text{and} \quad Aij = \partial FR_i / \partial DP_i$$

**Figure 2.7** Relationship between FR and DP **(2.2)**

The elements of the design matrix are defined from the set of equations (Suh, 1990):

$$\Delta FR_1 = \frac{\partial FR_1 * \Delta DP_1}{\partial DP_1} + \ldots + \frac{\partial FR_1 * \Delta DP_n}{\partial DP_n}$$

$$\vdots$$

$$\Delta FR_1 = \frac{\partial FR_n * \Delta DP_1}{\partial DP_1} + \ldots + \frac{\partial FR_n * \Delta DP_n}{\partial DP_n} \qquad (2.3)$$

Three types of the design matrix are given below: coupled design, decoupled design and uncoupled design. Ideal is the uncoupled design matrix (only one DP controls every FR). But, in reality most designs are not uncoupled. The decoupled design is usually adequate and in any situation, a coupled design should be kept away as much as possible (Thielman and GE, 2006).

$$\begin{pmatrix} FR11 \\ FR12 \\ FR13 \\ FR14 \end{pmatrix} = \begin{pmatrix} X & 0 & 0 & X \\ X & X & 0 & X \\ 0 & X & X & X \\ 0 & X & X & X \end{pmatrix} \begin{pmatrix} DP11 \\ DP12 \\ DP13 \\ DP14 \end{pmatrix} \qquad \begin{pmatrix} FR11 \\ FR12 \\ FR13 \\ FR14 \end{pmatrix} = \begin{pmatrix} X & 0 & 0 & 0 \\ X & X & 0 & 0 \\ 0 & X & X & 0 \\ 0 & 0 & X & X \end{pmatrix} \begin{pmatrix} DP11 \\ DP12 \\ DP13 \\ DP14 \end{pmatrix} \qquad \begin{pmatrix} FR11 \\ FR12 \\ FR13 \\ FR14 \end{pmatrix} = \begin{pmatrix} X & 0 & 0 & 0 \\ 0 & X & 0 & 0 \\ 0 & 0 & X & 0 \\ 0 & 0 & 0 & X \end{pmatrix} \begin{pmatrix} DP11 \\ DP12 \\ DP13 \\ DP14 \end{pmatrix}$$

Coupled | Decoupled | Uncoupled

**Figure 2.8** Design matrix types

The realization of discrete design at design problems is rarely achievable. On the contrary, the coupled design is realized more often because of the interaction between functional requirements. The coupled design leads to complicated structures. The coupled design during the formation and development process of designs results in more repetitive actions and/or non-operating design structures. As shown figure 2.10, the adverse effect of the coupled design is eliminated in the transformation method for the coupled design. For example, while designing an efficient production system having an ineffective machine localization is coupled design. To convert the localization to the decoupled design, first, we should change the localization of machine (Kulak and Durmuşoğlu, 2005).

$$\begin{pmatrix} FR21 \\ FR22 \\ FR23 \end{pmatrix} = \begin{pmatrix} X & X & 0 \\ 0 & X & X \\ 0 & 0 & X \end{pmatrix} \begin{pmatrix} DP21 \\ DP22 \\ DP23 \end{pmatrix} \qquad \begin{pmatrix} FR21 \\ FR22 \\ FR23 \end{pmatrix} = \begin{pmatrix} X & 0 & 0 \\ X & X & 0 \\ 0 & X & X \end{pmatrix} \begin{pmatrix} DP23 \\ DP22 \\ DP21 \end{pmatrix}$$

**Figure 2.9** Converting coupled design to decoupled design

**Axiom 2: Information Axiom**

The coupled design matrix includes non-zero values at the upper and lower triangles. That isn't suitable for design to AD. Because design process steps affect each other at the dependence design matrix. Therefore, the negative effect of dependence design must disappear because dependence designs will be converted to assorted matrix (Suh, 2001).

Axiom 2 will ensure choosing the best from all design alternatives that fulfills the requirements of Axiom 1 (Babic, 1999). The best solution is the one which fulfills FR's requirements and least information. Less information (more complex designs) will increase the success chances of a solution (Suh, 1990).

Axiom 1 will provide a simultaneous design process by the independence requirement. The second axiom is a continuation of the old approach which says "keep simple" (Chen et al, 2001).

Simply, the information access probability (Ii) to the given FR's. The design which has the highest probability is the best design. We can show the information formula for FR content:

$$I_i=\log_2(1/p_i) \quad (2.4)$$

$p_i$ is the success probability of functional requirement (FR). If the total FR number is n in design, the total information content of design is total of n number $I_i$. If I goes to infinity, it means that the designed system will never work. If total I is "1" I's are "0" or one of the probability is "0", the information content goes to infinity. As you see in the figure, the interface of two intervals gives proper solutions area (Suh, 1995).

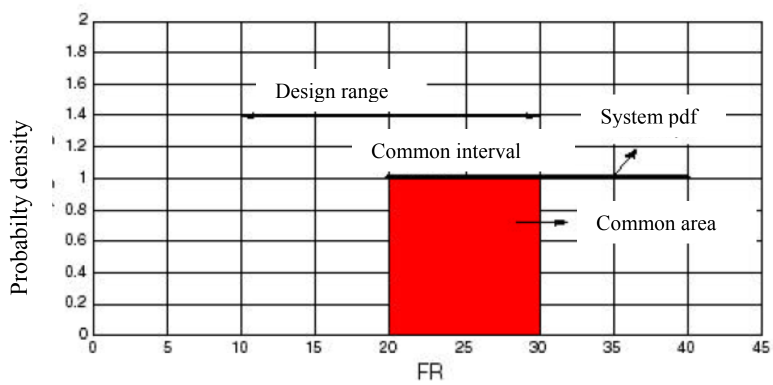



**Figure 2.10** Design interval, system interval, common interval and FR probability density function (Murat ve Kulak, 2005)

So, for regular probability distribution $p_i$: (2.5)

$p_i$= (common interval)/(system interval), and information content will be calculated as follows:

$I_i$= $\log_2$ [(system interval)/(common interval)], If we calculate FRi information content for the Figure 2.11; (2.6)

Common interval=30-20=10 and System interval=40-20=20, so that we find $I_i$= $\log_2$ (20)/(10)=1 (2.7)

At any design, the success probability is predicated on designer's reached level (design range) in terms of tolerances and system capacity (system range). In Figure 2.11, the acceptable solution range is an area that is between the design range defined by the designer and the system range that has system adequacy. Depending on this, the uniform probability distribution function $p_i$ is given as follows:

$$\int p_s\,(FR_i)\,dFR_i \qquad (2.8)$$

$p_s$(FRi) is the probability density function for FRi. As you see in Figure 2.12, the common range's area is equal to the success probability (Murat ve Kulak, 2005).

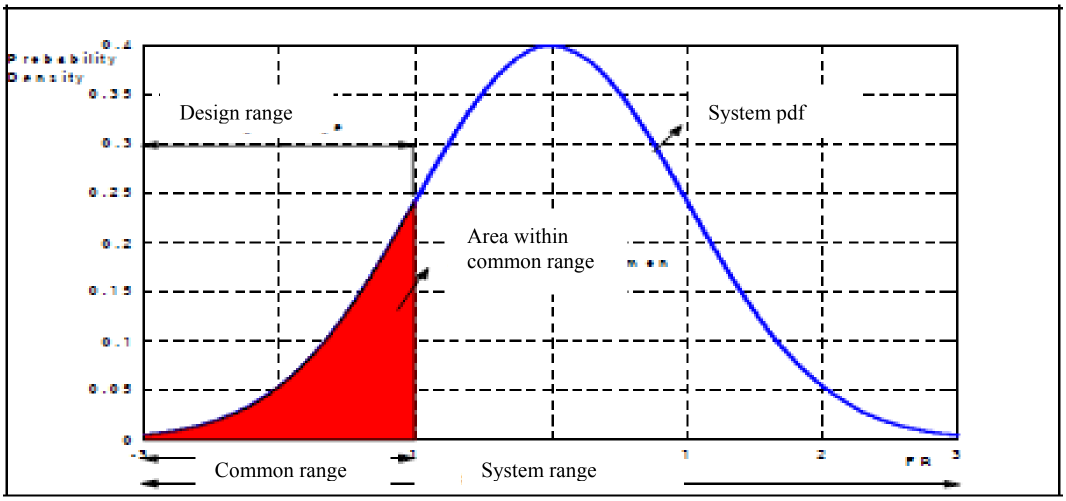



**Figure 2.11** Design intervals of functional need, system interval and common interval (Murat ve Kulak, 2005)

The logarithmic definition is convenient to use. When a given design involves several tasks with associated probabilities, the overall probability is the product of probabilities of all associated events. That is, the overall probability of independent events is multiplicative. A logarithmic definition is used so that the information measure is additive, rather than multiplicative, even when the overall probability of independent events is the product of the probabilities of each event (Suh, 1990).

**2.2.1.3 Decomposition, Zigzaging and Hierarchy**

The progress of events from high-level to low levels by more details during the design process is called as design hierarchy. The designer has to pass the physical information area after determining the functional requirements set at the specified level of the related design hierarchy and then establish the physical system corresponding to the determined functional requirements set. Afterwards, it forms the functional requirements set at the lower level by turning back to the functional information area again. As could be seen in Figure 2.13, the designer separates the design problem up to the point that the solution is recognized by making zig-zag(s) between the information areas for the sub-problems during the design process.

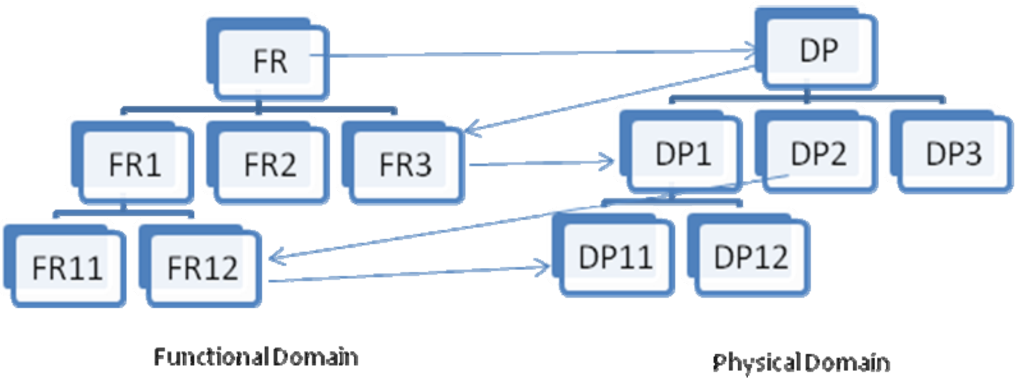



**Figure 2.12** The zigzagging process

If the design parameter corresponding to the functional requirement determined at the first step is not applied at the advanced level without elucidating, it is suggested within the design principles by axioms that the related functional requirement should be separated into the functional requirements set (FRs) at the lowest level by turning back to the functional area (Suh, 2001).

### 2.2.2 Use and Benefits of Axiomatic Design

The axiomatic design method since the early 1980s has been hailed as the scientific design approach. AD theory and its principles were introduced by Suh (1990) for the first time. Provided that, after Suh published his book in 1990, design engineering started to use it as a method and at many areas intensively for design processes. Especially the axiomatic design which was used intensively in various areas in the last decade, it continues to develop by adding new areas of use every day. AD was so far used in a wide range of areas including software design, e-commercial strategy design, quality systems design, general system, office cells planning, enterprise development planning, construction engineering buildings and environment problems solution. In these areas, a lot of solutions were found to design problems by using AD method (Suh, 1990). Citing several examples, we should mention that Kim et al (1991) applied AD principles to software design. Furthermore, AD principles were all used in the design of quality systems (Suh, 1995) as well as general system design. Suh et. al (1998) formed a manufacturing system design method by the help of AD. This method was developed by Cochran et. al (2001-2002). In addition to this, Babic (1999) applied AD to a flexible manufacturing system design. Other implementations of AD include process and manufacturing development by Suh (2001), design at constructional engineering structure by Albano and Suh (1992), and settlement of the environmental problem by Wallace and Suh (1993). Those types of studies demonstrate the feasibility as well as utilities of AD for the settlement of industrial problems (Durmuşoğlu and Kulak, 2008).

In real life, engineers solve complex problems by dividing them into subcomponents (or sub–problems) and they look for solutions to these sub-problems. AD ensures an effective mechanism for this division process (Chen and et al, 2001).

When studying for changing procedures, axiomatic design principles can be used to involve all related subjects and its effects for the system. Furthermore, the axiomatic design can be used to forecast applications. The axiomatic design makes it easier to decide real life issues. To decide soon, one should understand the subject and have information about procedure details (Suh, 1990).

The axiomatic design is a theoretical basis for rational design. It provides a framework for describing design objects that is consistent for all types of design problems and at all levels of detail. Design axioms provide a rational means for evaluating the quality of proposed designs, and the design process which is used guides designers to consider alternatives at all levels of detail and to makes choices between these alternatives more explicit. Furthermore, the axiomatic design theory encompasses a design process that has several benefits for the creation of designs. The design axioms provide a means for evaluating the quality of proposed designs so that design decisions may be made on a rational basis supported by easily understood analytical results. The designer becomes more creative by understanding a clearly defined problem before design begins and identifying innovative ways to fulfill the functional requirements (Suh, 2001).

## 2.3 PRODUCTION SYSTEMS

Production is defined as "carrying out modification on a physical asset to enhance its value or converting raw material and semi-finished one into end product" by engineers whereas economists consider production as creating benefit. Despite different definitions of production which has wide content, it is acknowledged by the groups that its objective is to respond to people's expectations (Özçelik, 1993).

On the other hand, production management is a concept about the organization, carrying out and monitoring of production activities. More precisely, production management is the operation function concerning with decision making required for obtaining goods and services on the intended standards, in the intended time and at minimum cost. As it was before, production management lost its operation function characteristic, which is limited only to manufacturing and it turns into one of the sub-systems of the operation system that is accepted as a system (Çelikçapa, 2000).

In conclusion, production is a function that aims to create value with regard to the society. As could be concluded here, the production concept should not be limited only to end product manufacturing. Yet, it is possible to create value by means of fulfilling the expectations of the society without making any amendments with regard to chemical or physical conditions (Özçelik, 1993).

When constituents generating the system are taken into consideration, it is considered that issues such as labor force, material, energy and knowledge are the inputs whereas goods and services which are to be obtained are the outputs in a system that is producing goods. The transformation of inputs into outputs is realized at operating units by using specific methods in terms of technology. Targeted production is carried out at manufacturing plants for tangible physical outputs such as goods such as machines, clothing, vehicles whereas transformation operation is realized at service units such as hospital, lorry or hotel for non-physical outputs such as health, transfer, accommodation, entertainment (Top, 2001).

The production system is a system that embodies the process of creating value for physical materials, or in other words, realizes production. Production systems could be considered fewer than three main headings depending upon material and product flow characteristics: Flow type, Function type and Project-type production systems (Özçelik, 1993).

When the relation between a production system on the basis of the manufacturing plant and the market is examined, then a feasibility study is prepared within the scope of the system at first stage. Demands from the market are examined in this section that by taking an affirmative decision, improvement studies with regard to the product to be put on the market are initiated. When the preparations of design drawings, calculations, manufacturing models and component lists with regard to this product are accomplished, then the preparation of work becomes part of an effort. Here, one will determine which pieces of the machinery will manufacture the component parts that make up the product, what operations will be performed, and how long it will take to manufacture the product. The commencement of component operation activities in terms of delivery amount to the customer as well as according to the date and checking those procedures now fall into the area of responsibility of the production planning and monitoring department. The chain will be accomplished by putting upon the market as a result of obtaining the components, product assembly, quality control and storing when required (Dinçmen, 1990).

It is possible to classify production types under three headings in general:

- Flow-type production
- Function type
- Project-type

For function-type production systems, each workstation is assigned to different functions that each product or order is directed towards only the related workstations (Özçelik, 1993). Departments were set up in terms of classification of machinery, equipment and labor force that have similar features. Production is not continuous; it is rather in batches and it is possible to follow different flow routes for each order. Thus, various inputs are logged in the system and hence it is possible to have outputs of wide range, but of limited number in terms of processing towards specific orders. Machines have general-purposes and are used by qualified personnel (Top, 2001). Since production is made according to the order, then the end-product stocks are low whereas if it is operated with a higher capacity and if there is more than one work simultaneously at one workstation, then there arises a high level of interim stock. Such production is available at the first stages where sales volume should be low whereas flexibility should be high (Çelikçapa, 2000).

The project-type production is prepared for once or for a limited quantity of outputs of the same end-product. There is no production flow. Instead, all operations are fulfilled within the scope of a specific sequence one by one with a view to reaching the final project objective. In such a production system, operations are not repeated and when the objective is attained, then the system is considered as liquidated (Özçelik, 1993).

In such systems in which a single output is obtained by bringing various inputs together, a high cost and a robust management planning and control is considered. Bosphorus Bridge or space travel could be cited for this type (Top, 2001).

Permanent as well as continuous flow of material or products is considered with regard to flow-type production systems. Exact opposite is possible which implies that material is constant and operations may be in a specific range. Flows may be ensured by the help of moving band between a series of operations one after another (Çelikçapa, 2000).

Benches may go beyond global and may become exclusive to the operation. Machines allocated to specific operations are arranged along a line usually with special or automatic benches and auxiliary equipment. Materials which are obtained as raw material or by-product on the one hand are taken as its operations completed or turning into a product at the end of the line. A time limit is allocated for each machine operation during the production. Therefore, standstill and waiting periods are to be minimized. Production line compensation is carried out to eliminate idleness that arises in the line production, delays and pile up of interim stocks.

Despite the fact that there is a great variety of inputs in the flow-type production system, the output is single or a few in variety and it has a higher and standard view in quantity. Thus, the demand should always be continuous, balanced and high (Çelikçapa, 2000).

Mass production is divided into two as continuous serial and discrete serial (flow line). Raw materials and products processed are spontaneously flowing in respect of their nature at continuous serial production. Cement, sugar, petro-chemistry and foodstuff are regarded as important examples of such production.

Products in the discrete serial production are formed in terms of single units by fulfilling the required operations at the workstations following each other. Motor vehicle assembly lines are regarded as the prime examples of such production type. Those systems in which facilities are designed according to the characteristics of the product to be manufactured constitute the state of the art production type in terms of technology. A production line (flow line) may be designed to produce a single product or similar models of the same product (having different operation sequences).

The interim stocks are low between units at flow-type production to ensure rapid flow without having any work delay. On the other hand, since the production is not considered with regard to a specific customer but it is towards a general demand, this leads to a higher level of finished goods stocks. The flow-type production which is also called as mass production is preferred because of the efficiency it ensures in cases where there is a high volume of production and standard products such as cars, home appliances etc. However, not only efficiency is taken into account but factors such as product obsolescence, weariness arise with regard to workforce and risk in technological change should also be taken into consideration (Top, 2001).

### 2.3.4 Pre-requisites for Serial (Flow-type) and Flow Line Production Systems

The most important condition for the serial production is the mass demand. Since flow line systems are the sub-branch of serial production systems, the mass demand condition is also prevailing for those systems.

The term “mass demand” emphasizes not only the demand level but also the continuity of demand. In other words, the establishment of such a system is meaningful if all the production outputs find a ready market and if such a situation is continuous. After all, flow line systems could be used to meet the demand at higher levels that are not continuous under some circumstances. Operating those systems efficiently considerably depend on the required inputs (materials, semi-finished goods etc.) to be ready at the intended location and intended time concurrently. Input deficiency at a specific stage will lead to a full-stop at the production line at short notice. Line balance and reliability are considered as two of the most important factors for the effective operation of the system.

The total work load should be allocated equally between workstations that generate the line for manufacturing a product efficiently on the flow line.

One of the significant features of flow line systems is the dependency of the stations on each other in the system. In other words, any failure at a specific stage will rapidly affect other stages. In that case, sub-systems of such systems shall be reliable in terms of operation. This requires that maintenance planning within the system should be implemented efficiently (Gökçen, 1994).

#### 2.3.4.1 Production Flow Lines

Flow lines are divided into two as transfer and assembly lines.

Transfer lines are also known as transfer machines. They are production systems composed of large, sophisticated machines. Those lines may be in types of in-line or rotary. The transfer of products or materials is made not by the workforce but by automatic action and transfer. Therefore, transfer lines are the production lines that are connected to each other by transfer tools and formed by series of automatic manufacturing machines.

Assembly Lines: the most specific features of those lines are the transfer of the materials by utilizing manpower along the production line and arranging operations on the parts along a line again.

It is possible to classify flow lines as follows:

i) Single-model lines: Those lines are used for the production of a single type product or model.

ii) Multiple-model lines: Different models (products) are manufactured in those lines. The manufacturing of different models is carried out separately in lots and during different periods. A model (product) is manufactured in batch at a specific period and then the manufacturing of another models is commenced. Models are never mingled together. Models may be different products or different models of the same product. In each case, products demonstrate different but similar production requirements. In practice, the assembly line is prepared for the first model. Afterwards, required adjustments are made for the lot production of the second, third etc. models.

iii) Complex-model lines: Those are the lines in which more than one similar type of models is produced in a complex manner at the same time. The most important benefit of the complex-model is the constant production of different models to meet the customer demand and it does not require large finished goods stocks. The disadvantages of the models arising from different operational periods are the irregularity in work flow, thus further station idle times, piles of semi-finished products may occur (Acar and Estaş, 1986).

### 2.3.5 Relation Between Lean Manufacturing and Line Balancing

Line balancing is the key to the success of lean manufacturing. Although individual production processes may require different process times, you can balance them by applying lean manufacturing. Lean manufacturing divides all work times into equal amounts of work. Line balancing is achieved among a variety of processes with different work times by adding or subtracting the number of manufacturing resources to the process. When the line is balanced, any process has more time than another. Balance should be at the center of every lean manufacturing line.

According to lean manufacturing, the balancing is realized based on the throughput volume of demand required on a particular process. Firstly, the throughput quantity is defined, then the manufacturing processes are divided into equal amounts of operations. While each manufacturing process for each product may have a different operation content time, the lean manufacturing methodologies balance the line using a time/volume relationship.

Actually, the lean manufacturing methodologies allow product to be produced one unit at a time at a formulated rate while eliminating nonvalue-adding wait time, queue time, or other delays.

A lean line inhibits the problem of imbalance. Lean lines are advanced assembly lines established with a facility layout that allow standard work tasks to be achieved in an order and advanced manner. All these processes are necessary to produce a product working together. The physical arrangement of the resources permits work operations to be distributed, accumulated, and balanced evenly throughout the entire manufacturing cycle.

The aim of lean manufacturing is to establish and design a production line capable of producing multiple products in cycle time. The techniques of lean manufacturing try to reduce the waste like nonvalue-adding wait, queue times to zero for line balancing. A lean manufacturing line requires that a rate of flow through the line be realized (Hobbs, 2003).

### 2.3.6 Assembly Line

Assembly lines are the most preferred mass-production methods today. The assembly line was pioneered by Henry Ford (1863-1947), the revolutionary American industrialist in automotive production. Ford primarily aimed business efficiency and standardization of products and by the system developed, he intended to separate the work into several pieces as well as standardize each piece and produce them serially in large scales. Here, it was contemplated to reduce dependence on the skills of workers by the use of moving (flowing) belt conveyors. The belt that carries the components of the would-be product flows along the machine and workstations arranged according to the sequence of actions required by the production process. What the workers at the machine and workstations should do are to pull the lever or to step on the pedal. Thus, works divided into small pieces are arranged according to the sequence of accomplishment and to have pieces due to the work or running between machines (waste of time) will be prevented during the production period.

As a result of diligent time and motion studies carried out in 1913, the production process was divided among 140 workers along about 50 meters of a production line and the duration of 12 hours 28 minutes required for the assembly of the chassis was reduced to 5 hours 50 minutes. The line moved mechanically in 1914 which implied that when the belt conveyors were put into production, this duration was reduced to 1 hour 30 minutes.

Assembly lines give many advantages to the enterprises, namely, they

1. Ensure regular material flow.
2. Ensure the utilization of man power and bench capacities at maximum.
3. Aim to reduce idle time to minimum.
4. Allocate idle times between work stations properly.
5. Minimize production costs.

Although assembly lines have many advantages, there are important points to be taken into account. Workers employed at assembly lines have lower abilities and monotony is an issue because of continuously doing the same actions. Furthermore, the changing ratio in demand and the efficiency of production system are directly associated.

The main problem arising at a line design is the accomplishment of balanced loading for workstations at production lines. Circumstances where the balance could not be accomplished lead to higher workloads when compared with the others at some stations and longer cycle time and efficiency losses (Acar, 2006).

### 2.3.7 Assembly Line Balancing

In today's globalizing world and international competition, enterprises have become aware that the key to industrial success is effective manufacturing systems, and geared their attention to how such systems may be set up with low costs. In the new system, the way to reduce manufacturing costs involves producing standardized products in large volumes which is only possible by assembly lines.

Assembly lines are systems that come about as a result of moving of work pieces that are being produced from one station to the other. In such systems, it is essential to separate the work into as many pieces as possible and standardize each piece. Production is carried out in serially in large scales. Thereby, an attempt is made to eliminate or minimize loss of time and labor.

Assembly lines play a significant role in the efficiency of the production systems. Setting up of or reorganizing a line is a costly investment. Therefore, it is important to organize the line effectively right from the start. The basic problem during the design of the assembly line is to balance the processing time with regard to workstations on production lines. Unbalanced lines lead to inefficiency in production, increases in costs and further losses in technology and workmanship (Çakır 2006).

The problem of assembly line balancing is defined as assigning the works to consecutive workstations in such manner to optimize the fulfillment of a performance criterion in light of the works required to carry out assembly operations, times required for such operations and the priority of their inter-relations. Performance criteria used in the assembly line balancing problems is usually the minimization of the number of stations or the cycle time (Ağpak et al, 2002).

Time differences between stations at plants cause waits at the previous station, delays and clogging between operations. Activities that eliminate such adverse outcome are collectively called “Assembly Line Balancing” or “Balancing”. If the production at individual stations is accomplished within the unit time, the balancing is complete. Under such circumstances no delay, pile-up etc. will occur, and the flow is smooth. However, it is impossible to have the complete balancing. In practice, the aim is to approximate to the complete balancing, which means that we should go for minimizing the total capacity difference between stations.

When installing the mass production systems, we encounter the need for balancing. Particularly for assembly lines, efforts are made to minimize the operation time differences due to a large number and a high speed of operations.

The main aim of Toyota Production System is to reduce costs by preventing waste. To this end, we should reduce waste like stock over, excess manpower at all steps of production.

It is necessary to standardize the operations to the farthest extent possible to carry out the production with minimum labor. In this regard, the standard operation concept is of critical importance. The standardization of operations under the Toyota production system ensures balancing between all processes in terms of time. The concept of cycle time is integrated into the standard operations at this point. When balancing, it is necessary to re-distribute operations to the operators. Here we must be careful on two issues. First, each operator must perform the operation within the given cycle time; and second, we must take care that each individual operator should have the same cycle time when planning for the process distribution; thereby, operations will be balanced (Acar and Estaş, 1991).

The objective aim of assembly line balancing is to give each operator the same amount of work as nearly as possible. If one operator has more time than the others, some work from the busier operators could be transferred to him.

Always, there will be a workstation which has more operations than others. This workstation is defined as fully-loaded station or bottleneck station. And this station will define the quantity of the assembly line outputs. If we ease the bottleneck station’s workload by 1%, we get an additional 1% for all operators on the line, because they can produce 1% faster. We continue to ease the bottleneck station's operation time until another workstation becomes the bottleneck (100%) or busiest station. Then we do same to our new bottleneck station (Meyers, 1999).

At the end of the initial line balancing we will need some improvements. We considered the following actions in order to improve the line (make it better balanced):

1) Reducing the bottleneck station by adding an operator or reducing cost.

2) Combining the bottleneck station with the previous or earlier station by considering the sequence of operations.

3) Combining other operations to reduced the number of stations and eliminate one of the stations (Meyers, 1999).

Assembly line balancing is the problem of redistributing operations to the stations, while optimizing one or more objectives by observing constraints on the line (Song and Kim, 2007).

An assembly line is flow-oriented production system which realize the processes with stations in serial condition (Boysen, Fliedner and Scholl, 2007). The work piece comes orderly to the stations and when one station finishes operation, the work piece goes to the next station by some kind of transportation system. Assembly lines are too important for industrial production of high quantity standardized commodities. Actually, assembly lines are used for a cost efficient mass production of standardized products. In order to meet ever-changing customer needs companies need assembly lines (Dar-El, 1989, Scholl, 1999).

For balancing, all production processes on the production line should be divided into tasks which will then be allocated to workstations. Such divisions and allocations must be done in a feasible order and within an acceptable production time (cycle time). The cycle time is the time between to sequential operations, and it is set by the workstation which needs the longest time. The work flow may not be faster than the slowest workstation. If any individual workstation does more work than other stations, some of the work should be distributed to other stations with lighter workload.

Ideally, every workstation must have the same workload. This line is balanced. Every workstation is prepared for working at the fastest pace. Line balancing requires that available combinations of performing necessary tasks at every workstation must occur at available time and position. It is necessary to minimize the given cycle time vis-à-vis the workstations or workers in order to balance the line (Semetay, 1999).

Normally, the process design should be easy, but getting smooth flow through the process can be difficult. The operation is usually split into a number workstations, so for all workstations the time spent in each must be about the same. That means the line is balanced. For an imbalanced line, some workstations finish their operations for products quickly, thus they start to pile up the stocks of work in progress in front of the next work station that is working more slowly.

There is an open and simple way for balancing, which involves three steps:

**Step 1.** Find the cycle time, which is the maximum time any workstation can work on a unit. This is found by dividing the planned output by one shift time. If any operations take more time than the cycle time there is a bottleneck and we should make reduce the time at this workstation otherwise the planned output cannot be achieved.

**Step 2.** Compute the theoretical minimum number of workstations needed for the product wanted. We can find it by dividing the required total time to make a product by the cycle time. Usually if the result of this calculation is not an integer it means that we should increase the number of workstations beyond this minimum number.

**Step 3.** Do the line balancing. Re-distribute long operations of workstations which make this workstation a bottleneck, so that the total time of each station will be as close as possible to the cycle time and each other (Armstrong, 2006).

### 2.3.7.1 Assembly Line Balancing Problem

The assembly line balancing problem is one that has an important part with regard to production planning and control studies (Günay et al, 2004).

The assembly of a product at assembly lines is realized by bringing together components and subassemblies that form the product and carrying out a number of procedures on it. Those who carry out the operations are worker groups arranged along the line, or in other words, workstations. The fundamental feature of an assembly line is the movement of working pieces from one station to the other. The main problem encountered at assembly lines is the assignment of the tasks to be accomplished to the stations on the lines under the constraints associated with the product and the production system. This problem is called as the balancing problem (Ağpak 2001).

Performance criteria used in assembly line balancing problem can be grouped under two main headings as minimizing the cycle time when the number of stations is given and minimizing the number of stations when the cycle time is provided. While increasing the production amount at the first performance criterion is targeted, the second performance criterion relates to the reduction of labor cost (Ignall 1965).

#### 2.3.7.2 Basic Concepts of Assembly Line Balancing Problem

It is useful to explain some of the concepts to understand assembly line balancing problems better. Those concepts are briefly explained below:

Assembly: It is the process of bringing different pieces close together and then to unify them to form a finished product. Pieces that form the product, assembly order of the pieces and the durations required for unifying those pieces are demonstrated by priority diagrams.

Assembly Line: An assembly line is composed of a specific number of sequential *stations* that is connected with each other by a material conveyor system. Materials are moved by a constant conveyance speed between these stations. In each station, a part of the *duties* required for the accomplishment of the procedures of the product are carried out and when reaching the end of the line, then all procedures of the product is considered as accomplished.

Task: It is the smallest divisible piece of the total work required to be carried out at an assembly line. For example, screwing by mounting the hard disc during assembling of a computer is one of the smallest piece of this assembly procedure that is quite many in number and it is called as a task.

Workstation: It is the unit in which one or more operations are carried out on the assembly line. Usually one person is employed at a station. Depending on operational requirements, it is possible to employ more than one person at a workstation.

Stations may be “Open” or “Closed”. It is obligatory to carry out work within the boundaries of the station at closed ones. Whereas at open stations, the operator could move outside the station to the boundaries determined. Therefore, there is flexibility at accomplishment times of duties at open stations (Dar-El, 1978).

Cycle time: Cycle time may be defined as the maximum duration that a product could remain at the assembly line or the required time for accomplishment of the necessary works to be carried out at this station by the worker at a workstation.

In other words, it is the time allocated for the stations forming the assembly line to accomplish the assigned duties to that station. The cycle time of an assembly line is equal to the longest of the station times. The longest duty times at assembly process is the lower limit for the cycle time. To meet the demand belonging to a specific production period, it should not exceed a definite upper limit of cycle time ($C^{upper}$). This upper limit is calculated by using the following equation 2.1:

$$C^{upper} = T/D \text{ (minute/quantity)} \qquad (2.1)$$

Station Time: Sum of function time of the duties accomplished at a station in an assembly line are composing station time (work load) of this station.

Total work time: Time required for the accomplishment of duties to be performed during the assembly of a product on the assembly line.

Station Latency Time/Idle Time : Difference between the cycle time and the station time is called as the station latency time or idle time (Çakır 2006).

#### 2.3.7.3 Constraints Encountered in Line Balancing Problems

There are some basic rules that must be observed during line balancing studies carried out to ensure equal workload distribution to the stations to enhance the performance of the line. Such rules could be enumerated as follows (Sönmez, 1991):

- All works as well as work elements should be appointed to work stations,
- A work element could be appointed only to one work station,
- The total duration of the work elements appointed to the work station should not exceed the cycle time,
- Priority relations arising from the technological relations between work elements and influencing the performance order of the work should not be disturbed.

Apart from those basic constraints, additional constraints arise according to the characteristics of the product and the line may be encountered. Examples of such constraints are as follows (Ghosh and Gagnon, 1989);

- Regional constraints that prevent the appointment of a group of work elements to the same work station (negative) or that require the accomplishment of a number of work elements at the same work station (positive),
- Necessity of parallel stations,
- Limitations on the number of equipment,
- The position of stations that they are either on the right and left side,
- Existence of stations that give rise to  bottlenecks,
- Limitations on the length of the line,
- Lack of any specific time of movement for the workers and etc.

In solving the line balancing problem encountered in the real world, it is necessary to take technological limitations, equipment constraints, constraints with regard to the workstation, limitations concerning the personnel, limitations regarding the process and the facility into consideration as well as to find appropriate solutions to optimize those conditions.

### 2.3.7.4 Criteria for Assembly Line Balancing

The objective in assembly line balancing problems is to allocate operations to workstations in such a manner to optimize a criterion specified by considering the constraints regarding the accomplishment of the work. Objectives addressed at line balancing problems are classified as two main types which could be enumerated as follows;

Technical criteria:

- Minimizing the number of work stations for the cycle time given,
- Minimizing the cycle time for the number of work stations given,
- Minimizing the total idle time along the line,
- Minimizing the balance delay,
- Minimizing the length of line,
- Minimizing the throughput time,
- Minimizing the probability of workstations to exceed cycle time.

Economic criteria:

- Minimizing the total cost of labor, workstations and unfinished works,
- Minimizing the labor cost,
- Minimizing the total (penalty) suffered in case of inefficiency,
- Minimizing stock, calibration and idle time costs,
- Minimizing in-process stock cost,
- Maximizing the net profit.

While the minimization of the number of workstations for cycle time is the one that is mostly used among technical criteria, the minimization of the cycle time for the number of workstations given and minimization of the total idle time along line are the other technical criteria principally used with regard to the methods developed for assembly line balancing problems. Economically, minimizing the total cost of labor, work stations and unfinished works and minimizing labor cost are the leading economic criteria mostly used (Ghosh and Gagnon, 1989).

# CHAPTER 3

# FORMING THE LINE BALANCING MODEL BY AXIOMATIC DESIGN

This chapter in general explains in a simple way the method of balancing the assembly line using the axiomatic design, which is an application of lean manufacturing. The chapter will, in a sense, serve as a guideline for the applying this method to solve real-life problems.

Our assembly line had time differences among operations as would any other assembly line have. Such time difference makes assembly line imbalanced. The assembly line cannot produce efficiently, operators have to wait for the others to finish operations, and consequently one cannot take outputs in the required quantity and on time from the assembly line. As a result, one cannot send products on time and in full to one's customers. Customers will complain about the delay to the manufacturing company which will eventually lose esteem. The company's costs will go up, and profits down. The most important outcome is that the company's customers will be dissatisfied. As time goes, the company's losses will grow and finally the company will go bankrupt. In order to prevent losing customers and profits, we must take some preventive actions. Thus, we balanced the assembly line by using the AD method.

In our application, the axiomatic design helped us make decisions and choose the best alternative as suggested by the axiomatic design. Also, AD helped us identify potential improvement points. In this study, we managed to solve our assembly line balancing problem by applying the AD principles. Then we applied the outcomes of the AD method to the assembly line. Here, FRs are the physical elements that need improvement and DPs are the actions and rules which enhance performance.

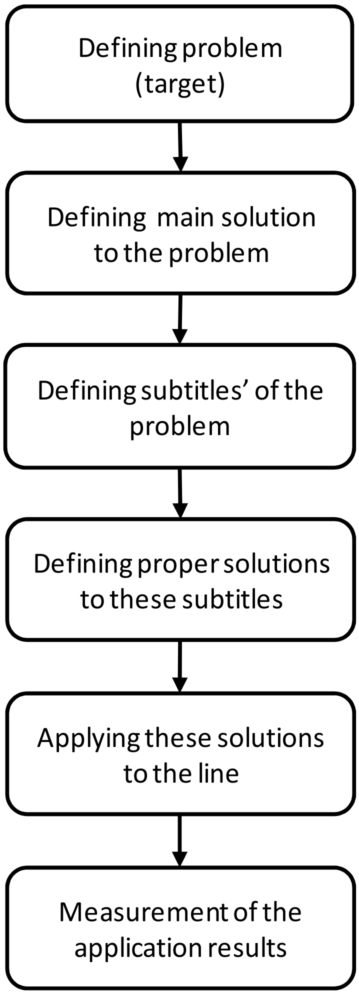



**Figure 3.1** Application Process of the Method

Now, the application method will be explained on the basis of a flowchart of application process step by step.

The first step is to define the problem. This problem will be the main functional requirement (FR) of the AD method. At this step, we define "what we want to do or what we want to achieve". For example we want to improve a product, like having higher quality, lower cost, longer life etc. Here, for quality, the problem definition or main FR will be to increase the quality of the product; for the cheaper product, it will be to reduce the product's labor cost, for longer life, it will be to make the product more durable etc.

The second step of the application process is to identify the main solution to the problem. This solution will be the main design parameter (DP) of the AD method. At this step, we define “how we will achieve our target or how we will solve our problem”. If we give examples in reference to the examples of the previous step; to increase quality of the product main solution, the DP may be to prepare the QFD matrix, to reduce the product’s labor cost, the main DP may be to increase productivity, to make the product more durable, the main DP may be to increase product endurance etc. It is possible to give many examples on this topic.

Then, the next step is to define the subcomponents of the problem. The meaning of this step to identify sub-steps (FRi), we divide the main problem to sub-steps. We define sublevel demands related with the main problem. For instance, to increase quality of the product, the sublevel functional requirement (FRi) may be to define the specifications of the product; to reduce the product’s labor cost, FRi may be to reduce the product’s man*hour; to make it more durable, the subcomponent of the main problem may be to increase product performance etc.

The next step is to identify proper solutions to these subcomponents. These sublevel solutions (DPs) will meet the previous step’s sublevel functional requirements (FRs). It means that at this step, we will define how we will realize sublevel demands (wanted situation lower titles-FRs). If we refer to the examples of the previous step; to define the product specifications, the proper sublevel method for this DPs may be to define the customer demands; to reduce the product’s man*hour, DPs may be to analyze the operators’ operations; to increase the product performance, DPs may be to define and improve the product’s performance criteria.

When we complete the fourth step, we have a hierarchical diagram because we define what we want and how we will realize them in a hierarchical system. While realizing the hierarchical system, we do that on the basis of decomposition. When we increase the level of FRs and DPs, we decompose them on two sides. Also, there is correlation between the previous sublevel DPs and the next sublevel FRs that is called zigzagging. On the other hand, no DPs meet the previous FRs. If that happens, our method will not work, the solutions and problems coincide with each other. We can show these concepts on the following basic figure.

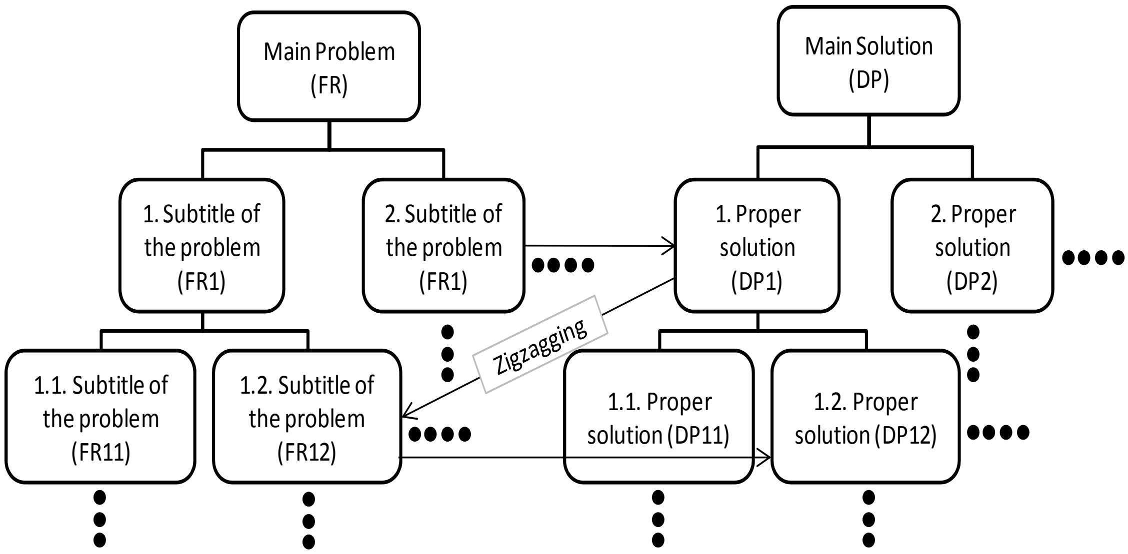



**Figure 3.2** Hierarchical system, decomposing and zigzagging

The fifth step is the application of the solutions to the work area. For our study, the work area is the line, but for applications it may be a department, a process, a product etc. Now, we will implement this solution (lowest level DPs) to achieve the target or the main FR. We will make improvements, corrections, checks, modifications, innovations etc. in the work area. This application will take us to the target.

The last step is to measure the application results. For our study, we analyze line productivity, the number of men, production quantities, production times, and man*hours for each product. For different problems, results may be the quantity or quality of the defect, the quantity of customer complaints, product cost, product life etc.

Through the use of the axiomatic design method, we identified the applications which would enable us to realize the desired outcome. AD helped us to decide how we could find proper solutions to achieving our target. The axiomatic design makes us understand the situation better, and we could see different solutions without applying. After we analyzed the solution alternatives, we applied them. This also reduced the cost of achieving this target.

# CHAPTER 4

# APPLICATION OF AXIOMATIC DESIGN TO LINE BALANCING PROBLEM

## 4.1 AXIOMATIC DESIGN APPLICATION

In order to meet customer demand on time and in full, we should obtain the required volumes of production from the assembly line. The first step to apply axiomatic design is to define the purpose that is most important thing for the design process. We should describe the purpose clearly. Here, the purpose is to fulfill our main functional requirement (FR1). After that we will define the design parameter (DP1) which shows how the functional requirement is to be achieved. These are our first level FRs and DPs. When we complete defining the main FR and DP, we will move on to define the second, third, so forth FRs and DPs step by step.

The main problem is that we cannot produce the production volume needed. So we need to balance the line to meet our required production volume. For our application, main FRs and DPs are as follows:

**Step 1.** We define the highest level functional requirement which is in the functional information area

FR: Realize the required production volume on the assembly line

**Step 2.** We define design parameters which meet this functional requirement.

DP: Balance the line to the required production volume

**Step 3.** We decompose FRs which are defined at step 1. These are more sub-level functional requirements of the previous functional requirement.

FR1: Make operator times smaller or equal to production cycle time

FR2: Make machine operation times smaller or equal to production cycle time

FR3: Ensure that operators know which operation they do

FR4: Ensure real continuation of information flow

**Step 4.** We define DPs meets for each sub level FRs by mapping.

DP1: Check availability of operator times

DP2: Check availability of machine times

DP3: Check operators' knowledge

DP4: Design a system which strengthens the communication information network

**Step 5.** We define the design matrix between these sub level FRs and DPs. Here, X show the relationship between FRs and DPs.

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \\ FR4 \end{Bmatrix} = \begin{pmatrix} X & 0 & 0 & 0 \\ 0 & X & 0 & 0 \\ 0 & 0 & X & 0 \\ 0 & 0 & 0 & X \end{pmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \\ DP4 \end{Bmatrix}$$

**Step 6:** After completing step 5 this cycle continues. Again we turn to functional area and decompose FRs and define DPs that meet these FRs.

We will expand the model by using the following steps:

FR11: Define operations which can eliminate or combine

FR12: Define operators' operation times

FR13: Define non-value adding operations and take action

FR14: Allocate operations to the operator in a balanced manner and without exceeding the cycle time

The design parameters for FR11, FR12, FR13, FR14 are as follows:

DP11: Method study

DP12: Time study

DP13: Make improvements with ECRS analysis

DP14: Apply line balancing

The design equation which shows relationship between functional requirements and design parameters is represented as follows:

$$\begin{pmatrix} FR11 \\ FR12 \\ FR13 \\ FR14 \end{pmatrix} = \begin{pmatrix} X & 0 & 0 & 0 \\ 0 & X & 0 & 0 \\ X & X & X & 0 \\ X & X & X & X \end{pmatrix} \begin{pmatrix} DP11 \\ DP12 \\ DP13 \\ DP14 \end{pmatrix}$$

The resulting design matrix is a decoupled one and there is an extra relationship between "Apply line balancing" and DP11, DP12, DP13, DP14.

FR21: Define machine operation times

FR22: Define non-value adding operations and take action

FR23: Allocate operations to machines in a balanced manner and without exceeding the cycle time

And design parameters are:

DP21: Time study

DP22: Make improvements with ECRS analysis

DP23: Balance machine times

The design equation which shows the relationship between functional requirements and design parameters is represented as follows:

$$\begin{pmatrix} FR21 \\ FR22 \\ FR23 \end{pmatrix} = \begin{pmatrix} X & 0 & 0 \\ X & X & 0 \\ X & X & X \end{pmatrix} \begin{pmatrix} DP21 \\ DP22 \\ DP23 \end{pmatrix}$$

The resulting design matrix is a decoupled one and there is an extra relationship between "Balance machine times" and DP21, DP22, DP23.

FR221: Reduce material carrying

FR222: Reduce walking time

FR223: Reduce waste

FR224: Prevent needless movements

FR225: Prevent waiting

FR226: Prevent overproduction

FR227: Prevent needless operations

Design parameters of these FRs are:

DP221: Place machinery closer

DP222: Put materials to the usage area

DP223: Apply jidoka

DP224: Arrange working area by considering ergonomy and productivity

DP225: Optimize information and material transfer

DP226: Apply kanban

DP227: Apply standard operation procedure

The design equation which shows the relationship between functional requirements and design parameters is represented as follows:

$$\begin{pmatrix} FR221 \\ FR222 \\ FR223 \\ FR224 \\ FR225 \\ FR226 \\ FR227 \end{pmatrix} = \begin{pmatrix} X & 0 & 0 & 0 & 0 & 0 & 0 \\ X & X & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & X & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & X & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & X & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & X & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & X \end{pmatrix} \begin{pmatrix} DP221 \\ DP222 \\ DP223 \\ DP224 \\ DP225 \\ DP226 \\ DP227 \end{pmatrix}$$

The resulting design matrix is a decoupled one and there is an extra relationship between “reduce walking time” and “place machinery closer”.

FR2211: Carry what is needed

DP2211: Apply milkrun

Overhead, only one FR and DP, there is correlation between FR2211 and DP2211.

FR31: Define operations

FR32: Define current information level

FR33: Define needed trainings

FR34: Realize trainings

FR35: Analyze adequacy of knowledge level of operators

FR36: Visualization of results

Design parameters of these FRs are as follows:

DP31: Apply standard operation procedures

DP32: Do practical examination

DP33: Training matrix

DP34: Apply training plan

DP35: Do practical exam

DP36: Skill matrix

The design equation which shows the relationship between functional requirements and design parameters is represented as follows:

$$\begin{pmatrix} FR31 \\ FR32 \\ FR33 \\ FR34 \\ FR35 \\ FR36 \end{pmatrix} = \begin{pmatrix} X & 0 & 0 & 0 & 0 & 0 \\ X & X & 0 & 0 & 0 & 0 \\ X & X & X & 0 & 0 & 0 \\ X & X & X & X & 0 & 0 \\ X & X & X & X & X & 0 \\ X & X & X & X & X & X \end{pmatrix} \begin{pmatrix} DP31 \\ DP32 \\ DP33 \\ DP34 \\ DP35 \\ DP36 \end{pmatrix}$$

As you see, we need standard operation procedures to define operation procedures and previous level FR27 which is “prevent needless operations”.

FR331: Improve operator’s skill to do one more operation

DP331: Multifunctional operator training programme

When we apply that we have one more operator for each operation. This enables us not to depend on one operator for any operation.

FR41: Ensure continuity of information flow between departments

DP41: Application of report system and visualization

Overhead, only one FR and DP, there is correlation between FR41 and DP41. And now we decompose FR41 and DP41:

FR411: Define needed data to improve information flow

FR412: Ensure to update needed data

DP411: Install new data system or improve current system

DP412: Update data on defined times

The design equation which shows the relationship between functional requirements and design parameters is represented as follows:

$$\begin{pmatrix} FR411 \\ FR412 \end{pmatrix} = \begin{pmatrix} X & 0 \\ X & X \end{pmatrix} \begin{pmatrix} DP411 \\ DP412 \end{pmatrix}$$

And, when we decompose FR412 and DP412:

FR4121: Control and track data system

DP4121: Assign responsible people

Now, we can show all FRs and DPs together.

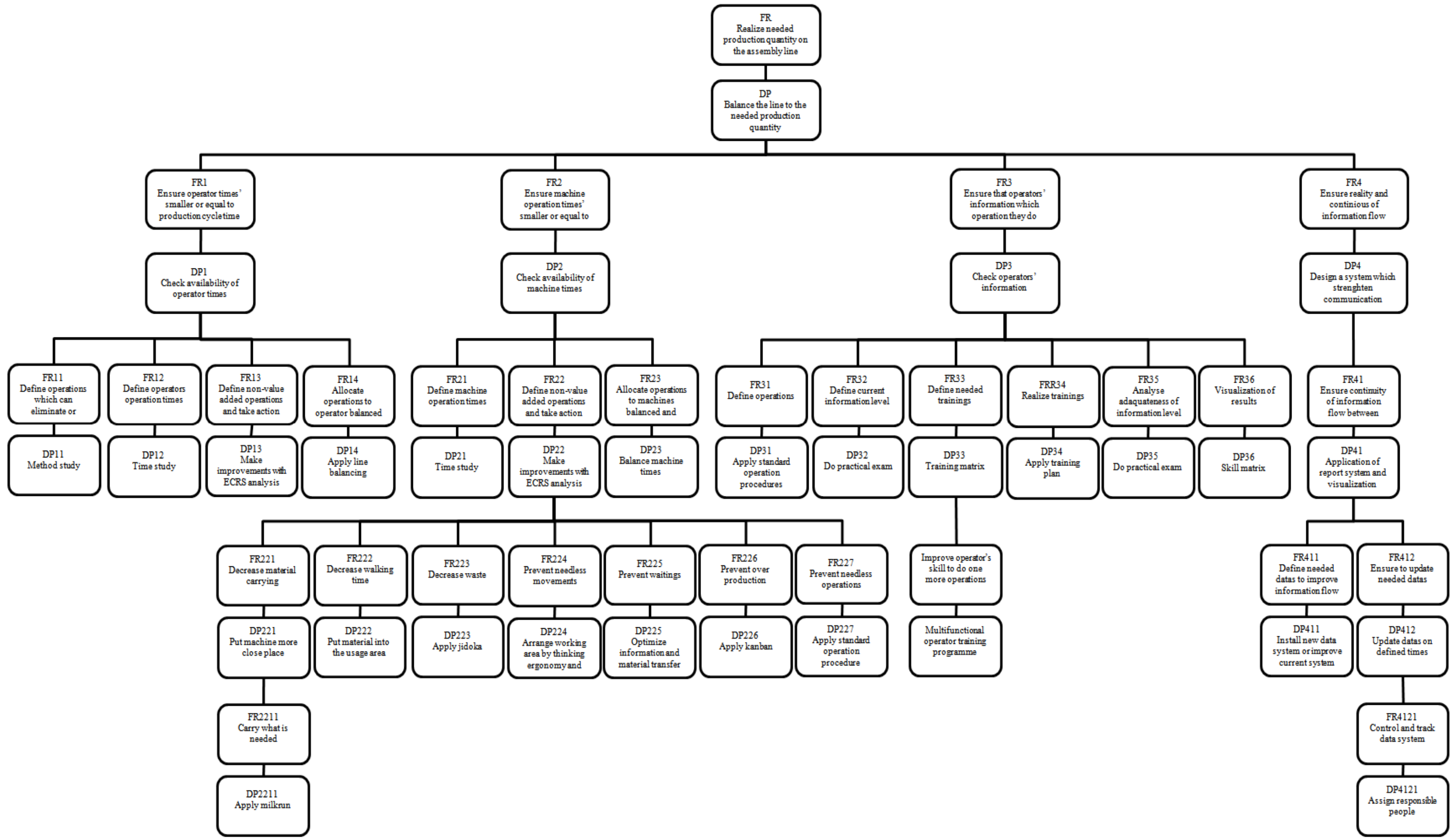



**Figure 4.1** Axiomatic design applications

One of our functional requirements (FR) is to make operator times equal to or smaller than the production cycle time (FR1-FR2) in order to make possible that the required volume of production would be run on the assembly line when the study is completed. In order to do that, we defined FR11, FR12, FR13 and FR14. And we decided to do that by DP11 (Method study), DP12 (Time study), DP13 (improvements with ECRS analysis) and DP14 (Apply line balancing) meet this FRs. After we found these results, we decided to balance the assembly line. When we balanced the line and used machines' times all together we could produce the required volume on the assembly line. Also, we needed to realize other applications (communication boards, milkrun etc.) which were told in the previous paragraphs. Now, we will explain the assembly line balancing application found as a one result of axiomatic design.

## 4.2 PRESENTATION OF COMPANY- CASE STUDY

Frigoglass is a global leading manufacturer and solution provider in commercial refrigeration and West Africa's leading glass producer, providing for the needs of beverage customers around the world. Frigoglass offers effective solutions in commercial refrigeration, supporting beverage customers to increase cold drink availability across different trade channels.

The company began operating in 1982 as an industrial division of the Hellenic Bottling Company, with one commercial refrigeration plant in Greece. Seven years later, the company was spun-off to develop independently, and in 1999, after demonstrating its viability and having established a record of good corporate governance, Frigoglass was listed on the Athens Stock Exchange.

Frigoglass currently has operations in 19 countries across five continents including production hubs in Romania, Russia, Greece, Turkey, India, China, Indonesia, South Africa, Nigeria and USA, sales offices in Poland, Norway, Ireland, Kenya, Philippines and Germany, and sales representatives in U.K., France and Australia. The company's customer base consists of the Coca-Cola Company Bottlers (Coca-Cola Hellenic, Coca-Cola Enterprises, BIG, Coca-Cola Amatil, Coca-Cola Sabco), brewers (Heineken, SABMiller, Carlsberg, ABInbev, Efes) and dairy companies (Nestle, Danone) and many others. Take a closer look at the countries where ICM Manufacturing operates.

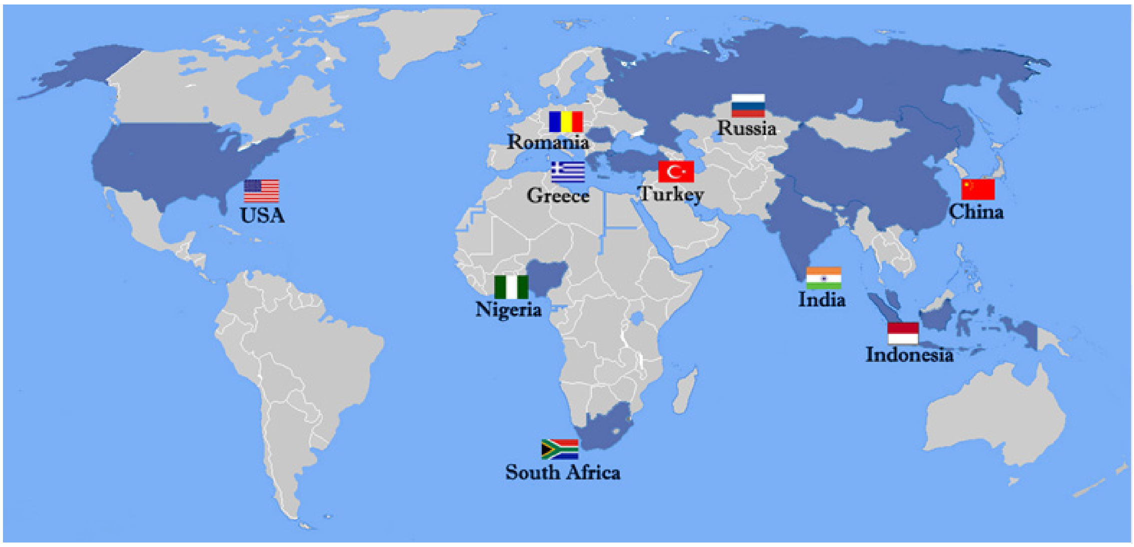



**Figure 4.2** Plants of Frigoglass company

The company's global market share in 2007 was 18.3% with notable market shares in Eastern Europe (45%), Western Europe (32%) and Africa/Middle East (35%).

Frigoglass aims to provide superior, bespoke solutions in commercial refrigeration which support customers' cold drink consumption channel sales and is committed to promoting sustainable development towards its business, the environment and the society. In this context, Frigoglass is heavily investing in the next generation of refrigeration technologies that consume less energy and use environment-friendly refrigerants and insulation agents.

A brief history of Frigoglass is presented in the following paragraphs:

*The beginning*

1982-96: It began operating as an industrial division of Hellenic Bottling Company with one commercial refrigeration plant in Greece until 1996 when it spun off establishing the Frigoglass Group.

*The expansion*

1997-99: It became a global enterprise by acquiring companies in Nigeria, Bulgaria, Romania, Kenya, Norway, Poland as well as establishing new businesses in Russia and Indonesia.

*The rationalization*

2000-03: It concentrated on the markets with greatest future growth potential through acquisitions and new businesses while divesting shareholding interests in companies at hand with lower potential.

*Focus on core business*

2004-06: It focused on design, production and marketing of Ice Cold Merchandisers and related products throughout the world and, in 2000 it acquired 86% of shares in SFA Cool of Turkey.

## 4.3 PRESENTATION OF PLANT

SFA Cool is a Frigoglass plant in Turkey. Eren Family, producing industrial and commercial coolers and freezers since the 1970s, founded SFA Soğutma San. ve Tic. A.Ş. company which became a leader in the sector. The plant was moved in 1997 from Sefaköy, Istanbul to Silivri, Istanbul.

The company signed in 2000 a partnership agreement with AHT which was the leader of the same sector in Australia. The company's shares were wholly transferred to Frigoglass Company which operated in the same sector in 10 countries as of 28 April 2008. So, SFA became a fully international company.

SFA produces more than 100 kinds of products at nearly 60.000 m2 area (28.000 m2 of which is closed space). Main product varieties are vertical and horizontal coolers, ice-cream coolers, vertical and horizontal deep freezers, wine coolers, backbar coolers and air curtain coolers.

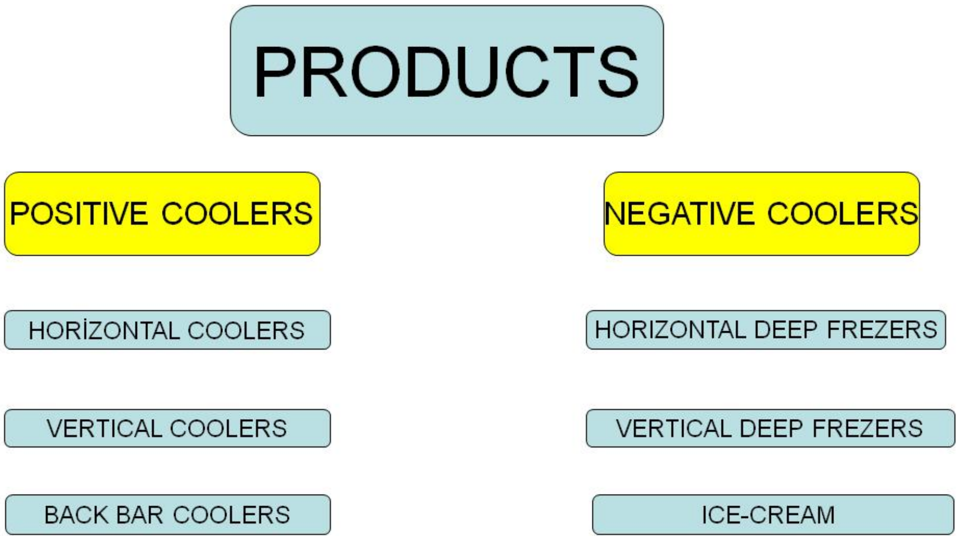



**Figure 4.3** Product groups of plant

SFA ranks the 200th among Turkey's top 500 exporters. About 80% of its production is exported to such foreign customers as Redbull, Schweppes, Miller, Heineken, Danone and Interbrew etc. that are well known in the world.

**Figure 4.4** Some examples of products

The following is a brief history of SFA as a timeline:

1992: Foundation

1993: Collaboration with Iberna of Italy and Caravell of Denmark

1998: Setting up a new factory in Silivri / Istanbul with an initial capacity of 250 unit/day on a covered area of 5000m2

1999: Collaboration with AHT of Austria

2000: Signing partnership agreement with AHT whilst giving 20% of SFA

2002: Start of chest freezer production; the covered area increased to 22000m2

2006: Turnover reaches $ 62 million

2006: ADM capital of Hong Kong managing $2 billion in investment funds acquires equity stake of SFA

2008: Frigoglass acquires 86% shares of SFA

2009: Authorization of SFA by TCCC to be a supplier plant.

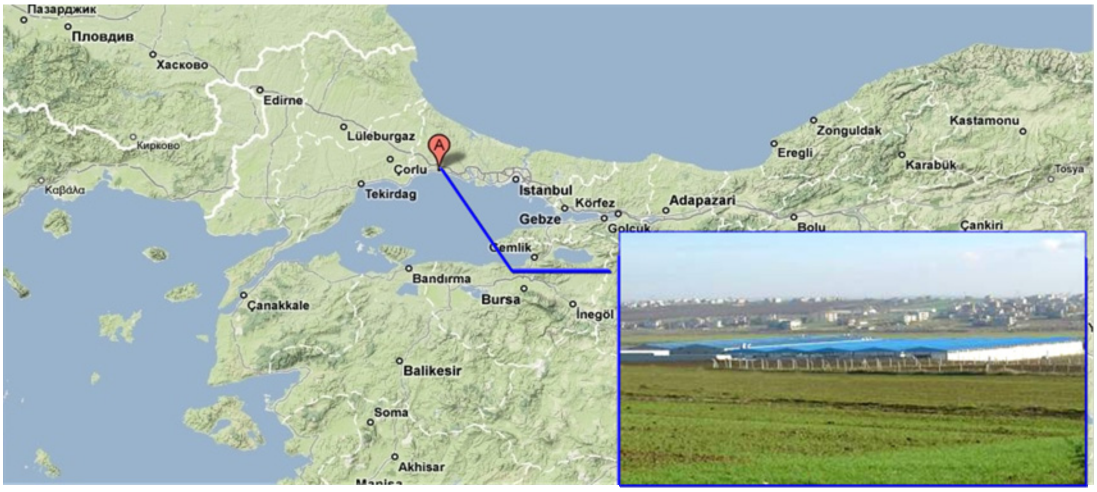



**Figure 4.5** Plant location

## 4.4 PRESENTATION OF PRODUCTION

We have 3 production lines. All these lines have sub-assembly and body preparation departments. We assemble the coolers' parts and materials on the assembly line. The subassembly prepares some parts, the body preparation prepares bodies of the coolers. And there are other departments as a supplier which are mechanical, thermoform, painting, serigraphy, door production and warehouses. The mechanic department produces metal parts of coolers, the thermoform produces plastic body parts of coolers, the painting department paints some of metal pieces which are produced or not produced by the mechanic department, the serigraphy produces stickers which sticks top, right-left, back and bottom sides of the coolers and the door production produces doors for the coolers. In the mechanical department we have cutting, punching, guillotine cutter and bending machines. For the thermoform there are CNC, cutting and thermoform machines and in the painting we have painting cabinets, ovens.

Furthermore, we have two warehouses: one of them is the material warehouse and the other one is the finished good warehouse. The material warehouse sends materials to the production department and the finished good warehouse loads finished goods to the vehicles and sends them to the customers.

In the following figure, you can see SFA layout divided into departments.

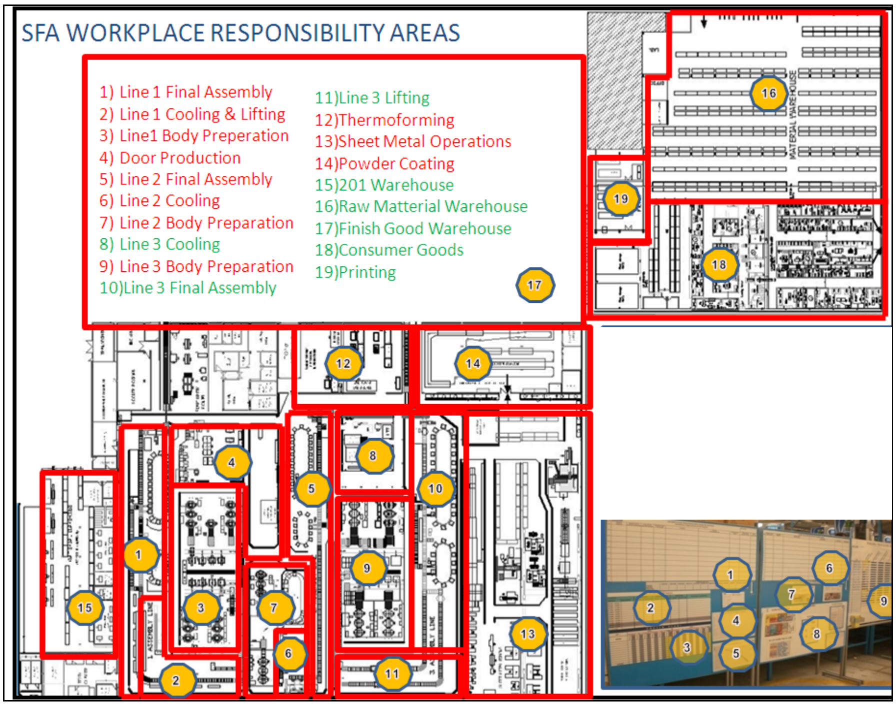



**Figure 4.6** Plant Layout

In the following figure, in order to better explain the flow of one cooler, we show the general processes (general flow) which are necessary to produce the cooler to the assembly order. We can see all departments and all connections among the all departments of the plant.

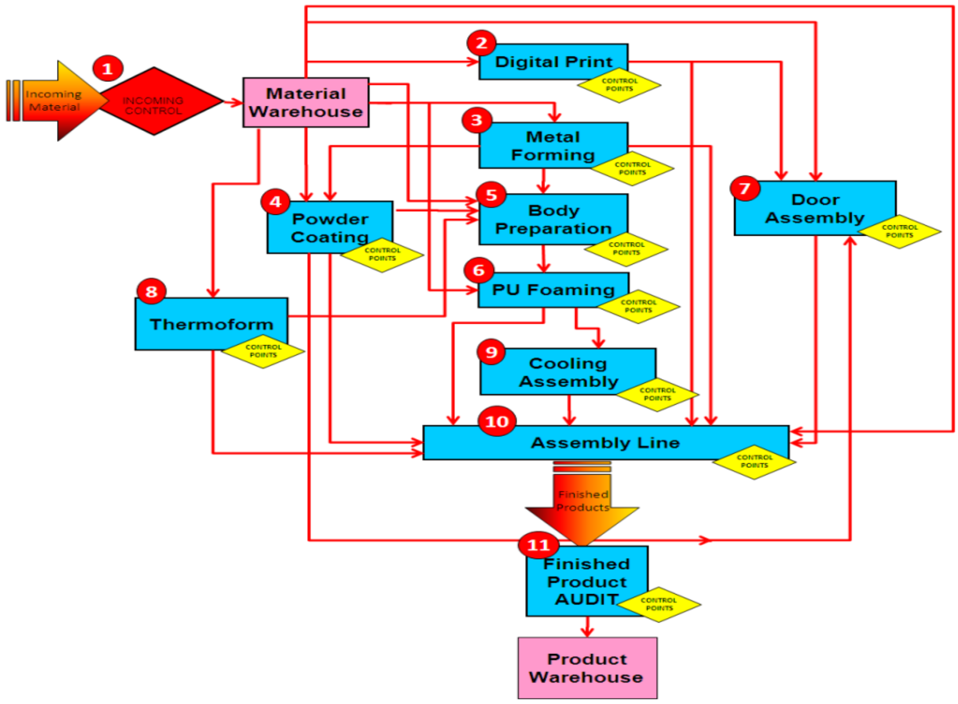



**Figure 4.7** General Cooler Processes (General Flow)

### 4.4.1 Defining Current Situation

Now, we can tell the processes which apply on the assembly line by our balancing model “Slim”. Here, we need 31 different operations and 32 operators to produce “Slim”. If we explain these operations shortly: operators 1 and 2 assemble body materials, operator 3 assembles the evaporator, operator 4 assembles the compressor and the evaporation tube, operator 5 does pre-welding preparation operations, operator 6 welds joints of compressor tubes, operator 7 assembles the condenser fan, operator 8 assembles the evaporator fan cable, operator 9 assembles the condenser, operator 10 connects thermostat cables, operator 11 assembles compressor fan, operator 12 does the Helium test, operator 13 assembles the evaporator box styrophore and the compressor cover styrophore, operator 14 assembles two internal metals of the cooler, operators 15 and 16 assemble the glass and the LED, operator 17 cleans the glasses, operator 18 sticks the sticker, operator 19 place the shelves, operators 20 and 21 top side materials and top cover metal, operator 22 cleans the cooling system tubes by vacuuming, operator 23 pumps from the tubes cooling system gas, operator 24 checks high voltage and gas leakage, operator 25 checks the cooling and working performance of the cooler, operators 26 and 27 assemble external metals of the cooler, operator 28 cleans inside and outside of the cooler, operator 29 checks the cooler aesthetically and working, operators 30, 31 and 32 pack and send the cooler. When we examine the balancing, the detailed operation of each operator is written there. All operations are shown below.

In the following section, we examined processes of the assembly line. This shows the flow of our balancing model “Slim”.

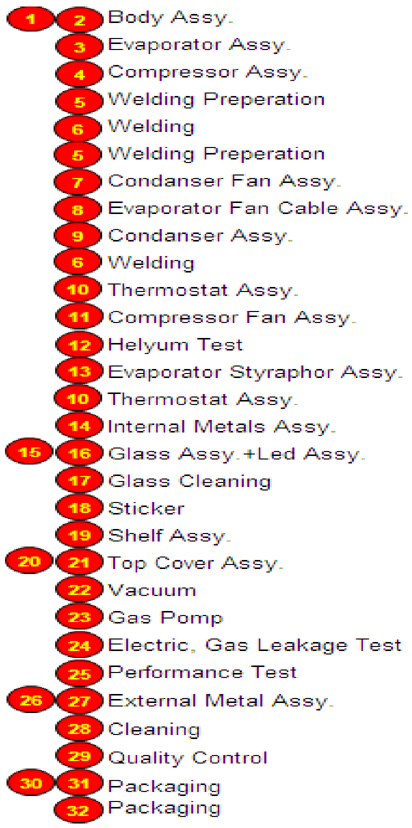



**Figure 4.8** Flow of Slim Model

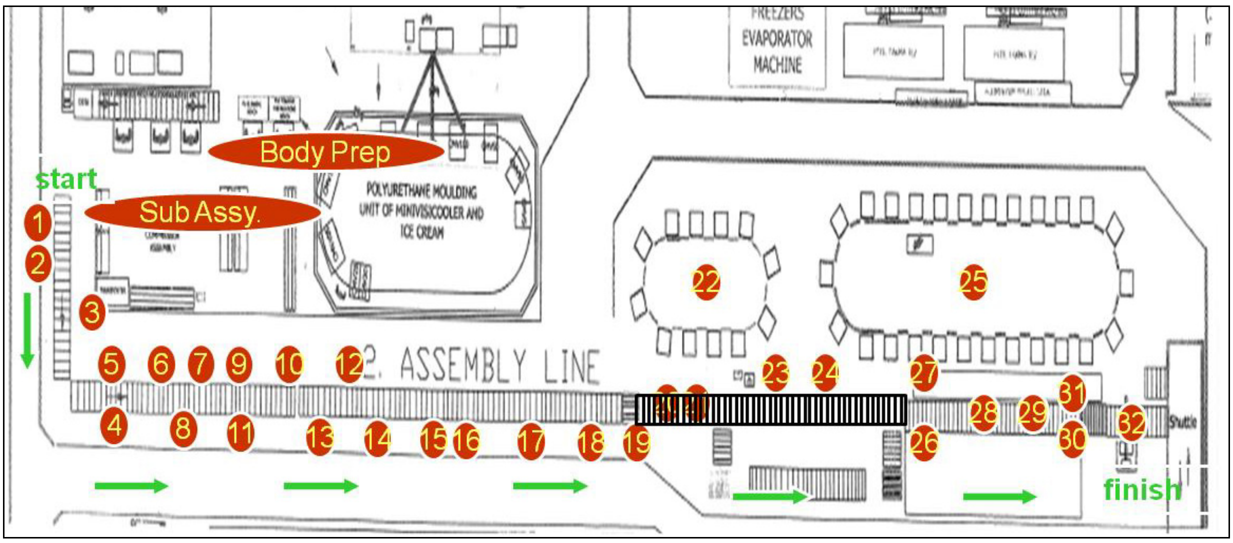



**Figure 4.9** Flow of Slim model on the line layout

Let's start to explain defining the current situation of the assembly line for balancing. Firstly, we defined a pilot model for the assembly line balancing. This model is called "Slim" which came from Poland plant at the end of last year. So, we needed to balance the final assembly processes of Slim. To start balancing, firstly we analyzed the operators while they were producing the Slim. After that we wrote an explanation of operations to a balancing table in MS Excel format. While analyzing operators' jobs we signed off-line operations. It means that we defined non value-adding activities at the same time. After we finished writing operations, we took 15 measurements for each operation by timer. Here, the operations must be in the same sequence as they appear on cooler's assembly sequence. Every task should be split in the minimum possible time period per operator All of this information was written into the Excel table shown below.

Working tasks (1)

Operator No (2) and respective time (3) per operator in second

Operator No (4) corresponding to task

In the table, operator 1 performs his first operation which is bending mechanism support base in 5 seconds.

**Table 4.1** Table of line balancing which shows operator's times

Operation — Operators — Time (sec) — Operator no

| | | | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|
| **1** | bend mechanism support base (Destek çıtasını eğ) | 1 | | 5 | | | |
| **2** | fix left and right pillars to the cabin (Sağ ve sol dikmeleri kabine sabitle) | 1-2 | | 30 | 30 | | |
| **3** | fix external cabins support to the cabin (Kabin iç destek çıtasını kabine sabitle) | 1-2 | | 10 | 10 | | |
| **4** | assembly wheels to the shaft (Tekerlekleri tekerlek şaftına monte et) | 2 | | | 18 | | |
| **5** | screw wheels to the cabin's base (Tekerlekleri kabinin tabanına vidala) | 1-2 | | 24 | 24 | | |
| **6** | fixing 2 legs bases (2 ayağı kabinin alt kısmına sabitle) | 1-2 | | 12 | 12 | | |
| **7** | assemby handle (sac tutamağını monte et ) | 1-2 | | 16 | 16 | | |
| **8** | screw (2+2) back cabin metal to the back side (arka gövde sacını vidala | 1-2 | | 30 | 15 | | |
| **9** | move wooden pallet to the line (Tahta paleti hatta koy) | 2 | | | 5 | | |
| **10** | move cabin on wooden pallet (Kabini tahta palet üzerine koy) | 1-2 | | 6 | 6 | | |
| **11** | screwing plate to the cabin's base (Alt gövde sacını kabinin temeline vidala) | 1-2 | | 27 | 27 | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **12** | turn over cabin (Kabini çevir) | 2 | | | 5 | | |
| **off** | preparing legs (ayak hazırlama) | 1 | | 15 | | | |
| | | | | | | | |
| **1** | place copper tubes and plastic hoses to the plate (4+4) (Bakır boruları ve plastik boruları alt gövde sacına yerleştir) | 3 | | | | 8 | |
| **2** | assy evap. Box+compr. Drip tray (Evaporatör kutusunu ve kompresör su tasını birbirine monte et) | 3 | | | | 20 | |
| **3** | place (Evap. Box+Compr.drip tray) onto the plate (Evap kutusu+kompresör su tasını kabin tabanına yerleştir) | 3 | | | | 12 | |
| **4** | enlarge evap.'s hangers (evap'ın kancalarını genişlet) | 3 | | | | 10 | |
| **5.1** | stick 1 sponge to evap. motor (1. süngeri evap. motoruna yapıştır) | 3 | | | | 6 | |
| **5.2** | stick 1 sponge to evap. motor (2. süngeri evap. motoruna yapıştır) | 3 | | | | 6 | |
| **6 (off)** | put probe cable into macaron (Prob kablosunu makaronun içinden geçir) | 3 | | | | 5 | |
| **7 (off)** | place probe sensor into evaporator (Prob sensörünü evap.'ın içine yerleştir) | 3 | | | | 8 | |
| **8** | place evap in to evap box (Evaporatörü evap kutusuna yerleştir) | 3 | | | | 14 | |
| **9 (off)** | cut and stick 2 pieces sponges to evap top side (2 adet süngeri kes ve evap.ın tavanına yapıştır) | 3 | | | | 8 | |
| **10** | place evap top side (Evaporatörün üst metal parçasını evaporatöre yerleştir) | 3 | | | | 5 | |
| **11** | screw evap top side (2screws) (Evap.'ın üst metal parçasını vidala (2 vida) | 3 | | | | 14 | |
| **12** | stick dryer tube with mastich to evap box's hole (Dryer borularını macunla evap kutusunun deliğine yapıştır) | 3 | | | | 10 | |
| **off** | cut white plastic hose in 4 pcs (Beyaz plastik tüpleri kes (4 pcs) | 3 | | | | 4 | |
| **off** | bring evap box(4 adet evap kutusu getir) | 3 | | | | 3 | |
| **off** | bring compressor drip tray (black 10pcs/time) (Kompresör su tasını getir) | 3 | | | | 1 | |
| **off** | bring evap. (20pcs/each time) (Evaporatör getir) | 3 | | | | 1 | |
| **off** | cut macaron (Makaronu kes) | 3 | | | | 3 | |
| **off** | cut prob cable's fastening material (Prob kablosunun kablo tutucusunu kes) | 3 | | | | 3 | |

If we explain the table, every task is written with minimum possible time. For every operation we gave operator numbers to the assembly queue. We wrote operators time stair shape as a Gantt chart. These operator times are the average of 15 measurements for every operation. And for non value-adding activities we took notes like “off”. While balancing the line, those “off” notes will make the improvement easier for us.

When we finished writing operations and times for each operation there would be some calculations for the line:

**Output;** How many coolers were produced for per shift (per shift is 540 minutes). We will balance the line to this value. This value is given as our target.

**Operator's working time per cycle;** Total of operator times which are measured by timer.

**Average operator's working time per cycle;** Average of all operator's working time per cycle.

**Operator's efficiency;** It shows saturity of operator.

Operator's working time per cycle / (540min*60sec/output)

**Average efficiency;** It shows average of operator's efficiency

Average operator's working time per cycle / (540min*60sec/output)

**Balancing ratio;** Average operator's working time per cycle / Maximum operator's working time per cycle

We can explain Slim model's values as follows:

*Output* is given as 155 to us, we will balance the line to this output.

*Operator's working time per cycle* is for operator 1 is total of his operations (5+30+10+22+12+13+30+6+27+15=170 sec) is equal to 170 seconds.

*Average operator's working time per cycle* is calculated by summing all operation times of 32 operators after dividing the number of operators, 32.

*Operator's efficiency* is for operator 1 is 0,81. It means he uses 81% of his cycle time. We can calculate this value as follows: 170sec/(540*60/155) = 81%, here 540 minute is one shift time, we turn it to seconds by multiplying by 60. When we divide it by 155 outputs, we find the cycle time as 167 seconds.

*Average efficiency* is calculated by summing all efficiencies of 32 operators after dividing by the number of operator, 32. For this example average efficiency is 55%. That means operators average use 55% of their cycle time which is 167 seconds.

*Balancing ratio* is 42%. It is calculated by dividing the average of all 32 operator's working time by the maximum operator working time. To have good balanced line we should increase this value approximately by 80%.

**Table 4.2** Values of line balancing table

Output | Average efficieny | Average operator working time | Operator's working time per cycle | Operator's efficiency

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Max efficiency | 131,6% | | 0,81 | 0,80 | 0,67 |
| | | Min efficiency | 23,0% | | | | |
| | | | | | 3 | 1 | |
| | | 155 | | | 167 | 167 | 167 |
| | | | 115 | | 70 | 168 | 141 |
| | | average efficiency | 55,0% | Current | 1 | 2 | 3 |
| 1-2 | 1 | bend mechanism support base (Destek çıtasını eğ) | 1 | | 5 | | |
| | 2 | fix left and right pillars to the cabin (Sağ ve sol dikmeleri kabine sabitle) | 1-2 | | 30 | 30 | |
| | 3 | fix external cabins support to the cabin (Kabin iç destek çıtasını kabine sabitle) | 1-2 | | 10 | 10 | |
| | 4 | assembly wheels to the shaft (Tekerlekleri tekerlek şaftına monte et) | 2 | | | 18 | |
| | 5 | screw wheels to the cabin's base (Tekerlekleri kabinin tabanına vidala) | 1-2 | | 22 | 22 | |
| | 6 | fixing 2 legs bases (2 ayağı kabinin alt kısmına sabitle) | 1-2 | | 12 | 12 | |
| | 7 | assemby handle (sac tutamağını monte et ) | 1-2 | | 13 | 13 | |
| | 8 | screw (2+2) back cabin metal to the back side (arka gövde sacını vidala | 1-2 | | 30 | 15 | |
| | 9 | move wooden pallet to the line (Tahta paleti hatta koy) | 2 | | | 5 | |
| | 10 | move cabin on wooden pallet (Kabini tahta palet üzerine koy) | 1-2 | | 6 | 6 | |
| | 11 | screwing plate to the cabin's base (Alt gövde sacını kabinin temeline vidala) | 1-2 | | 27 | 27 | |
| | 12 | turn over cabin (Kabini çevir) | 2 | | | 5 | |
| | off | match left and right pillars | 1 | | | 5 | |
| | off | preparing legs (ayak hazırlama) | 1 | | 15 | | |
| | | | | | | | |
| 3 | 1 | place copper tubes and plastic hoses to the plate (4+4) (Bakır boruları ve plastik boruları alt gövde sacına yerleştir) | 3 | | | | 8 |
| | 2 | assy evap. Box+compr. Drip tray (Evaporatör kutusunu ve kompresör su tasını birbirine monte et) | 3 | | | | 20 |
| | 3 | place (Evap. Box+Compr.drip tray) onto the plate (Evap kutusu+kompresör su tasını kabin tabanına yerleştir) | 3 | | | | 12 |
| | 4 | enlarge evap.'s hangers (evap'ın kancalarını genişlet) | 3 | | | | 10 |
| | 5.1 | stick 1 sponge to evap. motor (1. süngeri evap. motoruna yapıştır) | 3 | | | | 6 |
| | 5.2 | stick 1 sponge to evap. motor (2. süngeri evap. motoruna yapıştır) | 3 | | | | 6 |
| | 6 (off) | put probe cable into macaron (Prob kablosunu makaronun içinden geçir) | 3 | | | | 5 |
| | 7 (off) | place probe sensor into evaporator (Prob sensörünü evap.'ın içine yerleştir) | 3 | | | | 8 |
| | 8 | place evap in to evap box (Evaporatörü evap kutusuna yerleştir) | 3 | | | | 14 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **9 (off)** | cut and stick 2 pieces sponges to evap top side (2 adet süngeri kes ve evap.ın tavanına yapıştır) | 3 | | | | 8 |
| | **10** | place evap top side (Evaporatörün üst metal parçasını evaporatöre yerleştir) | 3 | | | | 5 |
| | **11** | screw evap top side (2screws) (Evap.'ın üst metal parçasını vidala (2 vida) | 3 | | | | 14 |
| | **12** | stick dryer tube with mastich to evap box's hole (Dryer borularını macunla evap kutusunun deliğine yapıştır) | 3 | | | | 10 |
| | **off** | cut white plastic hose in 4 pcs (Beyaz plastik tüpleri kes (4 pcs) | 3 | | | | 4 |
| | **off** | bring evap box(4 adet evap kutusu getir) | 3 | | | | 3 |
| | **off** | bring compressor drip tray (black 10pcs/time) (Kompresör su tasını getir) | 3 | | | | 1 |
| | **off** | bring evap. (20pcs/each time) (Evaporatör getir) | 3 | | | | 1 |
| | **off** | cut macaron (Makaronu kes) | 3 | | | | 3 |
| | **off** | cut prob cable's fastening material (Prob kablosunun kablo tutucusunu kes) | 3 | | | | 3 |

Thus, when we found all these values, we finished the data collection step. Now, we can see the current values of the line which are short or long operation times, non-value-adding activities, difficult or easy operations, capable or incapable operators, efficiency of line and operators, saturity of line and operators. We can see all operations together which occurred in the way shown in appendix A.

### 4.4.2 Current Status Improvement

Firstly, we will define AD method FRs and DPs results by explaining correlation between applications. Aftr that we will tell line improvement which is one of the result of AD method.

FR2211: Carry what is needed
DP2211: Apply milkrun

Instead, “apply milkrun” relates to “prevent overproduction”. Because if you carry what is needed you cannot find excess material in the production area, so that you could not overproduce. In addition, we started in our company to apply milkrun for 3 production lines. Milkrun bring materials from the material warehouse to the production warehouse. After that, the production warehouse prepares materials adequate for 2 hours and milkrun takes away these materials to the assembly lines per 2 hours to the production plan. So that they can produce what is planned.


**Figure 4.10** Some photos of material handling system (milkrun)

FR31: Define operations

FR32: Define current information level

FR33: Define needed trainings

FR34: Realize trainings

FR35: Analyze adequacy of knowledge level of operators

FR36: Visualization of results

Design parameters of these FRs are as follows:

DP31: Apply standard operation procedures

DP32: Do practical examination

DP33: Training matrix

DP34: Apply training plan

DP35: Do practical exam

DP36: Skill matrix

When you define standard operation procedures, operators know which operation should do and they do written operations in the standard operation procedures. So, we prevent applying needless operations too. To ensure that we prepare standard operation procedures for our products. And to these procedures, we prepared a training plan for operators. Now, we continue to train operators. After the training is completed, we prepare skill matrices for operators which shows their capacity about the operation.

FR41: Ensure continuity of information flow between departments

DP41: Application of report system and visualization

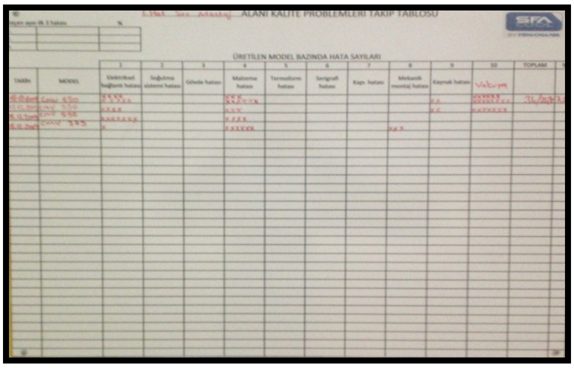
In order to increase and ensure the continuity of information flow, we defined key performance indicators and prepared charts to track them. After that, we prepared boards which contained all these indicators for every department to ensure visualizaiton. So, everybody can see whenever they want to learn values of indicators. If there is a problem when the department operative visits this board he/she can see the problem and communicate with the related department or person and solve the problem easily.

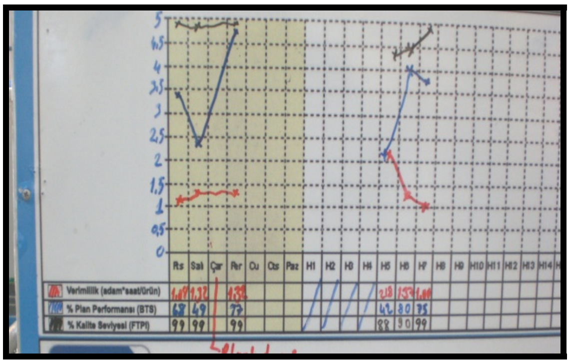
FR4121: Control and track data system

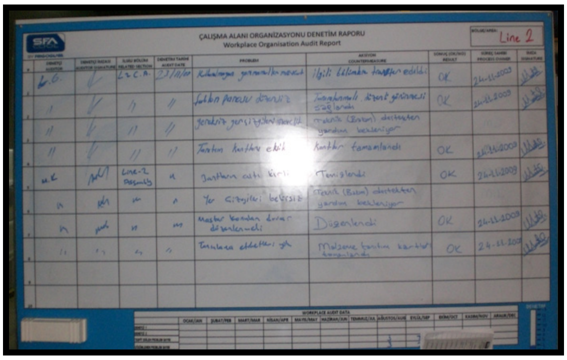
DP4121: Assign responsible people

As it is written at FR4121, we need responsible people to check and track the data. Otherwise we will not know who will input these data to the tables and how we could track. To prevent that, we defined area responsibles who are responsible for input of data. For example, at end of every hour these people write produced numbers to the production table. If they have a problem or stoppage etc. at the time of production, they input these data to the boards and give information to the department supervisor.

Some examples of tracking boards are given below. The first is the quality problems board, the second being the performance indicators (performance, productivity, quality) tracking board, the third is the area audit board, the fourth is the hourly production figures board, the fifth is the department's request and the last one is the production plan board.


ALANI KALİTE PROBLEMLERİ TAKİP TABLOSU
ÜRETİLEN MODEL BAZINDA HATA SAYILARI


Verimlilik (adam*saat/Ürün)
% Plan Performansı (BTS)
% Kalite Seviyesi (FTPI)


ÇALIŞMA ALANI ORGANİZASYONU DENETİM RAPORU
Workplace Organisation Audit Report


SAATLİK ÜRETİM TAKİP PANOSU
TARİH
SAAT
MODEL
HEDEF
ÜRETİLEN
SAPMA
ADET
TOPLAM
SAPMA NEDENİ

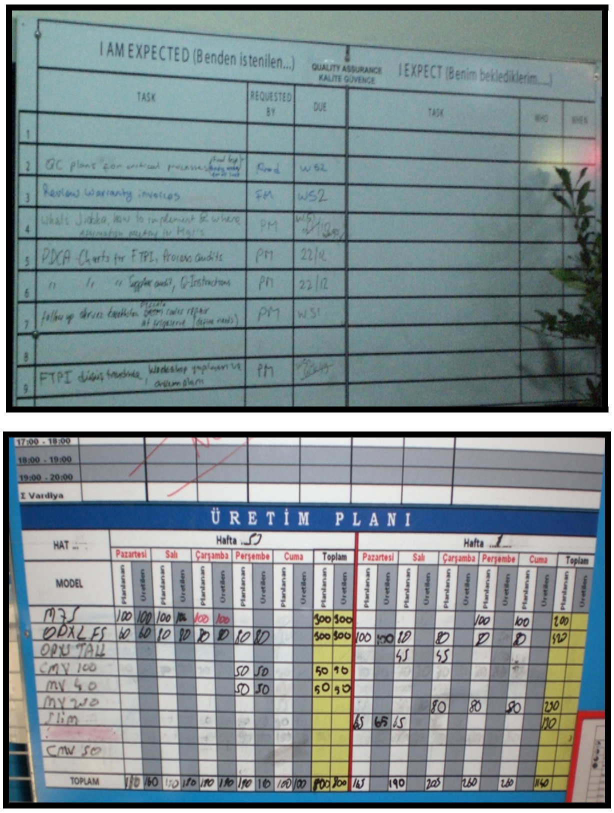



**Figure 4.11** Some examples of communication boards

Any possibility for the process/operation improvement should be studied in this step of the methodology. Potential benefits of these changes should be evaluated. If any change is decided, it should be considered when implementing task allocation. Accordingly we did improvements, rearrangements and task allocations, and made some operations easier. To realize these we followed the following principles:

- Distribute the working tasks to operators. The operators should be occupied with tasks of maximum duration in order to fill efficiently their available time.
- Try different combinations of tasks allocation, aiming at balancing the working time per operator till the best scenario is found.
- However, the general instruction is that operator's working time should not exceed the available time.

According to these principles, we did these improvements and changes (these are written into the operator's unbalanced positions):

**1.** Operators 1 and 2 match the left and right pillar of the body before assembly. It takes extra time. It means that it is a non-value adding operation. To prevent that we spoke with the mechanical department and, now they will send matched pillars to the assembly line.

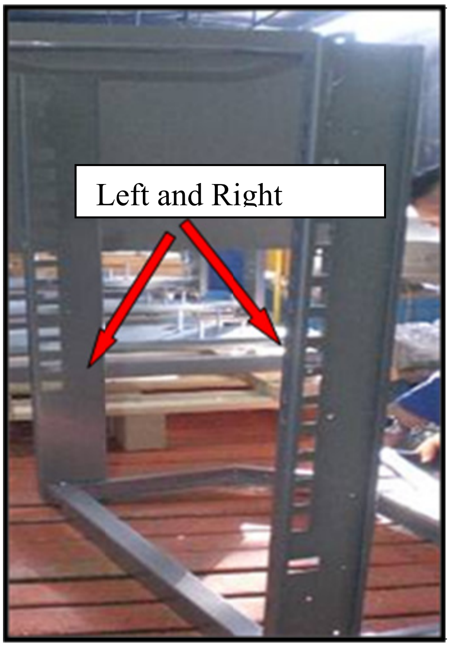



**Figure 4.12** Photo of improvement 1

**Table 4.3** Operation times of operators 1 and 2

| | | | | 167<br>165<br>1 | 167<br>163<br>2 |
|---|---|---|---|---|---|
| 1-2 | 1 | bend mechanism support base (Destek çıtasını eğ) | 1 | 5 | |
| | 2 | fix left and right pillars to the cabin (Sağ ve sol dikmeleri kabine sabitle) | 1-2 | 25 | 25 |
| | 3 | fix external cabins support to the cabin (Kabin iç destek çıtasını kabine sabitle) | 1-2 | 10 | 10 |
| | 4 | assembly wheels to the shaft (Tekerlekleri tekerlek şaftına monte et) | 2 | | 18 |
| | 5 | screw wheels to the cabin's base (Tekerlekleri kabinin tabanına vidala) | 1-2 | 22 | 22 |
| | 6 | fixing 2 legs bases (2 ayağı kabinin alt kısmına sabitle) | 1-2 | 12 | 12 |
| | 7 | assemby handle (sac tutamağını monte et ) | 1-2 | 13 | 13 |
| | 8 | screw (2+2) back cabin metal to the back side (arka gövde sacını vidala | 1-2 | 30 | 15 |
| | 9 | move wooden pallet to the line (Tahta paleti hatta koy) | 2 | | 5 |
| | 10 | move cabin on wooden pallet (Kabini tahta palet üzerine koy) | 1-2 | 6 | 6 |
| | 11 | screwing plate to the cabin's base (Alt gövde sacını kabinin temeline vidala) | 1-2 | 27 | 27 |
| | 12 | turn over cabin (Kabini çevir) | 2 | | 5 |
| | off | match left and right pillars | 1 | | 5 |
| | off | preparing legs (ayak hazırlama) | 1 | 15 | |

There will be 2 welding operators on the line which are operators 4 and 8.

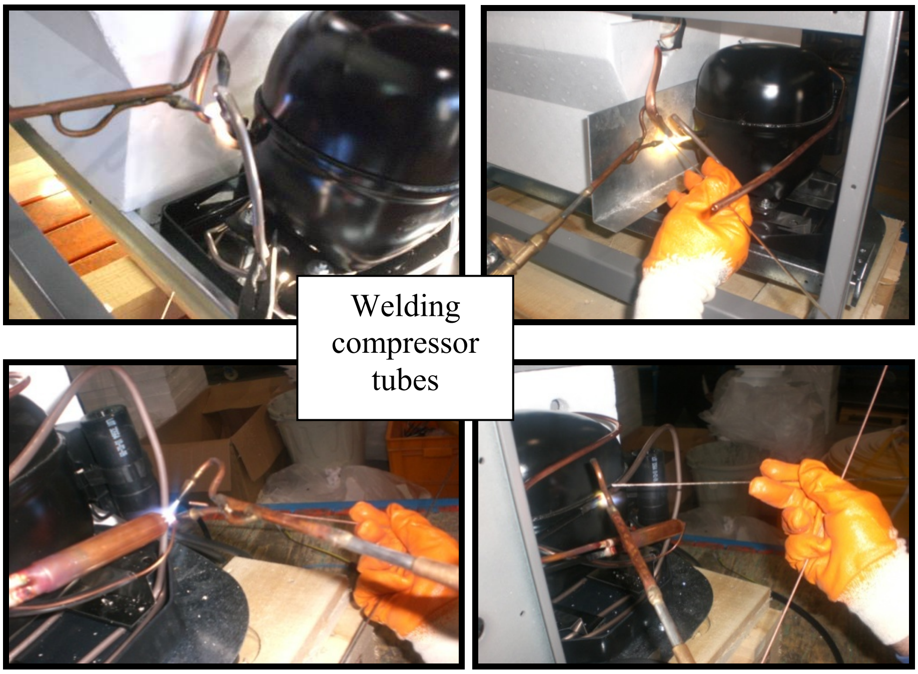



**Figure 4.13** Photos of welding operation

**2.** Operator 4 places the evaporation tube, then places two fixing metals onto the evaporation tube, and prepares fixing metals. These operations (first two operations and fixing metal preparation) were given to operator 3 who assemblies the evaporator to the body.

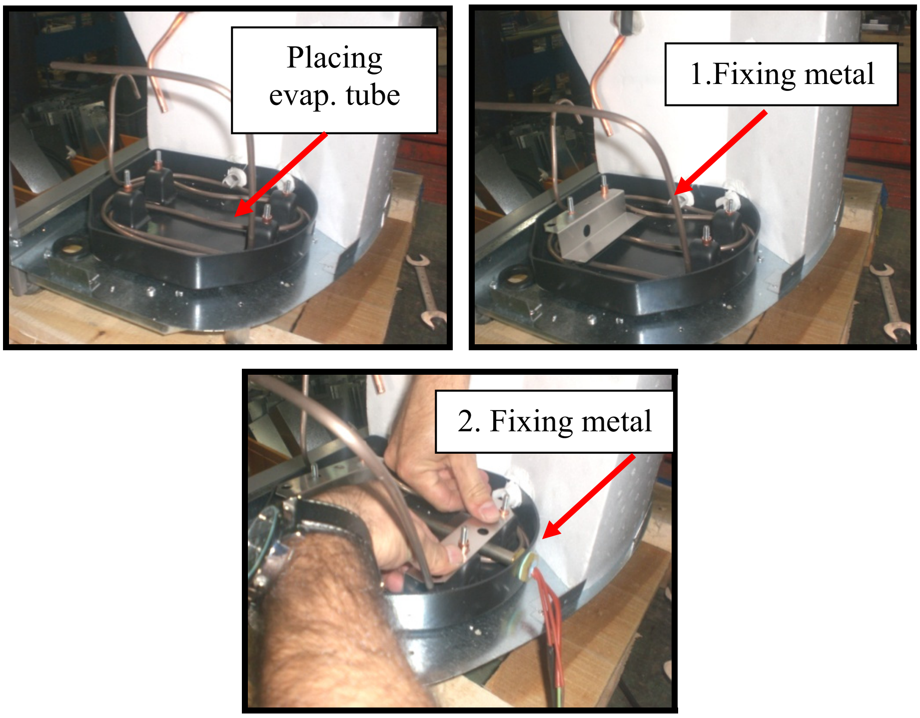



**Figure 4.14** Some photos of assembly fixing metal

**Table 4.4** Befpore balancing operation times of improvement 3 and 4

| | | | | 167 | 167 |
|---|---|---|---|---|---|
| | | | | 141 | 92 |
| | | | | **3** | **4** |
| 4 | **1** | place evaporation tube into drip tray (to eliminate water) (buharlaştırma borusunu su tasına yerleştir) | 4 | | 8 |
| | **2** | put 2 evaporator tube fix metal onto the evaporator tube (2 adet buh. borusu sabitleme sacını buh. borusu üzerine koy) | 4 | | 6 |
| | **3** | place compressor into the drip tray (kompresörü su tasına yerleştir) | 4 | | 12 |
| | **4** | arrange tubes and put compressor's cable into the oring (boruları düzenle ve kompresörün kablosunu oringten geçir) | 4 | | 6 |
| | **5** | place spacer and washer and screw them (set from 4) (pul, civata ve vidayı yerleştir ve vidala) | 4 | | 45 |
| | **6** | put the cooler on the green pallet (soğutucuyu yeşil paletin üzerine koy) | 4 | | 5 |
| | **off** | bring green pallet (yeşil paleti getir) | 8 | | |
| | **off** | put green pallet (yeşil paleti koy) | 8 | | |
| | **off** | stick sponge to the 2 evaporator fix metals (2 buh. borusu sabitleme sacına sünger yapıştır) | 4 | | 10 |

**Table 4.5** After balancing operation times of improvement 3

| | | | | |
|---|---|---|---|---|
| | | | | 167 |
| | | | | 165 |
| | | | | 3 |
| 3 | 1 | place copper tubes and plastic hoses to the plate (4+4) (Bakır boruları ve plastik boruları alt gövde sacına yerleştir) | 3 | 8 |
| | 2 | assy evap. Box+compr. Drip tray (Evaporatör kutusunu ve kompresör su tasını birbirine monte et) | 3 | 20 |
| | 3 | place (Evap. Box+Compr.drip tray) onto the plate (Evap kutusu+kompresör su tasını kabin tabanına yerleştir) | 3 | 12 |
| | 4 | enlarge evap.'s hangers (evap'ın kancalarını genişlet) | 3 | 10 |
| | 5.1 (off) | stick 1 sponge to evap. motor (1. süngeri evap. motoruna yapıştır) | 3 | 6 |
| | 5.2 (off) | stick 1 sponge to evap. motor (2. süngeri evap. motoruna yapıştır) | 3 | 6 |
| | 6 (off) | put probe cable into macaron (Prob kablosunu makaronun içinden geçir) | 3 | 5 |
| | 7 (off) | place probe sensor into evaporator (Prob sensörünü evap.'ın içine yerleştir) | 3 | 8 |
| | 8 | place evap in to evap box (Evaporatörü evap kutusuna yerleştir) | 3 | 14 |
| | 9 (off) | cut and stick 2 pieces sponges to evap top side (2 adet süngeri kes ve evap.ın tavanına yapıştır) | 3 | 8 |
| | 10 | place evap top side (Evaporatörün üst metal parçasını evaporatöre yerleştir) | 3 | 5 |
| | 11 | screw evap top side (2screws) (Evap.'ın üst metal parçasını vidala (2 vida) | 3 | 14 |
| | 12 | stick dryer tube with mastich to evap box's hole (Dryer borularını macunla evap kutusunun deliğine yapıştır) | 3 | 10 |
| | 14 | place evaporation tube into drip tray (to eliminate water) (buharlaştırma borusunu su tasına yerleştir) | 3 | 8 |
| | 15 | put 2 evaporator tube fix metal onto the evaporator tube (2 adet buh. borusu sabitleme sacını buh. borusu üzerine koy) | 3 | 6 |
| | off | cut white plastic hose in 4 pcs (Beyaz plastik tüpleri kes (4 pcs) | 3 | 4 |
| | off | bring evap box(4 adet evap kutusu getir) | 3 | 3 |
| | off | bring compressor drip tray (black 10pcs/time) (Kompresör su tasını getir) | 3 | 1 |
| | off | bring evap. (20pcs/each time) (Evaporatör getir) | 3 | 1 |
| | off | stick sponge to the 2 evaporator fix metals (2 buh. borusu sabitleme sacına sünger yapıştır) | 3 | 10 |
| | off | cut macaron (Makaronu kes) | 3 | 3 |
| | off | cut prob cable's fastening material (Prob kablosunun kablo tutucusunu kes) | 3 | 3 |

These operations in red letters come from operator 4 to operator 3

**3.** Condenser fan motor is turning one tour to fit to the body. This is a non-value adding operation. We told that to the supplier, and they started to send turned condenser fans.

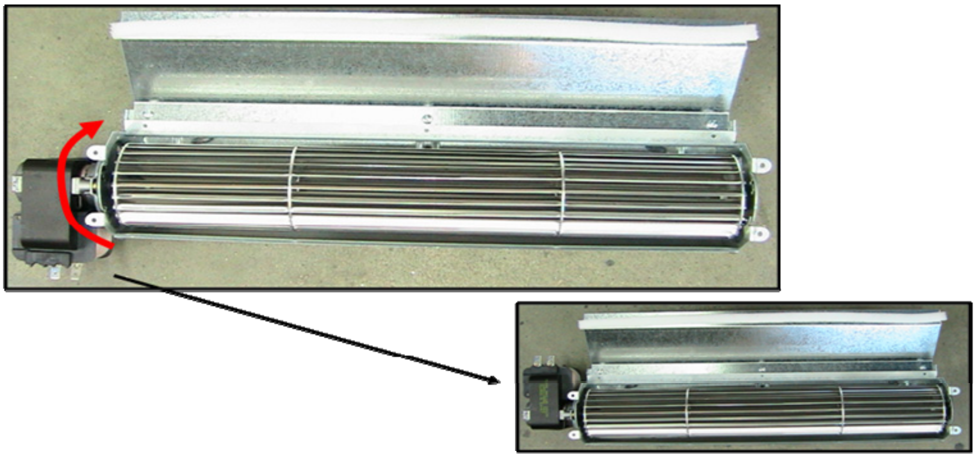


**Figure 4.15** Photos of turning condenser

**4.** While assembling the compressor to the body, it is difficult to fix the back nuts, an action which requires the operator to spend extra time. This is a non-value adding operation. To make easier the compressor assembly to the body we use “L” shape screw gun, so that operator will screw easily.

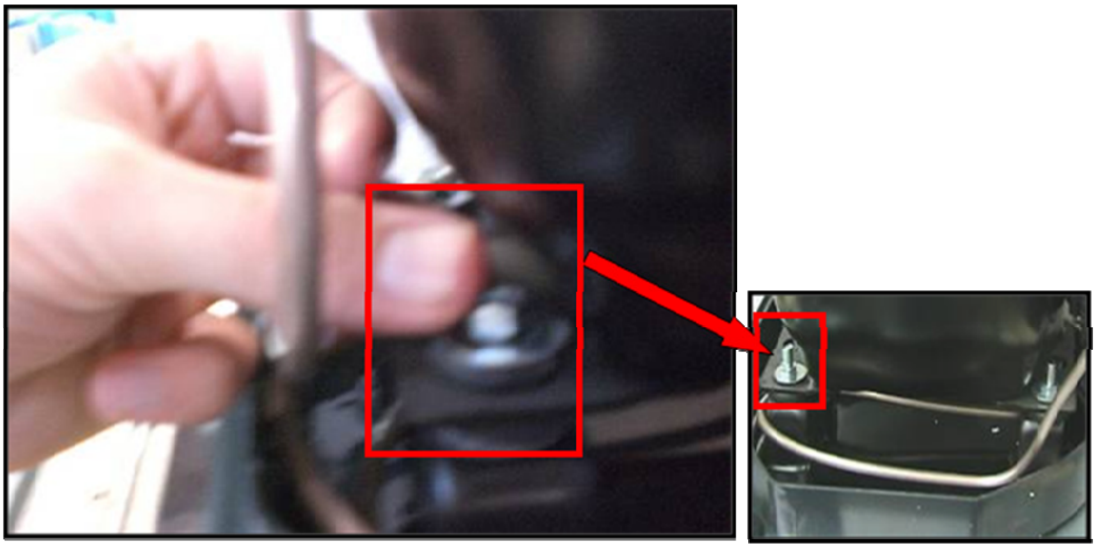


**Figure 4.16** Photos of compressor back nuts

**Table 4.6** Before and after operation times of improvement 4

| | | | | 92 |
|---|---|---|---|---|
| 4 | 1 | place evaporation tube into drip tray (to eliminate water) (buharlaştırma borusunu su tasına yerleştir) | 4 | 8 |
| | 2 | put 2 evaporator tube fix metal onto the evaporator tube (2 adet buh. borusu sabitleme sacını buh. borusu üzerine koy) | 4 | 6 |
| | 3 | place compressor into the drip tray (kompresörü su tasına yerleştir) | 4 | 12 |
| | 4 | arrange tubes and put compressor's cable into the oring (boruları düzenle ve kompresörün kablosunu oringten geçir) | 4 | 6 |
| | 5 | place spacer and washer and screw them (set from 4) (pul, civata ve vidayı yerleştir ve vidala) | 4 | 45 |
| | 6 | put the cooler on the green pallet (soğutucuyu yeşil paletin üzerine koy) | 4 | 5 |
| | off | bring green pallet (yeşil paleti getir) | 8 | |
| | off | put green pallet (yeşil paleti koy) | 8 | |
| | off | stick sponge to the 2 evaporator fix metals (2 buh. borusu sabitleme sacına sünger yapıştır) | 4 | 10 |

| | | | | 150 |
|---|---|---|---|---|
| | | | | 4 |
| 4 | 1 | place compressor into the drip tray (kompresörü su tasına yerleştir) | 4 | 12 |
| | 2 | arrange tubes and put compressor's cable into the oring (boruları düzenle ve kompresörün kablosunu oringten geçir) | 4 | 6 |
| | 3 | place spacer and washer and screw them (set from 4) (pul, civata ve vidayı yerleştir ve vidala) | 4 | 35 |
| | 4 | put the cooler on the green pallet (soğutucuyu yeşil paletin üzerine koy) | 4 | 5 |
| | 5 | eject stickers from compressor tubes (kompresör borularının etiketilerini çıkar) | 4 | 7 |
| | 6 | eject cap from evaporation tube (buharlaştırma borusundan kapağı çıkar) | 4 | 3 |
| | 7 | eject cap from compressor tube (kompresör borusundan kapağı çıkar) | 4 | 3 |
| | 8 | enlarge compressor tubes (Kompresör borularını genişlet) | 4 | 10 |
| | 9 | fix 1.compressor tube to evap.'s tube (1.kompresör borusunu evap.'ın borusuna tak) | 4 | 13 |
| | 10 | fix 2.compressor tube to evaporation tube (2.kompresör borusunu buharlaştırma borusuna tak) | 4 | 8 |
| | 11 | put soldering metal (lehimleme metalini koy) | 4 | 3 |
| | 12 | bring solder gun (lehim tabancasını getir) | 4 | 5 |
| | 13 | solder 1. compressor tube to the evap's tube (1. kompresör borusunu evap'ın borusuna lehimle) | 4 | 22 |
| | 14 | solder 2. compressor tube to the evaporation tube (2. kompresör borusunu buharlaştırma borusuna lehimle) | 4 | 15 |
| | 15 | take the soldering metal (lehimleme metalini al) | 4 | 3 |

**5.** Operator 5 prepares tubes for welding before welding. He does at 3 sections his work. Operator 5's first section works were given to operator 4, the second section works were given to operator 7 and the third section works were given to operator 6. So, we will not need the welding preparation operator. We eliminated this operator.

**Table 4.7** Before and after operation time of improvement 5

| | | | | 150 |
|---|---|---|---|---|
| | | | | 4 |
| 4 | 1 | place compressor into the drip tray (kompresörü su tasına yerleştir) | 4 | 12 |
| | 2 | arrange tubes and put compressor's cable into the oring (boruları düzenle ve kompresörün kablosunu oringten geçir) | 4 | 6 |
| | 3 | place spacer and washer and screw them (set from 4) (pul, civata ve vidayı yerleştir ve vidala) | 4 | 35 |
| | 4 | put the cooler on the green pallet (soğutucuyu yeşil paletin üzerine koy) | 4 | 5 |
| | 5 | eject stickers from compressor tubes (kompresör borularının etiketilerini çıkar) | 4 | 7 |
| | 6 | eject cap from evaporation tube (buharlaştırma borusundan kapağı çıkar) | 4 | 3 |
| | 7 | eject cap from compressor tube (kompresör borusundan kapağı çıkar) | 4 | 3 |
| | 8 | enlarge compressor tubes (Kompresör borularını genişlet) | 4 | 10 |
| | 9 | fix 1.compressor tube to evap.'s tube (1.kompresör borusunu evap.'ın borusuna tak) | 4 | 13 |
| | 10 | fix 2.compressor tube to evaporation tube (2.kompresör borusunu buharlaştırma borusuna tak) | 4 | 8 |
| | 11 | put soldering metal (lehimleme metalini koy) | 4 | 3 |
| | 12 | bring solder gun (lehim tabancasını getir) | 4 | 5 |
| | 13 | solder 1. compressor tube to the evap's tube (1. kompresör borusunu evap'ın borusuna lehimle) | 4 | 22 |
| | 14 | solder 2. compressor tube to the evaporation tube (2. kompresör borusunu buharlaştırma borusuna lehimle) | 4 | 15 |
| | 15 | take the soldering metal (lehimleme metalini al) | 4 | 3 |

These come from operator 5 to operator 4

**Table 4.8** Before and after operation times for improvement 6

| | | | | 153 |
|---|---|---|---|---|
| | | | | 5 |
| 5 | 1 | make colder solder area (lehim yapılan bölgeyi soğut) | 5 | 15 |
| | 2 | fix insulation sponge (izolasyon süngerini tak) | 5 | 7 |
| | 3 | fix first fastening material to the isolation sponge (İzolasyon süngerine 1. kablo bağını tak) | 5 | 5 |
| | 4 | fix second fastening material to the isolation sponge (İzolasyon süngerine 2. kablo bağını tak) | 5 | 7 |
| | 5 | cut end of fastening materials (kablo bağlarının ucunu kes) | 5 | 5 |
| | 6 | screw condenser blower metal to the cabin (6 screws) (kondenser fan sacını kabine vidala) | 5 | 40 |
| | 7 | put condenser blower cable inside clip (kondenser fan kablosunu klipsin içinden geçir) | 5 | 13 |
| | 9 | stick 2 sponges to the pillars (2 süngeri sağ ve sol dikmelere yapıştır) | 6 | |
| | 10 | take compressor and evap blower cable from front side to the back side (komp. ve evap fan kablosunu ön taraftan arka tarafa al) | 5-6 | 12 |
| | 11 | put prob cable through evap. box's hole (prob kablosunu evap'ın deliğinden geçir) | 6 | |
| | 12 | take the display and compressor cable from back side to the front side display ve komp. kablosunu arka taraftan ön tarafa al) | 5-6 | 15 |
| | 13 | screw blower to the blower metal (2+2 screws) (fanı fan sacına vidala) | 5 | 18 |
| | 14 | fix 2 cables (blue and yellow) to the blower (2 kabloyu fana tak) | 5 | 8 |
| | 15 | screw ground cable to the blower motor (topraklama kablosunu fan motoruna vidala) | 5 | 5 |
| | off | cut isolation sponge (izolasyon süngerini kes) | 5 | 3 |

These come from operator 5 to operator 7

| | | | | |
|---|---|---|---|---|
| | | | | 145 |
| | | | | 8 |
| 8 | 1 | turn the pallet (paleti çevir) | 5 | 5 |
| | 2 | arrange tubes (boruları düzenle) | 5 | 6 |
| | 3 | eject condenser tubes' cap (kondenser borularının şapkasını çıkar) | 5 | 5 |
| | 4 | fix condenser tube to the dual dryer tube (kondenser borusunu ikili dryer borusuna tak) | 5 | 20 |
| | 5 | fix condenser tube to the evaporation tube (Kondanser borusunu buharlaştırma borusuna tak) | 5 | 7 |
| | 6 | fix service tube to the dryer (servis borusunu dryer'e tak) | 5 | 8 |
| | 8 | take the solder gun (lehim tabancasını al) | 5 | 3 |
| | 9 | solder this tubes (bu boruları lehimle) | 5 | 25 |
| | 10 | fix again service tube to the dryer (servis borusunu tekrar dryer'a tak) | 5 | 3 |
| | 11 | take the solder gun (lehim tabancasını al) | 5 | 5 |
| | 12 | solder this tube (bu boruyu lehimle) | 5 | 25 |
| | 13 | soldering condenser's addition points (kondanserin ek noktasının kaynak teli yardımı ile sert lehimlenmesi) | 5 | 28 |
| | 14 | leave solder gun (salamanın yerine bırakılması) | 5 | 5 |

These come from operator 5 to operator 6

**6.** One subassembly operator prepares the condenser for the assembly. These operators' fixing internal and external condensers to each other operation is given to operator 9. And this subassembly operator's condenser welding operations are given to operator 6 (welding operator).

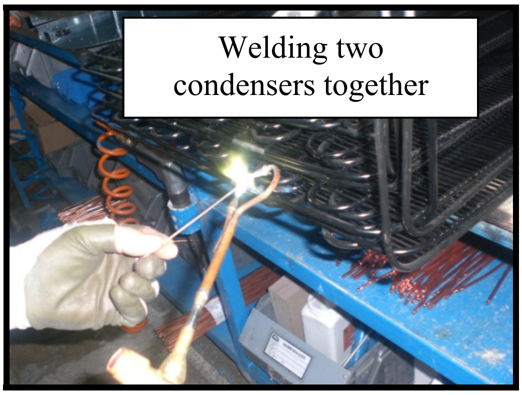



**Figure 3.17** Photo of welding operation

**Table 4.9** Table of improvement 6 times

| | | | | |
|---|---|---|---|---|
| | | | | 141 |
| | | | | 7 |
| 7 | 1 | screw internal condenser to the cabin (2+2) | 7 | 55 |
| | 2 | screw external condenser to the cabin (2+2) | 7 | 55 |
| | 3 | take internal condenser (İç kondanserin istiften alınarak tezgaha getirilmesi) | 7 | 3 |
| | 4 | take external condenser (Dış kondanserin istiften alınarak tezgaha getirilmesi) | 7 | 3 |
| | 5 | take conders' cap (Kondanser tapalarının çıkartılması) | 7 | 5 |
| | 6 | combine internal and external condensers (iç ve dış kondanser arasına ilave boru takılarak birleştirilmesi) | 7 | 20 |

These come from the subassy. operator

**7.** Operator 8 realizes his operations in 3 sections. His third section work is far from his place. Because of that, he walks a lot among sections, that makes him tired, and his performance goes down. So, that walking is a non-value adding activity which makes process longer. Additionally, this operator's operation time is longer than the cycle time. In the light of this information we gave operator 6's third section work which is screwing grounding cable that comes from clamps to the evaporator fan to operator 11.

**Table 4.10** Before and after operation time of improvement 7

| | | | | 157 |
|---|---|---|---|---|
| | | | | **9** |
| 9 | **1** | put evap. fan cable (blue cable) into the evap box and press it's end (evap fan kablosunu evap kutusundan geçir ve ucunu ez) | 9 | 12 |
| | **2** | fix evap fan cable (blue) to the evap blower (evap fan kablosunu evap fanına tak) | 9 | 5 |
| | **3** | press end of evap fan cable and fix it to the evap. blower-brown cable (evap fan kablosunun ucunu ez ve evap.fanına tak) | 9 | 12 |
| | **4** | screw grounding cable which comes from clemens to the evap. blower (klemensten gelen topraklama kablosunu evap. fanına vidala) | 9 | 25 |
| | **5** | arrange fan cables and prob (fan kablolarını ve prob kablosunu düzenle) | 9 | 8 |
| | **6** | fix fastening material to cables and prob cable onto the evap (kabloları ve prob kablosunu kablo bağı ile evap üstüne bağla) | 9 | 18 |
| | **7** | cut end of fastening material (kablo bağının ucunu kes) | 9 | 3 |
| | **8** | sealing into the evap box hole which evap blower cables comes from there with mastich (evap. box'da evap fan kabloların geçtiği deliğin içine mastikle kapat) | 9 | 5 |
| | **9** | sealing out of the evap box hole with mastich (evap. Box'da kabloların geçtiği deliğin dışını mastikle kapat) | 9 | 5 |
| | **10** | press end of compressor blower cable-brown and fix it to the comp. blower(kompresör fan kablosunun ucunu ez ve komp. fanına tak) | 9 | 7 |
| | **11** | press end of compressor blower cable-blue and fix it to the comp. blower (kompresör fan kablosunun ucunu ez ve komp. fanına tak) | 9 | 7 |
| | **12** | screw grounding cable to the compressor blower metal (topraklama kablosunu kompresör fan sacına vidala) | 9 | 22 |
| | **13** | arrange compressor blower metal cables (kompresör fan metali kablolarını düzenle) | 9 | 5 |
| | **14** | fix pineed fastening material to the cables (kabloları iğneli kablo bağı ile bağla) | 9 | 12 |
| | **15** | cut end of fastening material (kablo bağının ucunu kes) | 9 | 3 |
| | **16** | place evap. blower cables between compress and evap.box (evap fan kablolarını kompresör ile evap. box'ın arasına yerleştir) | 9 | 5 |
| | **17** | cut end of fastening material (kablo bağının ucunu kes) | 9 | 3 |

This come from operator 8

**8.** Operator 10's operation time is longer than the cycle time. That prevents the output number, because this is bottleneck for the Slim. And this operator works at two places. So, we gave this operator's second section works to a new operator. It means that to balance this operator's time we put one extra operator.

**Table 4.11** Before and after operation time of improvement 8

| | | | | 275 |
| --- | --- | --- | --- | --- |
| | | | | 10 |
| 10 (2.kısım) | 1 | screw adaptor (1 screw) (adaptörü vidala) | 10 | 10 |
| | 2 | arrange cables and fix fastening material (kabloları düzenle ve kablo bağını tak) | 10 | 67 |
| | 3 | fix 2 latches to the electronic thermostat (elektronik termostat 2 adet kelepçe tak) | 10 | 24 |
| | 4 | place black thermostat box (siyah termostat kutusunu yerleştir) | 10 | 25 |
| | 5 | screw black thermostat box (siyah termostat kutusunu vidala) | 10 | 27 |

| | | | | 153 |
| --- | --- | --- | --- | --- |
| | | | | 13 |
| 13-new operator | 1 | screw adaptor (1 screw) (adaptörü vidala) | 13 | 10 |
| | 2 | arrange cables and fix fastening material (kabloları düzenle ve kablo bağını tak) | 13 | 67 |
| | 3 | fix 2 latches to the electronic thermostat (elektronik termostat 2 adet kelepçe tak) | 13 | 24 |
| | 4 | place black thermostat box (siyah termostat kutusunu yerleştir) | 13 | 25 |
| | 5 | screw black thermostat box (siyah termostat kutusunu vidala) | 13 | 27 |

**9.** Operators 13 and 14's saturity is not enough. It means operators 13 and 14's operation times are shorter than the cycle time, so these operators have idle time to do other operations. To prevent that, we combined these two operators' operations. By doing that, we eliminated one more operator.

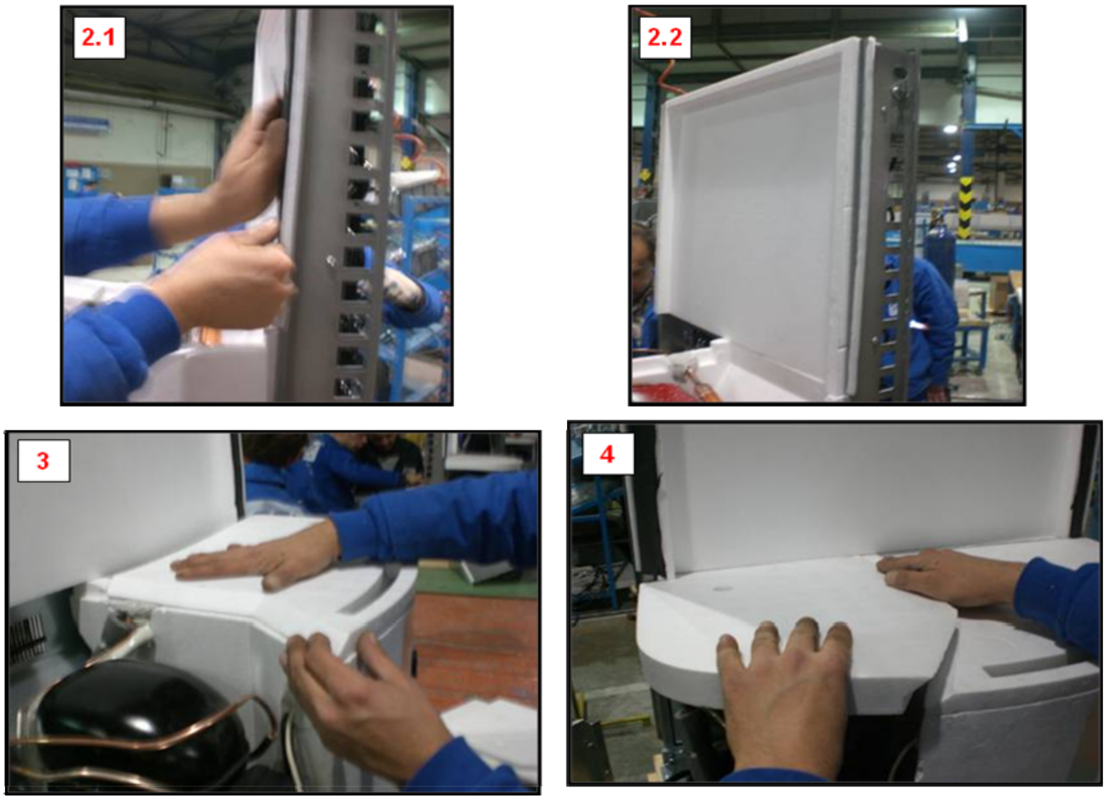



**Figure 3.18** Photos of improvement 9

**Table 4.12** Before and after operation time of improvement 9

| | | | | |
|---|---|---|---|---|
| | | | | 69 |
| | | | | 13 |
| 13 | 1 | place back eps to the metal (arka straforu saca yerleştir) | 13 | 6 |
| | 2 | stick 2 armouflex to the back eps (arka strafora 2 adet armaflex yapıştır) | 13 | 12 |
| | 3 | place evap. box eps cover to the evap. box (evap box strafor kapağını evap box kutusuna yerleştir) | 13 | 5 |
| | 4 (off) | cut a part from evap box eps cover (evap box strafor kapağından bir parça kes) | 13 | 5 |
| | 5 | stick aluminium tape on evap box eps cover (aliminyum bantı evap box strafor kapağına yapıştır) | 13 | 24 |
| | 6 | place compressor eps cover on the compressor (kompresör kapama straforunu kompresör üzerine yerleştir) | 13 | 4 |
| | 7 | squeeze silicon on the compressor eps cover (kompresör kapama staraforu üzerine silikon sık) | 13 | 5 |
| | off | bring evap. box eps cover, insulation eps and compressor cover eps (40-50 tane/each) (Evap üzeri strafor kapak, izolasyon straforu (arka sac üzerindeki) ve kompresör kapama straforunu getir) | 13 | 2 |
| | off | cut armaouflex (armaflexiler elle kesilip hazırlanır) | 13 | 3 |
| | off | cut aliminium tape (aliminyum bant kes) | 13 | 3 |

Operator 13's operations

| | | | | 103<br>14 |
|---|---|---|---|---|
| 14 | **1** | place and stick internal base metal on the evap. eps cover (iç taban sacını evap strafor kapağına yerleştir ve yapıştır) | 14 | 16 |
| | **2** | place internal back metal to the back metal (iç arka sacı arka saca yerleştir) | 14 | 10 |
| | **3** | put drainage tube's end into the drip tray (su tahliye borusunun ucunu su tasına koy) | 14 | 6 |
| | **4** | screw internal back metal to the cabin from the back side (2 screws) (iç arka sacı kabine vidala, vidalar kabinin arkasına vidalanacak) | 14 | 5 |
| | **5** | screw internal back metal to the cabin from the front right side (3 screws) (iç arka sacı kabine vidala, vidalar kabinin sağ ön tarafına vidalanacak) | 14 | 13 |
| | **6** | screw internal back metal to the cabin from the front left side (3 screws) (iç arka sacı kabine vidala) vidalar kabinin sol ön tarafına vidalanacak) | 14 | 13 |
| | **7** | screw mounting chanel for glass to the left side of internal back metal (cam yerleştirme kanalını iç arka metalin sol tarafına vidala) | 14 | 17 |
| | **8** | screw mounting chanel for glass to the right side of internal back metal (cam yerleştirme kanalını iç arka metalin sağ tarafına vidala) | 14 | 17 |
| | **9** | stick max load label into the cooler (max load etiketiketini kabinin içine yapıştır) | 14 | 6 |

Operator 14's operations

| Operator | No | Operation | | 166 |
|---|---|---|---|---|
| | | | | 12 |
| 12 | 1 | place back eps to the metal (arka straforu saca yerleştir) | 12 | 6 |
| 12 | 2 | stick 2 armouflex to the back eps (arka starafora 2 adet armaflex yapıştır) | 12 | 12 |
| 12 | 3 | place evap. box eps cover to the evap. box (evap box strafor kapağını evap box kutusuna yerleştir) | 12 | 5 |
| 12 | 4 (off) | cut a part from evap box eps cover (evap box strafor kapağından bir parça kes) | 12 | 5 |
| 12 | 5 | stick aluminium tape on evap box eps cover (aliminyum bantı evap box strafor kapağına yapıştır) | 12 | 24 |
| 12 | 6 | place compressor eps cover on the compressor (kompresör kapama straforunu kompresör üzerine yerleştir) | 12 | 4 |
| 12 | 7 | squeeze silicon on the compressor eps cover (kompresör kapama staraforu üzerine silikon sık) | 12 | 5 |
| 12 | 9 | place and stick internal base metal on the evap. eps cover (iç taban sacını evap strafor kapağına yerleştir ve yapıştır) | 12 | 16 |
| 12 | 8 | place internal back metal to the back metal (iç arka sacı arka saca yerleştir) | 12 | 10 |
| 12 | 10 | put drainage tube's end into the drip tray (su tahliye borusunun ucunu su tasına koy) | 12 | 6 |
| 12 | 11 | screw internal back metal to the cabin from the back side (2 screws) (iç arka sacı kabine vidala, vidalar kabinin arkasına vidalanacak) | 12 | 5 |
| 12 | 12 | screw internal back metal to the cabin from the front right side (3 screws) (iç arka sacı kabine vidala, vidalar kabinin sağ ön tarafına vidalanacak) | 12 | 13 |
| 12 | 13 | screw internal back metal to the cabin from the front left side (3 screws) (iç arka sacı kabine vidala) (vidalar kabinin sol ön tarafına vidalanacak) | 12 | 13 |
| 12 | 14 | screw mounting chanel for glass to the left side of internal back metal (cam yerleştirme kanalını iç arka metalin sol tarafına vidala) | 12 | 17 |
| 12 | 15 | screw mounting chanel for glass to the right side of internal back metal (cam yerleştirme kanalını iç arka metalin sağ tarafına vidala) | 12 | 17 |
| 12 | off | bring evap. box eps cover, insulation eps and compressor cover eps (40-50 tane/each) (Evap üzeri strafor kapak, izolasyon straforu (arka sac üzerindeki) ve kompresör kapama straforunu getir) | 12 | 2 |
| 12 | off | cut armaouflex (armaflexiler elle kesilip hazırlanır) | 12 | 3 |
| 12 | off | cut aliminium tape (aliminyum bant kes) | 12 | 3 |

We combined operators 13 and 14

In addition, to create enough time for combining operations, operator 14's sticking max load label operation is given to operator 19.

| Operator | No | Operation | | 56 |
|---|---|---|---|---|
| | | | | 17 |
| 17 | 1 | stick max load label into the cooler (max load etiketiketini kabinin içine yapıştır) | 17 | 6 |
| 17 | 2 | place 1. shelf into the cooler (1. rafı kabinin içine yerleştir) | 17 | 5 |
| 17 | 3 | screw 2. shelf into the cooler (2. rafı kabinin içine vidala) | 17 | 45 |

This operation come from operator 14

**10.** Operator 17 takes internal and external glass foils. But that doesn't take much time. This operator's operation doesn't fill his time. To increase saturity of operator 16 and eliminate this operator, we gave operator 17's operations to operator 16 who assembles the glasses of the cooler.

**Table 4.13** Before operation time of improvement 10

| | | | | 90 |
|---|---|---|---|---|
| | | | | **17** |
| **17** | **1** | take internal glass foil (iç cam koruyucu folyoyu çıkar) | 17 | 25 |
| | **2** | take external glass foil (dış cam koruyucu folyoyu çıkar) | 17 | 65 |

| | | | | 140 | 145 |
|---|---|---|---|---|---|
| | | | | **14** | **15** |
| **14-15** | **1** | squeeze silicon into the internal base metal (iç taban sacının içine silikon sık) | 14 | 25 | |
| | **2** | bring the internal glass (iç camı getir) | 15 | | 5 |
| | **3** | stick internal glass to the cabin (iç camı kabine yapıştır) | 14 | 30 | |
| | **4** | screw internal glass from right side (2 screws) (iç camı iç arka metal saca sağ taraftan vidala | 14 | 17 | |
| | **5** | screw internal glass from left side (2 screws) (iç camı iç arka metal saca sol taraftan vidala) | 14 | 17 | |
| | **6** | bring the external glass (dış camı getir) | 15 | | 5 |
| | **7** | place external glass (dış camı yerleştir) | 15 | | 12 |
| | **8** | screw internal base metal (3 screws) (iç taban sacını vidala) | 14 | 23 | |
| | **9** | screw external glass (dış camı vidala) | 14 | | 33 |
| | **10** | stick aluminium tape out of external glass (dış camın alt kısmına aliminyum bant yapıştır) | 15 | 28 | |
| | **11** | take internal glass foil (dış cam koruyucu folyoyu çıkar) | 15 | | 25 |
| | **12** | take external glass foil (dış cam koruyucu folyoyu çıkar) | 15 | | 65 |

These operations in red letters come from operator 17 to operator 14

**11.** Operators 20 and 21 assemble left-right pillars and top cover of the cooler together. But these two operators do one operator's work together. So, we combined these operators and we eliminated one of them.

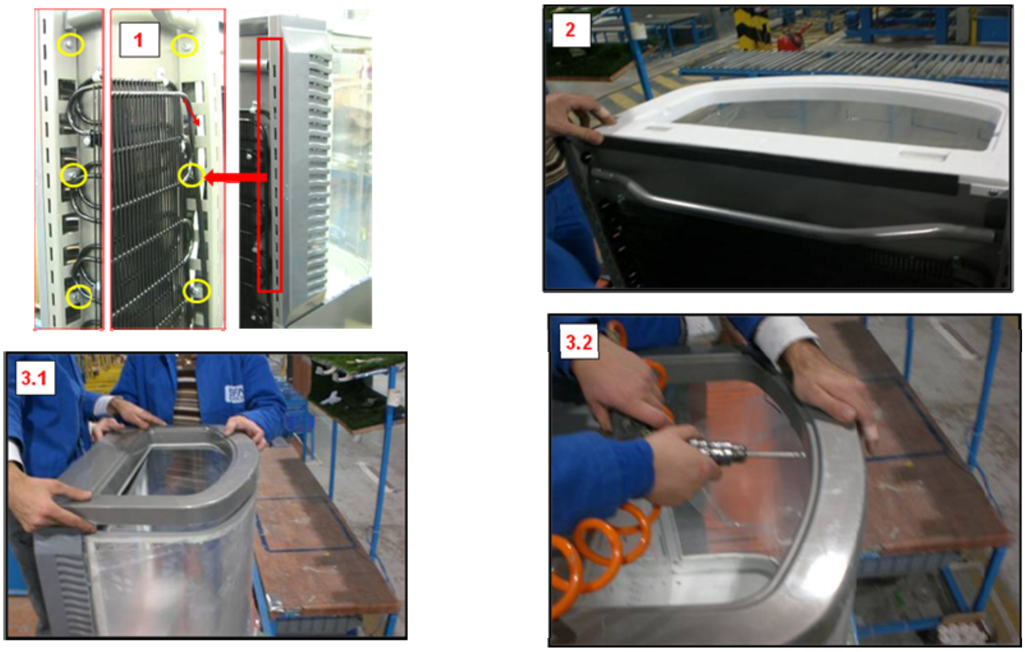



**Figure 4.19** Photos of Improvement 11

**Table 4.14** After operation time of improvement 11

| | | | | 71<br>**20** | 48<br>**21** |
|---|---|---|---|---|---|
| **20-21** | **1** | screw left decorative part (sol dekoratif parçayı vidala) | 20-21 | 9 | 9 |
| | **2** | screw right decorative part (sağ dekoratif parçayı vidala) | 20-21 | 9 | 9 |
| | **3** | stick 2 armouflex top of the cabin (kabinin üstüne 2 armaflex yapıştır) | 21 | | 20 |
| | **4** | place top cover eps (üst kapama straforunu yerleştir) | 20 | 25 | |
| | **5** | place grey top cover on the cabin (gri üst kapağı kabine yerleştir) | 20 | 15 | |
| | **6** | screw grey top cover to the cabin (gri üst kapağı kabine vidala-3 vida) | 20-21 | 10 | 10 |
| | **off** | cut armouflex tape (armaflex bandı kes) | 20 | 3 | |

We combined operators 20 and 21.

| | | | | 119<br>**18** |
|---|---|---|---|---|
| **18** | **1** | screw left decorative part (sol dekoratif parçayı vidala) | 18 | 18 |
| | **2** | screw right decorative part (sağ dekoratif parçayı vidala) | 18 | 18 |
| | **3** | stick 2 armouflex top of the cabin (kabinin üstüne 2 armaflex yapıştır) | 18 | 20 |
| | **4** | place top cover eps (üst kapama starforunu yerleştir) | 18 | 25 |
| | **5** | place grey top cover on the cabin (gri üst kapağı kabine yerleştir) | 18 | 15 |
| | **6** | screw grey top cover to the cabin (gri üst kapağı kabine vidala-3 vida) | 18 | 20 |
| | **off** | cut armouflex tape (armaflex bandı kes) | 18 | 3 |

**12.** Operators 30, 31 and 32 do packaging operations. But, each of these operators' operation times are too shorter than the cycle time. They have too much idle time. To reduce idle time and increase the saturity of each operator, we gave operator 31's first three and last two operations to the operator 30. So, operator 31 had much more idle time. For this idle time, we gave operator 32's all operations to the operator 31.

Also, operator 31 works with operator 30 and 32. That confuses his operations. And operators 30 and 32 may need him at the same time. This prevents operator 31 to realize his operations on time.

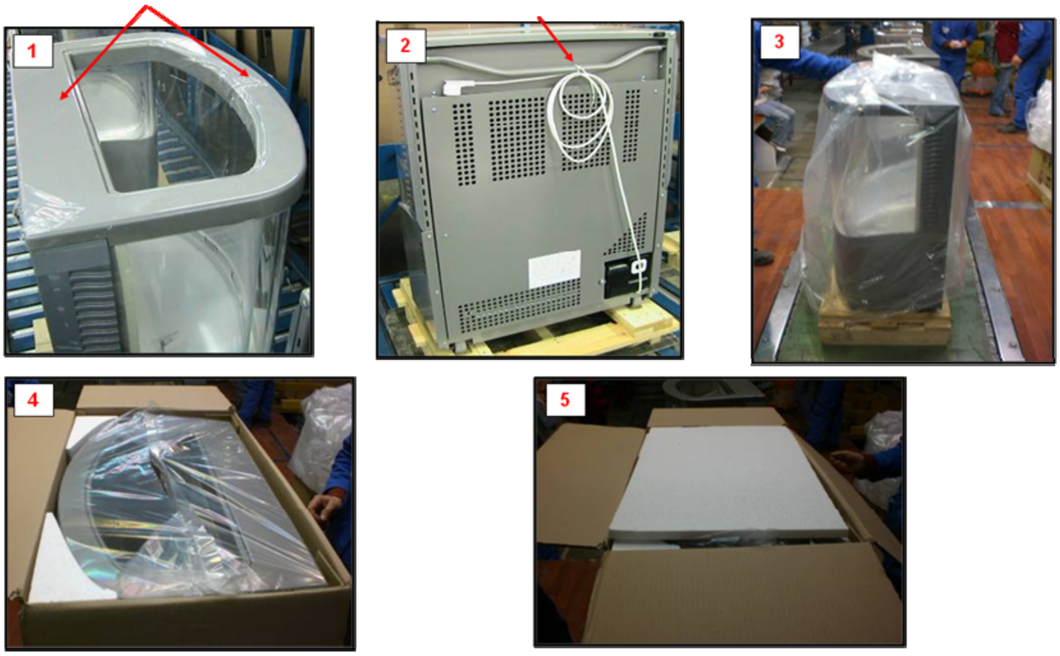



**Figure 4.20** Photos of operations of operators 30 and 31 for improvement 12


**Figure 4.21** Photos of operator 32's operations for Improvement 12

**Table 4.15** After operation time of improvement 12

| | | | | 93 | 78 | 64 |
|---|---|---|---|---|---|---|
| | | | | **30** | **31** | **32** |
| **30-31** | **1** | take grey top cover (gri üs kapaktan folyoyu al) | 31 | | 3 | |
| | **2** | stick sticker to the condenser cover metal (arka kapama sacına etiket yapıştır) | 31 | | 3 | |
| | **3** | unplug and wrap power cable (güç kablosunu sar) | 30 | 7 | | |
| | **4** | fix power cable to the handle with fastening material (güç kablosunu sac tutamağına kablo bağı ile bağla) | 30 | 17 | | |
| | **5** | put plastic bag on cooler (plastik poşeti soğutucuya geçir) | 30 | 15 | | |
| | **6** | cut the top of the plastik pocket (plastik poşetin üstünü kes) | 30 | 3 | | |
| | **7** | stick top of the cooler wtih band (soğutucunun üstünü 2 bantla yapıştır) | 30-31 | 16 | 10 | |
| | **8** | stick plastic and cartoon angle with band to the cooler (carton ve plastik köşebentleri bantla soğutucuya yapıştır) | 30-31 | 17 | 26 | |
| | **10** | put upper protective eps onto the box (kutunun üstüne üst koruyucu straforu koy) | 31 | | 5 | |
| | **11** | put cartoon box on the cooler (karton kutuyu soğutucunun üzerine koy) | 30-31 | 18 | 11 | |
| | **12** | stick label to the box (kutunun üstüne etiketi yapıştır) | 31 | | 5 | |
| | | | | | | |
| **32** | **1** | punch cover of box (kutunun kapağını zımbala) | 32 | | | 12 |
| | **2** | squeeze hot melt onto the 2 cartoon angles and stick onto the box (2 tane karton köşebente erimiş yapışkandan sık ve kutunun üzerine yapıştır) | 32 | | | 22 |
| | **3** | take gree pallet under the cooler (soğutucunun altından yeşil paleti al) | 31 | | 15 | |
| | **5** | wrap and fix stripes to the box (2 numbers) (şeritleri sar ve bağla) (machine time) | 32 | | | 30 |

| | | | | 119 | 116 |
|---|---|---|---|---|---|
| | | | | 27 | 28 |
| 27-28 | 1 | take grey top cover (gri üs kapaktan folyoyu al) | 27 | 3 | |
| | 2 | stick sticker to the condenser cover metal (arka kapama sacına etiket yapıştır) | 27 | 3 | |
| | 3 | unplug and wrap power cable (güç kablosunu sar) | 27 | 7 | |
| | 4 | fix power cable to the handle with fastening material (güç kablosunu sac tutamağına kablo bağı ile bağla) | 27 | 17 | |
| | 5 | put plastic bag on cooler (plastik poşeti soğutucuya geçir) | 27 | 15 | |
| | 6 | cut the top of the plastik pocket (plastik poşetin üstünü kes) | 27 | 3 | |
| | 7 | stick top of the cooler wtih band (soğutucunun üstünü 2 bantla yapıştır) | 27 | 26 | |
| | 8 | stick plastic and cartoon angle with band to the cooler (carton ve plastik köşebentleri bantla soğutucuya yapıştır) | 27-28 | 17 | 26 |
| | 10 | put upper protective eps onto the box (kutunun üstüne üst koruyucu straforu koy) | 27 | 5 | |
| | 11 | put cartoon box on the cooler (karton kutuyu soğutucunun üzerine koy) | 27-28 | 18 | 11 |
| | 12 | stick label to the box (kutunun üstüne etiketi yapıştır) | 27 | 5 | |
| | 13 | punch cover of box (kutunun kapağını zımbala) | 28 | | 12 |
| | 14 | squeeze hot melt onto the 2 cartoon angles and stick onto the box (2 tane karton köşebente erimiş yapışkandan sık ve kutunun üzerine yapıştır) | 28 | | 22 |
| | 15 | take green pallet under the cooler (soğutucunun altından yeşil paleti al) | 28 | | 15 |
| | 16 | wrap and fix stripes to the box (2 numbers) (şeritleri sar ve bağla) | 28 | | 30 |

These operations in red letters come from operator 31

These operations in red letters come from operator 32

### 4.4.3 Validation of the Balanced Situation

When we balanced the assembly line, our operators' efficiency, productivity, saturity etc. changed. After balancing we explained new values for the balanced assembly line.

We did some improvements and balanced the assembly line for Slim model. After these changes our line values were changed too. As you see below, the balanced situation table output is given as 150 to us, now we can produce 155 per shift. The average efficiency increased to 63.6%, we increased operators' usage of their cycle time. And the balancing ratio increased to 80%, yet we have acceptable balance ratio for Slim model.

**Table 4.16** Some parts of the balanced table

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Balancing Ratio** | **80%** | | | | |
| | | **Max efficiency** | **79,9%** | | 0,79 | 0,76 | 0,79 |
| | | **Min efficiency** | **26,8%** | | | | |
| | | | | | | | |
| | | **155** | | | 167 | 167 | 167 |
| | | | | | 165 | 158 | 165 |
| | | **average efficiency** | **63,6%** | **Current** | **1** | **2** | **3** |
| **1-2** | **1** | bend mechanism support base (Destek çıtasını eğ) | 1 | | 5 | | |
| | **2** | fix left and right pillars to the cabin (Sağ ve sol dikmeleri kabine sabitle) | 1-2 | | 25 | 25 | |
| | **3** | fix external cabins support to the cabin (Kabin iç destek çıtasını kabine sabitle) | 1-2 | | 10 | 10 | |
| | **4** | assembly wheels to the shaft (Tekerlekleri tekerlek şaftına monte et) | 2 | | | 18 | |
| | **5** | screw wheels to the cabin's base (Tekerlekleri kabinin tabanına vidala) | 1-2 | | 22 | 22 | |
| | **6** | fixing 2 legs bases (2 ayağı kabinin alt kısmına sabitle) | 1-2 | | 12 | 12 | |
| | **7** | assemby handle (sac tutamağını monte et ) | 1-2 | | 13 | 13 | |
| | **8** | screw (2+2) back cabin metal to the back side (arka gövde sacını vidala | 1-2 | | 30 | 15 | |
| | **9** | move wooden pallet to the line (Tahta paleti hatta koy) | 2 | | | 5 | |
| | **10** | move cabin on wooden pallet (Kabini tahta palet üzerine koy) | 1-2 | | 6 | 6 | |
| | **11** | screwing plate to the cabin's base (Alt gövde sacını kabinin temeline vidala) | 1-2 | | 27 | 27 | |
| | **12** | turn over cabin (Kabini çevir) | 2 | | | 5 | |
| | **off** | preparing legs (ayak hazırlama) | 1 | | 15 | | |
| | | | | | | | |
| **3** | **1** | place copper tubes and plastic hoses to the plate (4+4) (Bakır boruları ve plastik boruları alt gövde sacına yerleştir) | 3 | | | | 8 |
| | **2** | assy evap. Box+compr. Drip tray (Evaporatör kutusunu ve kompresör su tasını birbirine monte et) | 3 | | | | 20 |
| | **3** | place (Evap. Box+Compr.drip tray) onto the plate (Evap kutusu+kompresör su tasını kabin tabanına yerleştir) | 3 | | | | 12 |
| | **4** | enlarge evap.'s hangers (evap'ın kancalarını genişlet) | 3 | | | | 10 |
| | **5.1 (off)** | stick 1 sponge to evap. motor (1. süngeri evap. motoruna yapıştır) | 3 | | | | 6 |
| | **5.2 (off)** | stick 1 sponge to evap. motor (2. süngeri evap. motoruna yapıştır) | 3 | | | | 6 |
| | **6 (off)** | put probe cable into macaron (Prob kablosunu makaronun içinden geçir) | 3 | | | | 5 |
| | **7 (off)** | place probe sensor into evaporator (Prob sensörünü evap.'ın içine yerleştir) | 3 | | | | 8 |
| | **8** | place evap in to evap box (Evaporatörü evap kutusuna yerleştir) | 3 | | | | 14 |
| | **9 (off)** | cut and stick 2 pieces sponges to evap top side (2 adet süngeri kes ve evap.ın tavanına yapıştır) | 3 | | | | 8 |
| | **10** | place evap top side (Evaporatörün üst metal parçasını evaporatöre yerleştir) | 3 | | | | 5 |
| | **11** | screw evap top side (2screws) (Evap.'ın üst metal parçasını vidala (2 vida) | 3 | | | | 14 |
| | **12** | stick dryer tube with mastich to evap box's hole (Dryer borularını macunla evap kutusunun deliğine yapıştır) | 3 | | | | 10 |
| | **14** | place evaporation tube into drip tray (to eliminate water) (buharlaştırma borusunu su tasına yerleştir) | 3 | | | | 8 |
| | **15** | put 2 evaporator tube fix metal onto the evaporator tube (2 adet buh. borusu sabitleme sacını buh. borusu üzerine koy) | 3 | | | | 6 |

After balancing improvements, our final assembly process became as follows:

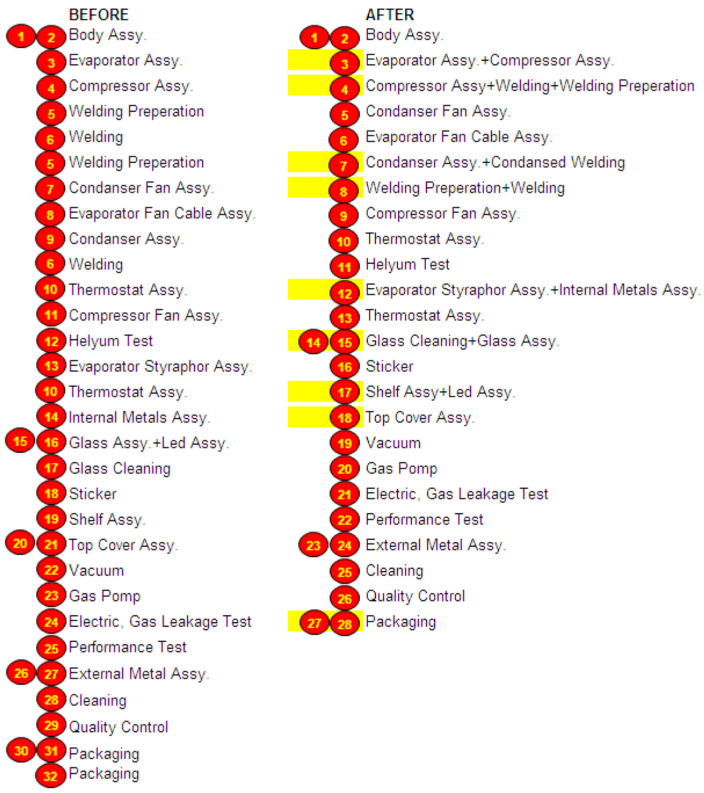



**Figure 4.22** Before and after operations

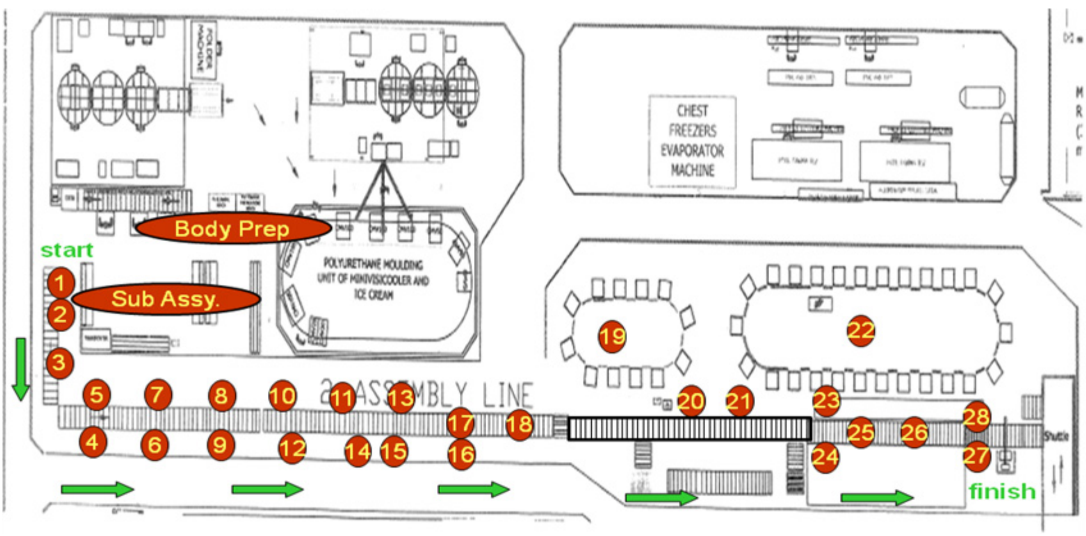



**Figure 4.23** Balanced flow on the line layout

# CHAPTER 5

# RESULTS AND CONCLUSION

When we balanced the assembly line for SLIM, we got some changes for our line indicators. Firstly, we can start with the operation times of the operators. In the following section, our 32 operators' time before balancing is shown as table and chart. In the chart, there is big difference among operators for operation times. Especially operator 10 differs greatly. To minimize these differences we balanced the line.

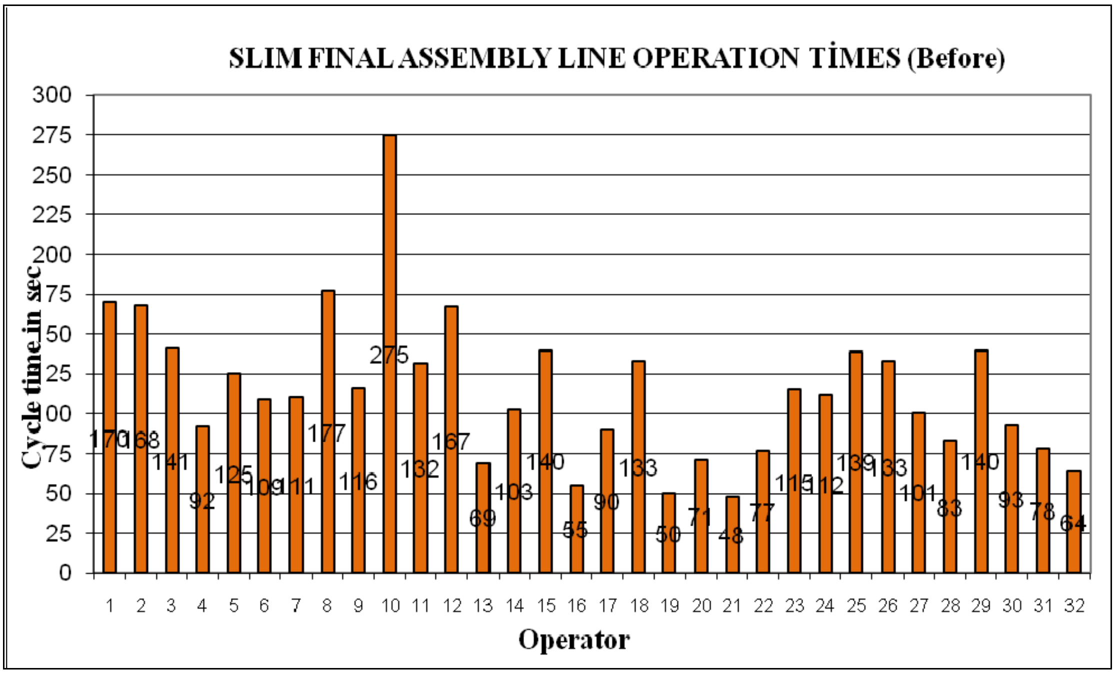



**Figure 5.1** Before balancing chart of operation times

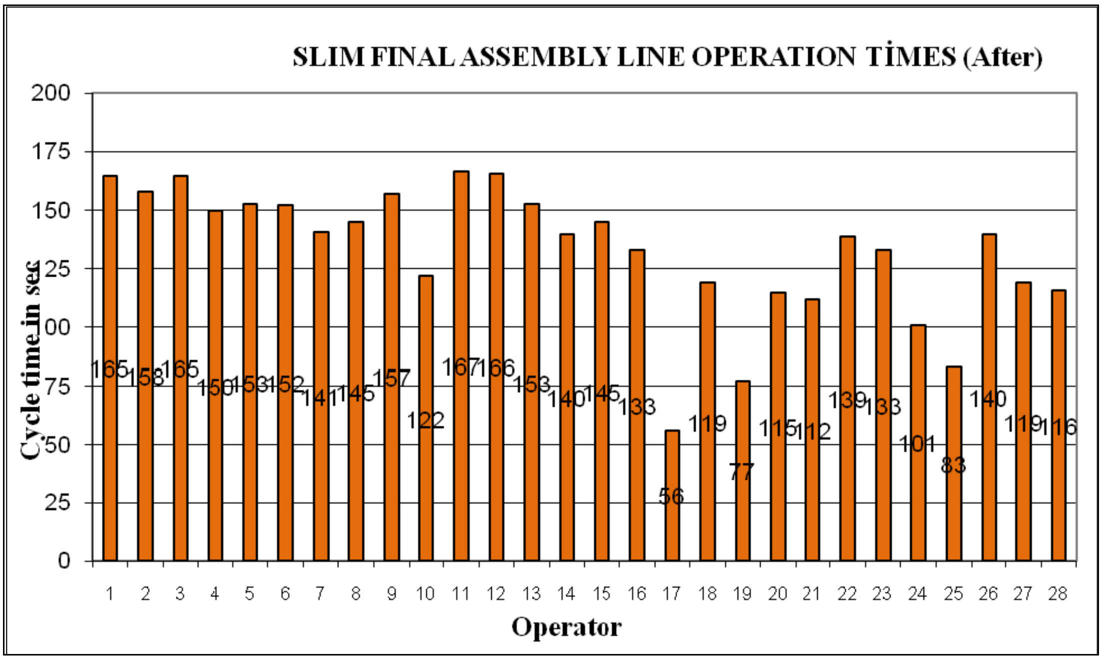



**Figure 5.2** After balancing chart of operation tims

After balancing we got the data shown in the following table and chart. We reduced the bottleneck operation time and time difference among the operators.

**Table 5.1** Assembly Line operation times before balancing

| Operator number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Operation time | 170 | 168 | 141 | 92 | 125 | 109 | 111 | 177 | 116 | 275 | 132 | 167 | 69 | 103 | 140 | 55 |
| **Operator number** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** | **31** | **32** |
| **Operation time** | 90 | 133 | 50 | 71 | 48 | 77 | 115 | 112 | 139 | 133 | 101 | 83 | 140 | 93 | 78 | 64 |

**Table 5.2** Operation times after balancing

| **Operator number** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Operation time** | 165 | 158 | 165 | 150 | 153 | 152 | 141 | 145 | 157 | 122 | 167 | 166 | 153 | 140 |
| **Operator number** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** |
| **Operation time** | 145 | 133 | 56 | 119 | 77 | 115 | 112 | 139 | 133 | 101 | 83 | 140 | 119 | 116 |

We reduced the idle time of the operators by an application of assembly line balancing. As seen in the following table, every operator has long idle times. For example the longest one is 222 second. This is too long for idle time. The average idle time was 155 seconds.

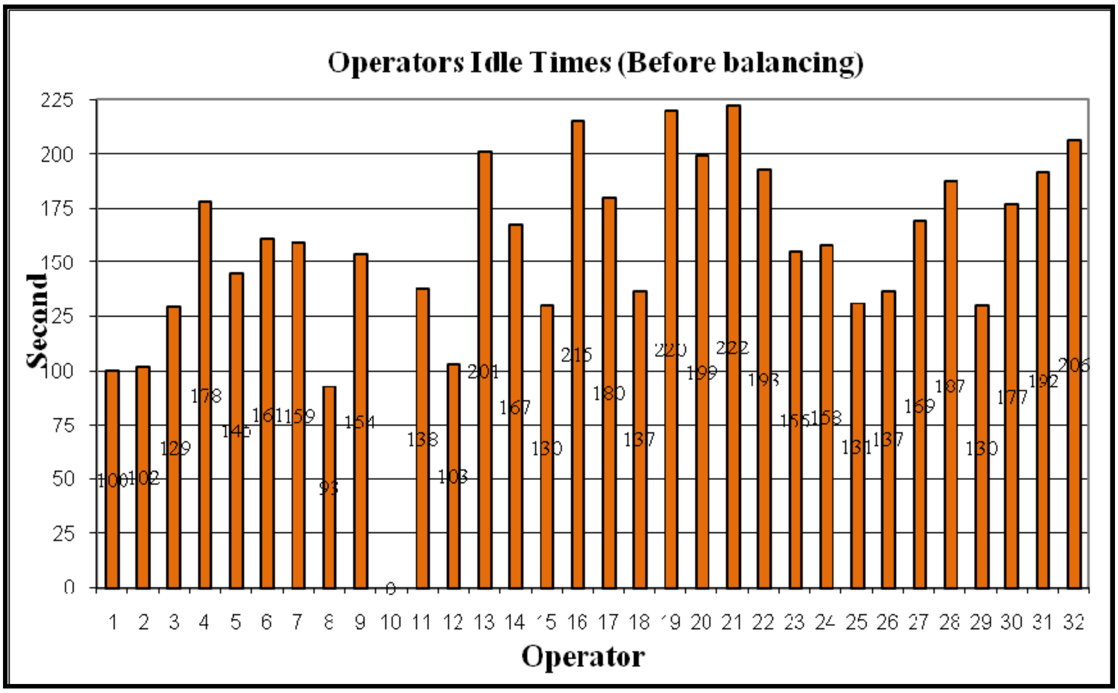



**Figure 5.3** Before balancing chart of idle times

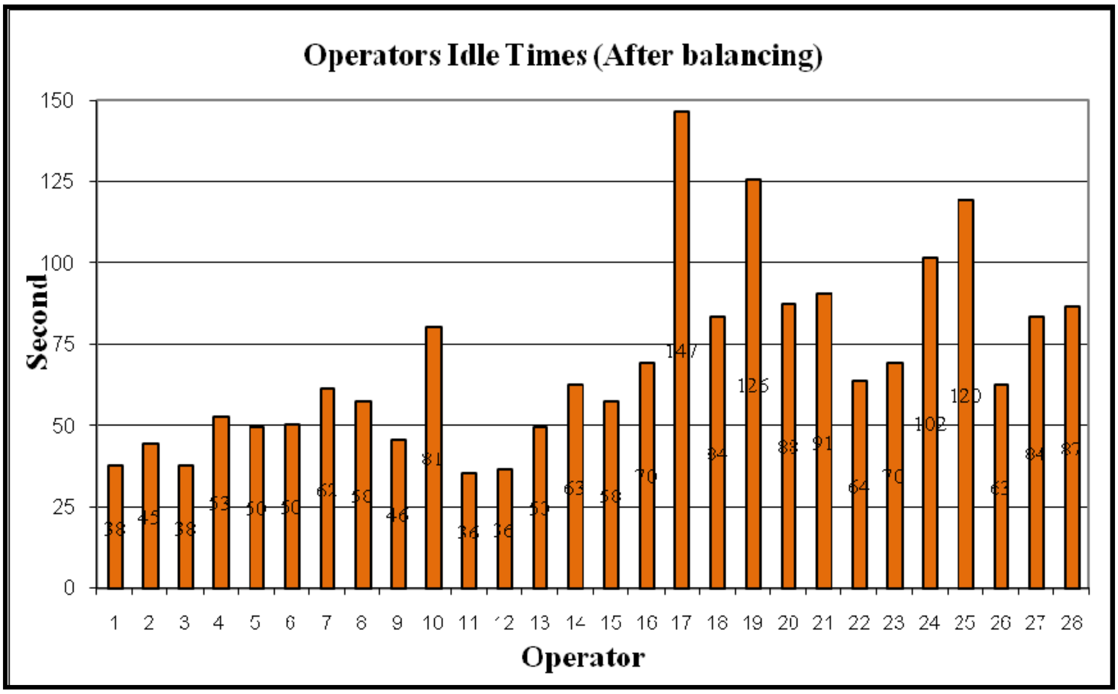



**Figure 5.4** After balancing chart of idle times

After balancing, the idle times were reduced for each operator. For example the longest idle time was 147 seconds and average 70 seconds.

**Table 5.3** Idle times of operators' before balancing

| Operator number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle time | 100 | 102 | 129 | 178 | 145 | 161 | 159 | 93 | 154 | 0 | 138 | 103 | 201 | 167 | 130 | 215 |
| **Operator number** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** | **31** | **32** |
| **Idle time** | 180 | 137 | 220 | 199 | 222 | 193 | 155 | 158 | 131 | 137 | 169 | 187 | 130 | 177 | 192 | 206 |

**Table 5.4** Idle times of operators' after balancing

| Operator number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle time | 38 | 45 | 38 | 53 | 50 | 50 | 62 | 58 | 46 | 81 | 36 | 36 | 50 | 63 |
| **Operator number** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** |
| **Idle time** | 58 | 70 | 147 | 84 | 126 | 88 | 91 | 64 | 70 | 102 | 120 | 63 | 84 | 87 |

If we analyze the other indicators;

**Table 5.5** Values of other indicators of assembly line

| | Before Balancing | After Balancing | Savings |
|---|---|---|---|
| **Number of final Assy. Operator** | 32 | 28 | 4 |
| **Output (unit)** | 118 | 155 | 37 |
| **Balancing ratio (%)** | 42,00 | 80,00 | 38,00 |
| **Productivity (manhour/unit)** | 0,52 | 0,40 | 0,12 |

Before balancing, there was 32 operators on the assembly line. But after balancing there are now 28 operators. That means we saved 4 operators for the line.

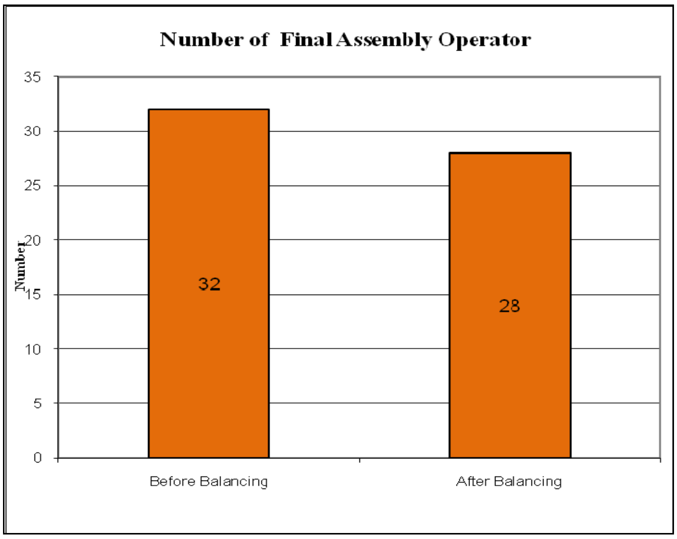



**Figure 5.5** Before and after balancing number of final assembly operators

Before balancing, we could produce 118 units per shift. But, that wasn't enough for our demands. We needed to increase it. After balancing, we can produce 155 units per shift. So, we could meet the customers' demands for this model. We increased output figure by 76% compared to the unbalanced situation.

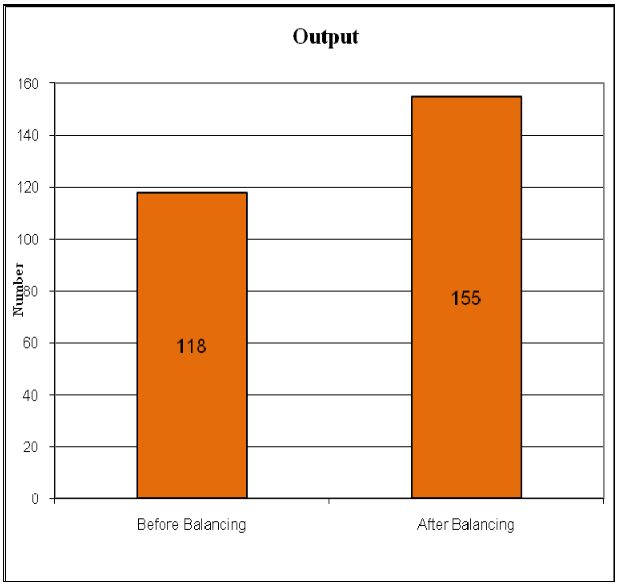



**Figure 5.6** Output volume before and after balancing

Before balancing, the balancing ratio of assembly line was 42%. But this wasn't enough for the product flow. After balancing improvements, the balancing ratio is 80% but the limit is 70% to meet the customer's demand. So that we achieved balancing better than the needed ratio. As a result, our balancing ratio increased by 52% compared to the unbalanced situation.

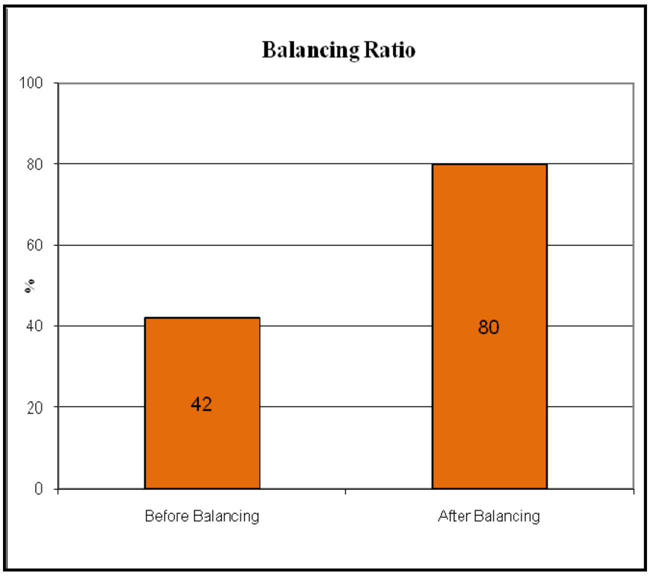



**Figure 5.7** Before and after balancing ratio

Productivity is our most effective and important indicator for balancing. That shows how much labor we need to assemble this product. Before balancing, we needed

0,52 man*hour to produce 1 unit; after balancing, this value changed to 0,40 man*hour. That means we gained 0,12 man*hour, yet we can produce at a productivity of 0,40 man*hour.

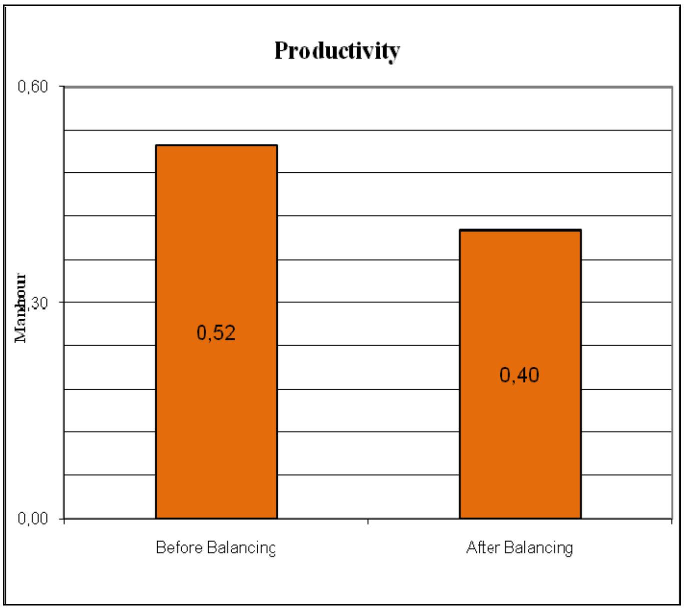



**Figure 5.8** Before and after productivity

# CONCLUSION

Assembly Line Balancing is one of the most important tools for assembly lines in order to increase productivity. There are many software programmes being developed to solve balance problems by using different methods in sectors.

The superior feature of this study is that it has used the axiomatic design method as a line balancing tool. The idea is to use the axiomatic decision design tree in order to improve productivity.

We achieved not only line balancing improvements but also improvements in material handling, communication, training system and tracking data. We also did applications on these areas too. In this way the axiomatic design showed us what we needed, which improvements were needed to balance the line.

When we found our improvements for balancing by the axiomatic design method, we applied them in the cooler manufacturing industry. We chose the most difficult and unproductive product SLIM for the factory. This model came from Poland plant to SFA plant and this was new model for the SFA plant. They had some difficulties as happened with every new model. They had to meet the customer demand. In order to realize the needed production, as results of axiomatic design show, the line must be balanced.

In order to balance this assembly line, firstly we defined the current situation. After that we identified potential improvements points in the direction of axiomatic design results. We combined some of the workstations, simplified or eliminated some of the operations, gave some of the operations to the supplier, built some apparatus to do the operation easier, gave training to operators, tracked line and departments' data, visualized and controlled them.

At the end of all these improvements, we balanced the line to a ratio of 80%. We needed a ratio of 75%, but we did better than needed. Also, we increased production volume from 118 units to 155 units per shift. We reduced operators' idle time and we turned these times to effective production times. We saw that axiomatic design was a useful method for the assembly line balancing. This method made balancing easier because it indicated focus points which enabled us to produce to meet the customer demands on time.

Future implementation for this research will be to increase productivity to a ratio of 85%. We will do that with new axiomatic design implementations. However, we will apply axiomatic design theory to other products which has assembly line problems. So, all productions in the plant can produce easily. Whenever we want, we can produce the volume needed. For further improvements, other problematic areas will be identified for the plant, then we will make improvements with the axiomatic design.

# REFERENCES


Acar, N., “Tam Zamanında Üretim ve Kanban Sistemi”, *Verimlilik Dergisi*, MPM Yayınları, Ankara, 1992.

Acar, N., *Tam Zamanında Üretim Uygulamalarında Kritik Başarı Faktörleri*, MPM Yayınları, Ankara, 1996.

Acar, N. and Astaş S., *Kesikli Seri Üretim Sistemlerinde Planlama ve Kontrol Çalışmaları*, MPM, Ankara, 1991.

Ağpak, K., *Tek Modelli Basit U Tipi Montaj Hattı Dengeleme Problemleri için Bir Sezgisel Metot*, M.S. Thesis, Gazi University, 2001.

Ağpak, K., Gökçen, H. and Saray, N. N. and Özel, S., “Stokastik Görev Zamanli Tek Modelli U Tipi Montaj Hatti Dengeleme Problemleri İçin Bir Sezgisel Yöntem”, *Journal of Faculty Engineering*, Vol. 17, No.4, pp. 115-124, 2002.

Akaryıldız, F., *Toplam Kalite Yönetimi*, M.S. Thesis, Yıldız Technical University, 2001.

Akçagün, E., *Hazır Giyim İşletmelerinde Yalın Üretim Tekniklerinin Araştırılması*, M.S. Thesis, Marmara University, 2006.

Armstrong, M., *Handbook of Management Techniques: A Comprehensive Guide to Achieving Managerial Excellence and Improved Decision Making*, Kogan Page, London, 2006.

Babic, B., 1999, “Axiomatic Design of Flexible Manufacturing Systems”, *International Journal of Production Research*, Vol. 37, No.5, pp. 1159-1173, 1999.

Baykasoglu, A. and Dereli, T. (editors), *Techniques and Practices to Improve Responsiveness in Industry*, Emerald Group Publishing Limited, Bradford, 2004.

Baraçlı, H., *Kalite Geliştirme ve Yönetimi Ders Notları*, İstanbul, 2004.

Boysen, N., Fliedner, M. and Scholl, A., “A Classification of Assembly Line Balancing Problems”, *European Journal of Operational Research,* Vol. 183, pp. 674–693, 2007.

Cavique, M. and Coelho, A. G., “An Energy Efficiency Framework for The Design of Hvac Systems”, *The Fifth International Conference on Axiomatic Design*, Campus de Caparica, March 25-27, 2009.

Cesur, N., *Yalın Üretimin Arkasındaki Nedenler*, MPM Yayınları, 1997.

Cochran, D. S., Eversheim, W., Kubin, G. and Sesterhenn, M. L., “The Application of Axiomatic Design and Lean Management Principles in the Scope of Production System Segmentation”, *International Journal of Production Research*, Vol. 38, No. 6, pp. 1377-1396, 2000.

Cochran, D. S., “The Production System Design and Deployment Framework”, *SAE International Automotive Manufacturing Conference and Exposition*, Detroit, Michigan, May 11-13, 1999.

Chen S.J., Chen L. C. and Linc, L., “Knowledge-Based Support for Simulation Analysis of Manufacturing Cells”, *Computers in Industry*, Vol. 44, pp. 33-49, 2001.

Çağlar, Ö., *Yalın Üretim Tarzı-Otomotiv Yan Sanayii Uygulaması,* M.S. Thesis, Marmara University, 2006.

Çakır, B., *Stokastik İşlem Zamanlı Montaj Hattı Dengeme için Tavlama Benzetimi Algoritması,* M.S. Thesis, Gazi University, 2006.

Çetinkaya, K., *Toplam Tasarım*, Gazi Kitapevi, Ankara, 2000.

Çelikçapa, F., *Üretim Yönetimi ve Teknikleri*, Alfa Yayınevi, İstanbul, 2000.

Dar-El, E. M. and Rabinovitch, M., “Optimal Planning and Scheduling of Assembly Lines”, *International Journal of Production Research*, Vol. 26, pp. 1433–1450,1988.

Dinçmen, M., *Bilgisayar Destekli Üretim ve Benzetim*, Bilgisayar Destekli Üretime Giriş Ders Notları, İstanbul, 1990.

Durmuşoğlu, M. B. and Kulak, O., “Aksiyomlarla Tasarım İlkelerine Göre Takım Çalışması Esaslı Ofis Hücrelerinin Planlanması ve Uygulanması”, İstanbul Teknik Üniversitesi, Endüstri Mühendisliği Bölümü, İstanbul, 2008.

Emre, A., *Tam Zamanında Üretim Sisteminin Ülkemizdeki Uygulamaları ve Sorunları*, MPM, Ankara, 1995.

Genç, A., *Toplam Verimli Bakım ve Uygulaması*, M.S. Thesis, Erciyes University, 2007.

Ghosh, S. and Gagnon, R. J., “A Comprehensive Literature Review and Analysis of the Design, Balancing and Scheduling of Assembly Systems”, *International Journal of Production Research*, Vol.27, No.4, pp. 637-670, 1989.

Gökçen, H., *Karışık Modelli Deterministik Hat Dengeleme Problemleri için Yeni Modeller*, Ph.D. Thesis, Gazi University, 1994.

Guillermo, O., Carlos, T. and Cochran D. S., "The Manufacturing System Design Decomposition in the Automotive Electronics Industry", to be submitted to *Journal of Production Research*,
Günay, K., Çetin, T. and Baykoç, Ö. F., "Montaj Hattı Dengelemede Geleneksel ve U Tipi Hatların Karşılaştırılması ve Bir Uygulama", *Teknoloji*, Vol. 3, pp. 351-359, 2004.

Güre, Z., *Bir Üretim Modeli Olarak Yalın Üretim: İmalat Sektöründe Bir Uygulama,* M.S. Thesis, Dumlupınar University, 2006.

Herron, C. and Hicks C., "The transfer of selected lean manufacturing techniques from Japanese automotive manufacturing into general manufacturing (UK) through change agents", *Robotics and Computer Integrated Manufacturing,* Vol. 24, pp. 524–531, 2008.

Hobbs, D. P., *Lean Manufacturing Implementation : A Complete Execution Manual for Any Size Manufacturer*, J. Ross Publishing Incorporated. USA, 2003.

Holweg, M., "The Genealogy of Lean Production", *Journal of Operations Management*, Vol. 25, pp. 420–437, 2007.

Ignall, E. J., "A Review of Assembly Line Balancing" *Journal of Industrial Engineering*, Vol. 16, 1965.

Imai, M., *Kaizen-The Key to Japanese Competitive Success*, Random House, New York, 1994.

Joosten, T., Bongers, I. and Janssen, R., "Application of Lean Thinking to Health Care:Issues and Observations, *International Journal for Quality in Health Care*, Vol. 21, No.5, pp. 341–347, 2009.

Karlsson, C. and Ahlstrom, P., "The difficult path to lean product Development", *International Journal of Product Innovation Management*, Vol. 13, No.4, 1996.

Kemal, A., *Yalın Üretim*, Ege Üniversitesi, Yalın Üretim Seminer Notları, pp. 2-11, 2004.

Kim, Y. K., Song, W. S. and Kim, J. H., "A Mathematical Model and a Genetic Algorithm for Two-Sided Assembly Line Balancing", *Computers & Operations Research*, Vol. 36, pp. 853–865, 2009.

Kulak, O. and Durmuşoğlu M. B., Tüfekci S., "A Complete Cellular Manufacturing System Design Methodology Based on Axiomatic Design Principles", Computers & Industrial Engineering, Vol.48, pp. 765–787, 2005.

Kulak, O. and Kahraman, C., "Fuzzy Multi-Attribute Selection Among Transportation Companies Using Axiomatic Design and Analytic Hierarchy Process", *Information Sciences*, Vol. 170, pp. 191-210, 2004.

Kumar, S. A., *Production and Operations Management,* New Age International, Delhi, 2008.

Lerc, Lean Enterprise Research Centre, Cardiff Business School, 2004, www.cf.ac.uk/carbs/lom/lerc
Martin, S. B. and Kar, A. K., “Developing E-Commerce Strategies Based on Axiomatic Design”, *Working Paper*, Marmara University, 2002.

Melton, T., “The Benefıts of Lean Manufacturing What Lean Thinking has to Offer the Process Industries*”, Chemical Engineering Research and Design*, Vol. 83, pp. 662–673, 2005.

Meyers, F. E., *Motion and Time Study*, Prentice Hall, Ohio, 1999.

Murat, Y. Ş. and Kulak, O., “Ulaşım Ağlarında Bilgi Aksiyomu Kullanılarak Güzergah (Rota) Seçimi”, *Mühendislik Bilimleri Dergisi*, Vol. 11, No.3, pp. 425-435, 2005.

Ohno, T., *Toyota Ruhu–Toyota Üretim Sisteminin Doğuşu ve Evrimi*, Scala Yayıncılık, İstanbul, 2008.

Okur, A. S., *Yalın Üretim-2000’li Yıllara Doğru Türkiye Sanayisi için Yapılanma Modeli*, Söz Yayın, İstanbul, 1997.

Oropeza, G., Tapia, C. and Cochran, D. S., “The Manufacturing System Design Decomposition in the Automotive Electronics Industry”, *to be submitted to the Journal of Production Research*, 2001.

Özçelikel, H., *Bir Personel Yöneticisinin Gözüyle Japon Yönetim Sistemleri*, Mess Eğitim Vakfı, İstanbul, 1994.

Özçelik, A., *Esnek Üretim Sistemleri*, M.S. Thesis, İstanbul Technical University, 1993.

Pavnaskar, S. J., Gershenson, S. J. and Jainbekar, A. B., “Classification Scheme for Lean Manufacturing Tools, *International Journal of Production Research,*Vol. 41, No.13, pp. 3075-3090, 2010.
Rother, M. and Shook, J., *Learning to See Value Stream Mapping to Create Value and Eliminate Muda*, The Lean Enterprise Institute, Brookline, Massachusetts, 1999.

Scholl, A., Balancing and Sequencing of Assembly Lines, Physica-Verlag, Heidelberg, 1999.

Semetay C. and Şenocak S., *Hat Operasyonları*, M.S. Thesis, İstanbul University.

Senge, P. M., *The Fifth Discipline: The Art and Practice of the Learning Organization,* Sol Publication, New York, 1990.

Shah, R. and Ward, P.T., “Defining and Developing Measures of Lean Production”, *Journal of Operations Management,* Vol. 25, pp. 785–805, 2007.

Shingo, S., *Non-Stock Production: The Shingo System for Continuous Improvement*, Productivity Pres, USA, 1988.

Shingo, S., *A Study of the Toyota Production System, Productıvıty Press*, Portland, 1989.
Singh, N., *Systems Approach to Computer, Integrated Design and Manufacturing,* John Wiley & Sons Inc., New York, 1996.

Suh, N. P., *The Principles of Design*, Oxford University Press, New York, 1990.

Suh, N. P., "Designing-in of Quality Through Axiomatic Design", *IEEE Transactions on Reliability*, Vol. 44, No. 2, pp. 256–264, 1995.

Suh, N. P., *Axiomatic Design: Advances and Applications*, Oxford University, Press, New York, 2001.

Suh, N. P., "Axiomatic Design Theory for Systems", *Working Paper*, MIT, 1998.

Thielman J. and Ge, P., "Applying Axiomatic Design Theory To The Evaluation And Optimization of Large-Scale Engineering Systems", *Journal of Engineering Design,* Vol. 17, No. 1, pp. 1-16, 2006.

Top, A., *Üretim Sistemleri Analiz Planlama ve Kontrolü*, Alfa Yayınevi, İstanbul, 2001.

Werneman A., Kjellberg, A. and Mattias, A., "Application of Axiomatic Design in Operational Development", Proceedings of Icad2000, *First International Conference on Axiomatic Design* ,Cambridge, June 21-23, 2000.

Womack, J. P. and Jones, D. T., *Lean Thinking*, Lean Enterprises Institute, 1996.
Womack, J. P., Jones, D. T. and Roos, D., *The Machine that Changed the World,* Rawson Macmillan Assocs, NewYork, 1990.
Womack, J., *Yalın Düşünce*, Scala Yayıncılık, İstanbul, 2003.

Womack, J. and Jones, D. T., *Yalın Düşünce*, Optimist Yayın, İstanbul, 2007.

Xiaochuan, C., Xiaobing, L. and Baobao, Z., "The Integration of Design Methods Based on Axiomatic Design", *Computer Integrated Manufacturing Systems-CIMS.* Vol. 3, pp. 75-79, 2000.

Yalın Enstitü Derneği, *Yalın Düşünce'nin İlkeleri, 2010,* http://www.yalinenstitu.org.tr/index.php?option=com_content&task=view&id=60&Itemid=13

# APPENDIX A

## SLIM FINAL ASSEMBLY UNBALANCED OPERATION TIMES

**SLIM FINAL ASSEMBLY LINE (UNBALANCED)**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Balancing Ratio | 42% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Max efficiency | 131,6% | | 0,81 | 0,80 | 0,67 | 0,44 | 0,60 | 0,52 | 0,53 | 0,85 | 0,55 | 1,32 | 0,63 | 0,80 | 0,33 | 0,49 | 0,67 | 0,26 | 0,43 | 0,64 | 0,24 | 0,34 | 0,23 | 0,37 | 0,55 | 0,54 | 0,66 | 0,64 | 0,48 | 0,40 | 0,67 | 0,44 | 0,37 | 0,31 |
| | | Min efficiency | 23,0% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | *Slim Black Battery-593-0000-007* | | | 3 | 1 | | | | | | 10 | | 108 | | | | | | | | | | | | | | | | | | | | | | |
| | | 155 | 167 | | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 |
| | | 1,86 | 115 | | 170 | 168 | 141 | 92 | 125 | 109 | 111 | 177 | 116 | 275 | 132 | 167 | 69 | 103 | 140 | 55 | 90 | 133 | 50 | 71 | 48 | 77 | 115 | 112 | 139 | 133 | 101 | 83 | 140 | 93 | 78 | 64 |
| | | average efficiency | 55,0% | Current | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
| 1-2 | 1 | bend mechanism support base (Destek çıtasını eğ) | 1 | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | fix left and right pillars to the cabin (Sağ ve sol dikmeleri kabine sabitle) | 1-2 | | 30 | 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | fix external cabins support to the cabin (Kabin iç destek çıtasını kabine sabitle) | 1-2 | | 10 | 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | assembly wheels to the shaft (Tekerlekleri tekerlek şaftına monte et) | 2 | | | 18 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | screw wheels to the cabin's base (Tekerlekleri kabinin tabanına vidala) | 1-2 | | 22 | 22 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 6 | fixing 2 legs bases (2 ayağı kabinin alt kısmına sabitle) | 1-2 | | 12 | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 7 | assemby handle (sac tutamağını monte et ) | 1-2 | | 13 | 13 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 8 | screw (2+2) back cabin metal to the back side (arka gövde sacını vidala | 1-2 | | 30 | 15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 9 | move wooden pallet to the line (Tahta paleti hatta koy) | 2 | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 10 | move cabin on wooden pallet (Kabini tahta palet üzerine koy) | 1-2 | | 6 | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 11 | screwing plate to the cabin's base (Alt gövde sacını kabinin temeline vidala) | 1-2 | | 27 | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 12 | turn over cabin (Kabini çevir) | 2 | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | match left and right pillars | 1 | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | preparing legs (ayak hazırlama) | 1 | | 15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1 | place copper tubes and plastic hoses to the plate (4+4) (Bakır boruları ve plastik boruları alt gövde sacına yerleştir) | 3 | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | assy evap. Box+compr. Drip tray (Evaporatör kutusunu ve kompresör su tasını birbirine monte et) | 3 | | | | 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | place (Evap. Box+Compr.drip tray) onto the plate (Evap kutusu+kompresör su tasını kabin tabanına yerleştir) | 3 | | | | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | enlarge evap.'s hangers (evap'ın kancalarını genişlet) | 3 | | | | 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5.1 | stick 1 sponge to evap. motor (1. süngeri evap. motoruna yapıştır) | 3 | | | | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 5.2 | stick 1 sponge to evap. motor (2. süngeri evap. motoruna yapıştır) | 3 | | | | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 6 (off) | put probe cable into macaron (Prob kablosunu makaronun içinden geçir) | 3 | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 7 (off) | place probe sensor into evaporator (Prob sensörünü evap.'ın içine yerleştir) | 3 | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 8 | place evap in to evap box (Evaporatörü evap kutusuna yerleştir) | 3 | | | | 14 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 9 (off) | cut and stick 2 pieces sponges to evap top side (2 adet süngeri kes ve evap.ın tavanına yapıştır) | 3 | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 10 | place evap top side (Evaporatörün üst metal parçasını evaporatöre yerleştir) | 3 | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 11 | screw evap top side (2screws) (Evap.'ın üst metal parçasını vidala (2 vida) | 3 | | | | 14 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 12 | stick dryer tube with mastich to evap box's hole (Dryer borularını macunla evap kutusunun deliğine yapıştır) | 3 | | | | 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | cut white plastic hose in 4 pcs (Beyaz plastik tüpleri kes (4 pcs) | 3 | | | | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | bring evap box(4 adet evap kutusu getir) | 3 | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | bring compressor drip tray (black 10pcs/time) (Kompresör su tasını getir) | 3 | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | bring evap. (20pcs/each time) (Evaporatör getir) | 3 | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | cut macaron (Makaronu kes) | 3 | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | cut prob cable's fastening material (Prob kablosunun kablo tutucusunu kes) | 3 | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | 1 | place evaporation tube into drip tray (to eliminate water) (buharlaştırma borusunu su tasına yerleştir) | 4 | | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | put 2 evaporator tube fix metal onto the evaporator tube (2 adet buh. borusu sabitleme sacını buh. borusu üzerine koy) | 4 | | | | | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | place compressor into the drip tray (kompresörü su tasına yerleştir) | 4 | | | | | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | arrange tubes and put compressor's cable into the oring (boruları düzenle ve kompresörün kablosunu oringten geçir) | 4 | | | | | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | place spacer and washer and screw them (set from 4) (pul, civata ve vidayı yerleştir ve vidala) | 4 | | | | | 45 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 6 | put the cooler on the green pallet (soğutucuyu yeşil paletin üzerine koy) | 4 | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | bring green pallet (yeşil paleti getir) | 8 | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | put green pallet (yeşil paleti koy) | 8 | | | | | | | | 6 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | stick sponge to the 2 evaporator fix metals (2 buh. borusu sabitleme sacına sünger yapıştır) | 4 | | | | | 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 (Pre solder) | 1 | eject stickers from compressor tubes (kompresör borularının etiketilerini çıkar) | 5 | | | | | | 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | eject cap from evaporation tube (buharlaştırma borusundan kapağı çıkar) | 5 | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | eject cap from compressor tube (kompresör borusundan kapağı çıkar) | 5 | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | enlarge compressor tubes (Kompresör borularını genişlet) | 5 | | | | | | 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | fix 1.compressor tube to evap.'s tube (1.kompresör borusunu evap.'ın borusuna tak) | 5 | | | | | | 13 | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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| | 6 | fix 2.compressor tube to evaporation tube (2.kompresör borusunu buharlaştırma borusuna tak) | 5 | | | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 7 | put soldering metal (lehimleme metalini koy) | 5 | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 (solderer) | 1 (off) | bring solder gun (lehim tabancasını getir) | 6 | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | solder 1. compressor tube to the evap's tube (1. kompresör borusunu evap'ın borusuna lehimle) | 6 | | | | | | | 22 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | solder 2. compressor tube to the evaporation tube (2. kompresör borusunu buharlaştırma borusuna lehimle) | 6 | | | | | | | 15 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | take the soldering metal (lehimleme metalini al) | 6 | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 (Pre solder) | 2 | fix isolation sponge (izolasyon süngerini tak) | 5 | | | | | | 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | fix first fastening material to the isolation sponge (İzolasyon süngerine 1. kablo bağını tak) | 5 | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | fix second fastening material to the isolation sponge (İzolasyon süngerine 2. kablo bağını tak) | 5 | | | | | | 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | cut end of fastening materials (kablo bağlarının ucunu kes) | 5 | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | cut isolation sponge (izolasyon süngerini kes) | 5 | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | 1 | screw condenser blower metal to the cabin (6 screws) (kondanser fan sacını kabine vidala) | 7 | | | | | | | | 40 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | put condenser blower cable inside clip (kondenser fan kablosunu klipsin içinden geçir) | 7 | | | | | | | | 13 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | stick 2 sponges to the pillars (2 süngeri sağ ve sol dikmelere yapıştır) | 8 | | | | | | | | | 25 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | take compressor and evap blower cable from front side to the back side (komp. ve evap fan kablosunu ön taraftan arka tarafa al) | 7-8 | | | | | | | | 12 | 12 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | put prob cable through evap. box's hole (prob kablosunu evap'ın deliğinden geçir) | 8 | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 6 | take the display and compressor cable from back side to the front side display ve komp. kablosunu arka taraftan ön tarafa al) | 7-8 | | | | | | | | 15 | 15 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 7 | screw blower to the blower metal (2+2 screws) (fanı fan sacına vidala) | 7 | | | | | | | | 18 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 8 | fix 2 cables (blue and yellow) to the blower (2 kabloyu fana tak) | 7 | | | | | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 9 | screw ground cable to the blower motor (topraklama kablosunu fan motoruna vidala) | 7 | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | cut adhesive sponges (yapışkan süngerleri kes) | 8 | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | 1 | screw notr cable (nötr kablosunu vidala) | 6 | | | | | | | | | 14 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | screw phase cable (faz kablosunu vidala) | 6 | | | | | | | | | 14 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | screw 2 ground cable to blower metal (2 topraklama kablosunu fan sacına vidala) | 6 | | | | | | | | | 17 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | fix 2 prob sockets to the thermostat (2 prob soketini fan termostata tak) | 6 | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | fix 3 compressor cables to the thermostat (3 kompresör kablosunu thermostata tak) | 6 | | | | | | | | | 25 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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| 9 | 1 | place condenser to the cabin | 9 | | | | | | | | | | 6 | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | screw internal condenser to the cabin (2+2) | 9 | | | | | | | | | | 55 | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | screw external condenser to the cabin (2+2) | 9 | | | | | | | | | | 55 | | | | | | | | | | | | | | | | | | | | | | |
| 5 | 1 | turn the pallet (paleti çevir) | 5 | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | arrange tubes (boruları düzenle) | 5 | | | | | | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | eject condenser tubes' cap (kondenser borularının şapkasını çıkar) | 5 | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | fix condenser tube to the dual dryer tube (kondenser borusunu ikili dryer borusuna tak) | 5 | | | | | | 20 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | fix condenser tube to the evaporation tube (Kondenser borusunu buharlaştırma borusuna tak) | 5 | | | | | | 7 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 6 | fix service tube to the dryer (servis borusunu dryer'e tak) | 5 | | | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | 1 | eject service tube from the dryer (servis borusunu kondanser'dan çıkar) | 6 | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | take the solder gun (lehim tabancasını al) | 6 | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | solder this tubes (bu boruları lehimle) | 6 | | | | | | | 25 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | fix again service tube to the dryer (servis borusunu tekrar dryer'a tak) | 6 | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | take the solder gun (lehim tabancasını al) | 6 | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 6 | solder this tube (bu boruyu lehimle) | 6 | | | | | | | 25 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 Ledsiz için (1. kısım) | 1 | screw blue cable to the clemens (Mavi kabloyu klemense vidala) | 10 | | | | | | | | | | | 12 | | | | | | | | | | | | | | | | | | | | | |
| | 2 | screw ground cable to the clemens (Topraklama kablosunu klemense vidala) | 10 | | | | | | | | | | | 12 | | | | | | | | | | | | | | | | | | | | | |
| | 3 | put cables into the black box (kabloları karakutudan geçir) | 10 | | | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | | | | |
| | 4 | screw red cable to the digital thermostat (Kırmızı kabloyu dijital termostata vidala) | 10 | | | | | | | | | | | 12 | | | | | | | | | | | | | | | | | | | | | |
| | 5 | screw 3 cables which come from compressor (kompresörden gelen kablonun 3 ucunu dijital termostata vidala) | 10 | | | | | | | | | | | 30 | | | | | | | | | | | | | | | | | | | | | |
| | 6 | divide black prob's end (siyah probun ucunu ikiye ayır) | 10 | | | | | | | | | | | 8 | | | | | | | | | | | | | | | | | | | | | |
| | 7 | screw black prob's one end (siyah probun 1 ucunu vidala) | 10 | | | | | | | | | | | 12 | | | | | | | | | | | | | | | | | | | | | |
| | 8 | screw black prob's other end with white prob's one end to the digital thermostat (siyah probun diğer ucunu beyaz prob'un bir ucuyla dijital termostata vidala) | 10 | | | | | | | | | | | 14 | | | | | | | | | | | | | | | | | | | | | |
| | 9 | screw white prob's other end (beyaz probun diğer ucunu vidala) | 10 | | | | | | | | | | | 12 | | | | | | | | | | | | | | | | | | | | | |
| 11 | 1 | put evap. fan cable (blue cable) into the evap box and press it's end (evap fan kablosunu evap kutusundan geçir ve ucunu ez) | 11 | | | | | | | | | | | | 12 | | | | | | | | | | | | | | | | | | | | |
| | 2 | fix evap fan cable (blue) to the evap blower (evap fan kablosunu evap fanına tak) | 11 | | | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | |
| | 3 | press end of evap fan cable and fix it to the evap. blower-brown cable (evap fan kablosunun ucunu ez ve evap.fanına tak) | 11 | | | | | | | | | | | | 12 | | | | | | | | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | screw grounding cable which comes from clemens to the evap. blower (klemensten gelen topraklama kablosunu evap. fanına vidala) | 8 | | | | | | | | | 25 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | arrange fan cables and prob (fan kablolarını ve prob kablosunu düzenle) | 11 | | | | | | | | | | | | 8 | | | | | | | | | | | | | | | | | | | | | |
| | 6 | fix fastening material to cables and prob cable onto the evap (kabloları ve prob kablosunu kablo bağı ile evap üstüne bağla) | 11 | | | | | | | | | | | | 18 | | | | | | | | | | | | | | | | | | | | | |
| | 7 | cut end of fastening material (kablo bağının ucunu kes) | 11 | | | | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | |
| | 8 | sealing into the evap box hole which evap blower cables comes from there with mastich (evap. box'da evap fan kabloların geçtiği deliğin içine mastikle kapat) | 11 | | | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | |
| | 9 | sealing out of the evap box hole with mastich (evap. Box'da kabloların geçtiği deliğin dışını mastikle kapat) | 11 | | | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | |
| | 10 | press end of compressor blower cable-brown and fix it to the comp. blower(kompresör fan kablosunun ucunu ez ve komp. fanına tak) | 11 | | | | | | | | | | | | 7 | | | | | | | | | | | | | | | | | | | | | |
| | 11 | press end of compressor blower cable-blue and fix it to the comp. blower (kompresör fan kablosunun ucunu ez ve komp. fanına tak) | 11 | | | | | | | | | | | | 7 | | | | | | | | | | | | | | | | | | | | | |
| | 12 | screw grounding cable to the compressor blower metal (topraklama kablosunu kompresör fan sacına vidala) | 11 | | | | | | | | | | | | 22 | | | | | | | | | | | | | | | | | | | | | |
| | 13 | arrange compressor blower metal cables (kompresör fan metali kablolarını düzenle) | 11 | | | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | |
| | 14 | fix pineed fastening material to the cables (kabloları iğneli kablo bağı ile bağla) | 11 | | | | | | | | | | | | 12 | | | | | | | | | | | | | | | | | | | | | |
| | 15 | cut end of fastening material (kablo bağının ucunu kes) | 11 | | | | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | |
| | 16 | place evap. blower cables between compress and evap.box (evap fan kablolarını kompresör ile evap. box'ın arasına yerleştir) | 11 | | | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | |
| | 17 | cut end of fastening material (kablo bağının ucunu kes) | 11 | | | | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | |
| 12 | 1 | mount the valves to the cooler and connect machine (vanaları yerleştir ve makinayla bağlantı kur) | 12 | | | | | | | | | | | | | 16 | | | | | | | | | | | | | | | | | | | | |
| 12 | 2 | pressure control (basınç kontrolü) (machine time) | M | 130 | | | | | | | | | | | | 90 | | | | | | | | | | | | | | | | | | | | |
| 12 | 3 | detect gas leak with hellium (helyumla gaz kaçağını kontrol et) | 12 | | | | | | | | | | | | | 25 | | | | | | | | | | | | | | | | | | | | |
| 12 | 4 | empty the gas (gazı boşalt) (machine time) | M | 12 | | | | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | | | |
| 12 | 5 | removing the hose and valves of the helium station from the cooling unit (helyum makinasının hortumunu ve valflerini soğutucudan çıkar) | 12 | | | | | | | | | | | | | 16 | | | | | | | | | | | | | | | | | | | | |
| 12 | 6 | plug cooler and control electric leak (soğutucunun fişini prize tak ve elektrik kaçağını kontrol et) | 12 | | | | | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | | | |
| 13 | 1 | place back eps to the metal (arka straforu saca yerleştir) | 13 | | | | | | | | | | | | | | 6 | | | | | | | | | | | | | | | | | | | |
| 13 | 2 | stick 2 armouflex to the back eps (arka strafora 2 adet armaflex yapıştır) | 13 | | | | | | | | | | | | | | 12 | | | | | | | | | | | | | | | | | | | |
| 13 | 3 | place evap. box eps cover to the evap. box (evap box strafor kapağını evap box kutusuna yerleştir) | 13 | | | | | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | |

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| | 4 (off) | cut a part from evap box eps cover (evap box strafor kapağından bir parça kes) | 13 | | | | | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | |
| | 5 | stick aluminium tape on evap box eps cover (aliminyum bantı evap box strafor kapağına yapıştır) | 13 | | | | | | | | | | | | | | 24 | | | | | | | | | | | | | | | | | | | |
| | 6 | place compressor eps cover on the compressor (kompresör kapama straforunu kompresör üzerine yerleştir) | 13 | | | | | | | | | | | | | | 4 | | | | | | | | | | | | | | | | | | | |
| | 7 | squeeze silicon on the compressor eps cover (kompresör kapama staraforu üzerine silikon sık) | 13 | | | | | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | |
| | off | bring evap. box eps cover, insulation eps and compressor cover eps (40-50 tane/each) (Evap üzeri strafor kapak, izolasyon straforu (arka sac üzerindeki) ve kompresör kapama straforunu getir) | 13 | | | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | | | |
| | off | cut armaouflex (armaflexiler elle kesilip hazırlanır) | 13 | | | | | | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | |
| | off | cut aliminium tape (aliminyum bant kes) | 13 | | | | | | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | |
| 10 (2.kısım) | 1 | screw adaptor (1 screw) (adaptörü vidala) | 10 | | | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | arrange cables and fix fastening material (kabloları düzenle ve kablo bağını tak) | 10 | | | | | | | | | | | 67 | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | fix 2 latches to the electronic thermostat (elektronik termostat 2 adet kelepçe tak) | 10 | | | | | | | | | | | 24 | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | place black thermostat box (siyah termostat kutusunu yerleştir) | 10 | | | | | | | | | | | 25 | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | screw black thermostat box (siyah termostat kutusunu vidala) | 10 | | | | | | | | | | | 27 | | | | | | | | | | | | | | | | | | | | | | |
| 14 | 1 | place and stick internal base metal on the evap. eps cover (iç taban sacını evap strafor kapağına yerleştir ve yapıştır) | 14 | | | | | | | | | | | | | | | 16 | | | | | | | | | | | | | | | | | | |
| | 2 | place internal back metal to the back metal (iç arka sacı arka saca yerleştir) | 14 | | | | | | | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | |
| | 3 | put drainage tube's end into the drip tray (su tahliye borusunun ucunu su tasına koy) | 14 | | | | | | | | | | | | | | | 6 | | | | | | | | | | | | | | | | | | |
| | 4 | screw internal back metal to the cabin from the back side (2 screws) (iç arka sacı kabine vidala, vidalar kabinin arkasına vidalanacak) | 14 | | | | | | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | |
| | 5 | screw internal back metal to the cabin from the front right side (3 screws) (iç arka sacı kabine vidala, vidalar kabinin sağ ön tarafına vidalanacak) | 14 | | | | | | | | | | | | | | | 13 | | | | | | | | | | | | | | | | | | |
| | 6 | screw internal back metal to the cabin from the front left side (3 screws) (iç arka sacı kabine vidala) vidalar kabinin sol ön tarafına vidalanacak) | 14 | | | | | | | | | | | | | | | 13 | | | | | | | | | | | | | | | | | | |
| | 7 | screw mounting chanel for glass to the left side of internal back metal (cam yerleştirme kanalını iç arka metalin sol tarafına vidala) | 14 | | | | | | | | | | | | | | | 17 | | | | | | | | | | | | | | | | | | |
| | 8 | screw mounting chanel for glass to the right side of internal back metal (cam yerleştirme kanalını iç arka metalin sağ tarafına vidala) | 14 | | | | | | | | | | | | | | | 17 | | | | | | | | | | | | | | | | | | |
| | 9 | stick max load label into the cooler (max load etiketiketini kabinin içine yapıştır) | 14 | | | | | | | | | | | | | | | 6 | | | | | | | | | | | | | | | | | | |
| 15-16 | 1 | squeeze silicon into the internal base metal (iç taban sacının içine silikon sık) | 15 | | | | | | | | | | | | | | | | 25 | | | | | | | | | | | | | | | | | |
| | 2 | bring the internal glass (iç camı getir) | 16 | | | | | | | | | | | | | | | | | 5 | | | | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | stick internal glass to the cabin (iç camı kabine yapıştır) | 15 | | | | | | | | | | | | | | | | 30 | | | | | | | | | | | | | | | | | |
| | 4 | screw internal glass from right side (2 screws) (iç camı iç arka metal saca sağ taraftan vidala | 15 | | | | | | | | | | | | | | | | 17 | | | | | | | | | | | | | | | | | |
| | 5 | screw internal glass from left side (2 screws) (iç camı iç arka metal saca sol taraftan vidala | 15 | | | | | | | | | | | | | | | | 17 | | | | | | | | | | | | | | | | | |
| | 6 | bring the external glass (dış camı getir) | 16 | | | | | | | | | | | | | | | | | 5 | | | | | | | | | | | | | | | | |
| | 7 | place external glass (dış camı yerleştir) | 16 | | | | | | | | | | | | | | | | | 12 | | | | | | | | | | | | | | | | |
| | 8 | screw internal base metal (3 screws) (iç taban sacını vidala) | 15 | | | | | | | | | | | | | | | | 23 | | | | | | | | | | | | | | | | | |
| | 9 | screw external glass (dış camı vidala) | 15 | | | | | | | | | | | | | | | | | 33 | | | | | | | | | | | | | | | | |
| | 10 | stick aluminium tape out of external glass (dış camın alt kısmına aliminyum bant yapıştır) | 15 | | | | | | | | | | | | | | | | 28 | | | | | | | | | | | | | | | | | |
| 17 | 1 | take internal glass foil (iç cam koruyucu folyoyu çıkar) | 17 | | | | | | | | | | | | | | | | | | 25 | | | | | | | | | | | | | | | |
| | 2 | take external glass foil (dış cam koruyucu folyoyu çıkar) | 17 | | | | | | | | | | | | | | | | | | 65 | | | | | | | | | | | | | | | |
| 18 | 1 | stick sticker to the grey top cover with mastar (gri üst kapağa mastarla etiketi yapıştır) | 18 | | | | | | | | | | | | | | | | | | | 32 | | | | | | | | | | | | | | |
| | 2 | clean front cover metal and soap with sponge (ön kapama sacını sil ve süngerle sabunla) | 18 | | | | | | | | | | | | | | | | | | | 13 | | | | | | | | | | | | | | |
| | 3 | open sticker and stick it (etiketi aç ve yapıştır) | 18 | | | | | | | | | | | | | | | | | | | 37 | | | | | | | | | | | | | | |
| | 4 | stick sticker to the front cover metal (etiketi ön kapama sacına yapıştır) | 18 | | | | | | | | | | | | | | | | | | | 42 | | | | | | | | | | | | | | |
| | 5 | dry the stick (etiketi kurula) | 18 | | | | | | | | | | | | | | | | | | | 9 | | | | | | | | | | | | | | |
| 19 | 1 | place 1. shelf into the cooler (1. rafı kabinin içine yerleştir) | 19 | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | | | | | | | |
| | 2 | screw 2. shelf into the cooler (2. rafı kabinin içine vidala) | 19 | | | | | | | | | | | | | | | | | | | | 45 | | | | | | | | | | | | | |
| 20-21 | 1 | screw left decorative part (sol dekoratif parçayı vidala) | 20-21 | | | | | | | | | | | | | | | | | | | | | 9 | 9 | | | | | | | | | | | |
| | 2 | screw right decorative part (sağ dekoratif parçayı vidala) | 20-21 | | | | | | | | | | | | | | | | | | | | | 9 | 9 | | | | | | | | | | | |
| | 3 | stick 2 armouflex top of the cabin (kabinin üstüne 2 armaflex yapıştır) | 21 | | | | | | | | | | | | | | | | | | | | | | 20 | | | | | | | | | | | |
| | 4 | place top cover eps (üst kapama straforunu yerleştir) | 20 | | | | | | | | | | | | | | | | | | | | | 25 | | | | | | | | | | | | |
| | 5 | place grey top cover on the cabin (gri üst kapağı kabine yerleştir) | 20 | | | | | | | | | | | | | | | | | | | | | 15 | | | | | | | | | | | | |
| | 6 | screw grey top cover to the cabin (gri üst kapağı kabine vidala-3 vida) | 20-21 | | | | | | | | | | | | | | | | | | | | | 10 | 10 | | | | | | | | | | | |
| | off | cut armouflex tape (armaflex bandı kes) | 20 | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | | | | | |
| 22 | 1 | cooler comes to the vacuum by caroser (soğutucu karoserle vakuma gider (machine time) | M | 22 | | | | | | | | | | | | | | | | | | | | | | 22 | | | | | | | | | | |
| | 2 | mounting 2 vacuum valves to the compressor and service tubes (vakum vanalarını kompresör ve servis borularına bağla) | 22 | | | | | | | | | | | | | | | | | | | | | | | 6 | | | | | | | | | | |
| | 3 | mounting 2 hoses to the vacuum valves (hortumları vakum vanalarına bağla) | 22 | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | | | | |
| | 4 | test (machine time) 12min*60=720 sec | M | 720 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | demount hoses from the vacuum valves (hortumları vakum vanasından sök) | 22 | | | | | | | | | | | | | | | | | | | | | | | | 6 | | | | | | | | | | |
| | 6 | fix isolation sponge | 22 | | | | | | | | | | | | | | | | | | | | | | | | 7 | | | | | | | | | | |
| | 7 | stick thermostat sticker | 22 | | | | | | | | | | | | | | | | | | | | | | | | 6 | | | | | | | | | | |
| | 8 | cooler comes from caroser to the conveyor (soğutucu karoserden konveyöre gelir) | M | 22 | | | | | | | | | | | | | | | | | | | | | | | 22 | | | | | | | | | | |
| | off | cut isolation sponge | 22 | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | | | |
| 23 | 1 | mount gas gun to the valve (gaz tabancasını vanaya bağla) | 23 | | | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | | | |
| | 2 | charging gas (machine time) (gaz doldur) | M | 43 | | | | | | | | | | | | | | | | | | | | | | | | 43 | | | | | | | | | |
| | 3 | demount gas gun (gaz tabancasını sök) | 23 | | | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | | | |
| | 4 | press end of cooler tube's with pinchoffs (soğutucu boruların ucunu pinchoff makasıyla ez) | 23 | | | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | | | | | |
| | 5 | demount valves (vanaları sök) | 23 | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | | |
| | 6 | solder end of compressor tube, service tube and melt corners of tube (kompresör borusunun ve servis borusunun ucunu lehimle ve köşeleri erit) (sert lehimleme) | 23 | | | | | | | | | | | | | | | | | | | | | | | | | 33 | | | | | | | | | |
| | 7 | bend 1. tube from the melt corner (1. boruyu eritilen yerden eğ) | 23 | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | | |
| | 8 | bend 2. tube from the melt corner (2. boruyu eritilen yerden eğ) | 23 | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | | |
| | 9 | write name and gas amount to the paper (sicilini ve gaz miktarını föy kağıdına yaz) | 23 | | | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | | | | | |
| 24 | 1 | cut fastening material from the power cable and plug to the machine (güç kablosundaki kablo bağını kes ve makinaya fişi tak) | 24 | | | | | | | | | | | | | | | | | | | | | | | | | | 15 | | | | | | | | |
| | 2 | plug power cable (güç kablosunu fişe tak) | 20 | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | |
| | 3 | read barcode (barkodu okut) | 24 | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | |
| | 4 | test high voltage and insulation test (yüksek gerilim ve izolasyonu kontrol et) | 24 | | | | | | | | | | | | | | | | | | | | | | | | | | 30 | | | | | | | | |
| | 5 | control gas leak (gaz kaçağını kontrol et) | 20 | | | | | | | | | | | | | | | | | | | | | | | | | | 50 | | | | | | | | |
| | 6 | stick barcode on the cabin (kabine etiketi yapıştır) | 24 | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | |
| | 7 | write number and seal to the paper (föy kağıdına sicilini yaz ve onay kaşesini bas) | 24 | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | | |
| | 8 | arrange power cable (güç kablosunu düzenle) | 24 | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | |
| 25 | 1 | cooler comes to caroser (soğutucu karosere gelir) | M | 22 | | | | | | | | | | | | | | | | | | | | | | | | | | 22 | | | | | | | |
| | 2 | plug power cable (güç kablosunu fişe tak) | 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | |
| | 3 | check the condenser, blower, blower motor manually | 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | | | |
| | 4 | put prob cable into the cartoon hole and place cartoon to the top of the cabin (prob kablosunu kartonun deliğinden geçir ve kartonu kabinin üstüne koy) | 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | 14 | | | | | | | |
| | 5 | read barcode and start testing the machine (machine time) (barkodu okut ve makinayı teste başlat) | M | 36 | | | | | | | | | | | | | | | | | | | | | | | | | | 36 | | | | | | | |
| | 6 | control performans and seal (performansını kontrol et ve kaşe bas) | | | | | | | | | | | | | | | | | | | | | | | | | | | | 20 | | | | | | | |
| | 7 | take the cartoon from top cover (test için soğutucu üzerine konulan kartonu al) | 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8 | cooler comes from caroser to the conveyor (soğutucu karoserden konveyöre gelir) | M | 22 | | | | | | | | | | | | | | | | | | | | | | | | | 22 | | | | | | | |
| 26-27 | 1 | take front metal cover and put the konveyor (ön kapama sacını al ve konveyöre koy) | 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | |
| 26-27 | 2 | paint solder points (lehim noktalarını boya) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | |
| 26-27 | 3 | give the condenser cover metal (kondenser kapama sacını ver) | 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | |
| 26-27 | 4 | place 1. screw with copper to the hole of the condenser cover metal and screw (1. vidayı bakırla kondenser kapama sacının deliğine yerleştir ve vidala) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | |
| 26-27 | 5 | place 2. screw with copper to the hole of the condenser cover metal and screw (2. vidayı bakırla kondenser kapama sacının deliğine yerleştir ve vidala) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | |
| 26-27 | 6 | place 3. screw with copper to the hole of the condenser cover metal and screw (3. vidayı bakırla kondenser kapama sacının deliğine yerleştir ve vidala) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 | | | | | |
| 26-27 | 7 | screw condenser cover metal near the thermostat (kondenser kapama sacını termostat yanından vidala) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 8 | | | | | |
| 26-27 | 8 | screw compressor blower metal to the cabin (kompresör fan sacını kabine vidala) | 26-27 | | | | | | | | | | | | | | | | | | | | | | | | | | | 24 | 19 | | | | | |
| 26-27 | 9 | stick aliminium tape on the compresor blower metal (aliminyum bantı kompresör fan sacının kenarına yapıştır) | 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 | | | | | | |
| 26-27 | 10 | screw front cover metal to the cabin (ön kapama sacını kabine vidala) | 26-27 | | | | | | | | | | | | | | | | | | | | | | | | | | | 33 | 33 | | | | | |
| 26-27 | 11 (off) | squeeze adhesive to the left air flow fin and stick (sol hava akış kanatçığına yapıştırıcı sık ve yapıştır) | 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | 21 | | | | | | |
| 26-27 | 12 (off) | squeeze adhesive to the middle air flow fin and stick (orta hava akış kanatçığına yapıştırıcı sık ve yapıştır) | 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | 16 | | | | | | |
| 26-27 | 13 (off) | squeeze adhesive to the right air flow fin and stick (sağ hava akış kanatçığına yapıştırıcı sık ve yapıştır) | 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | 18 | | | | | | |
| 26-27 | off | cut aluminium tape (aliminyum bant kes) | 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | |
| 28 | 1 | clean inside and outside of the cooler with air (dolabın içini, camlarını havayla temizle) | 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15 | | | | |
| 28 | 2 | clean outside of cooler with air (soğutucunun dışını havayla temizle) | 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 8 | | | | |
| 28 | 3 | clean inside and outside of cooler with alcohol (soğutucunun içini ve dışını alkolle temizle) | 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 60 | | | | |
| 29 (Quality Operator) | 1 | control cooler estetically (soğutucuyu estetik olarak kontrol et) | 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 100 | | | |
| 29 (Quality Operator) | 2 | plug cooler for electric control (elektrik kontrolü için soğutucuyu fişe tak) | 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | |
| 29 (Quality Operator) | 3 | control breakdown, control gas and cooling seals (arıza kaşesi, gaz ve soğutma mühürleri varmı kontrol et) | 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 8 | | | |
| 29 (Quality Operator) | 4 | read barcode (barkodu okut) | 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | | | |
| 29 (Quality Operator) | 5 | take labels and user manual and go to the cooler (etiketleri ve kullanıcı el kitabını al ve dolaba git) | 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15 | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | stick stickers to the glass and put user manual into the cooler (etiketleri cama yapıştır ve kullanıcı el kitabını soğutucunun içine koy) | 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 10 | | | |
| 30-31 | 1 | take grey top cover (gri üs kapaktan folyoyu al) | 31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | |
| 30-31 | 2 | stick sticker to the condenser cover metal (arka kapama sacına etiket yapıştır) | 31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | |
| 30-31 | 3 | unplug and wrap power cable (güç kablosunu sar) | 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 | | |
| 30-31 | 4 | fix power cable to the handle with fastening material (güç kablosunu sac tutamağına kablo bağı ile bağla) | 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 17 | | |
| 30-31 | 5 | put plastic bag on cooler (plastik poşeti soğutucuya geçir) | 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15 | | |
| 30-31 | 6 | cut the top of the plastik pocket (plastik poşetin üstünü kes) | 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | |
| 30-31 | 7 | stick top of the cooler wtih band (soğutucunun üstünü 2 bantla yapıştır) | 30-31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 16 | 10 | |
| 30-31 | 8 | stick plastic and cartoon angle with band to the cooler (carton ve plastik köşebentleri bantla soğutucuya yapıştır) | 30-31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 17 | 26 | |
| 30-31 | 10 | put upper protective eps onto the box (kutunun üstüne üst koruyucu straforu koy) | 31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | |
| 30-31 | 11 | put cartoon box on the cooler (karton kutuyu soğutucunun üzerine koy) | 30-31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 18 | 11 | |
| 30-31 | 12 | stick label to the box (kutunun üstüne etiketi yapıştır) | 31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | |
| 32 | 1 | punch cover of box (kutunun kapağını zımbala) | 32 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 12 |
| 32 | 2 | squeeze hot melt onto the 2 cartoon angles and stick onto the box (2 tane karton köşebente erimiş yapışkandan sık ve kutunun üzerine yapıştır) | 32 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 22 |
| 32 | 3 | take gree pallet under the cooler (soğutucunun altından yeşil paleti al) | 31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15 | |
| 32 | 5 | wrap and fix stripes to the box (2 numbers) (şeritleri sar ve bağla) (machine time) | 32 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 30 |

# APPENDIX B

## SLIM FINAL ASSEMBLY BALANCED OPERATION TIMES

### SLIM FINAL ASSEMBLY LINE (BALANCED)

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Balancing Ratio | 80% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Max efficiency | 79,9% | | 0,79 | 0,76 | 0,79 | 0,72 | 0,73 | 0,73 | 0,67 | 0,69 | 0,75 | 0,58 | 0,80 | 0,79 | 0,73 | 0,67 | 0,69 | 0,64 | 0,27 | 0,57 | 0,37 | 0,55 | 0,54 | 0,66 | 0,64 | 0,48 | 0,40 | 0,67 | 0,57 | 0,55 |
| | | Min efficiency | 26,8% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | *Slim Black Battery-593-0000-007* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 155 | 167 | | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 |
| | | 1,63 | 133 | | 165 | 158 | 165 | 150 | 153 | 152 | 141 | 145 | 157 | 122 | 167 | 166 | 153 | 140 | 145 | 133 | 56 | 119 | 77 | 115 | 112 | 139 | 133 | 101 | 83 | 140 | 119 | 116 |
| | | average efficiency | 63,6% | Current | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 1-2 | 1 | bend mechanism support base (Destek çıtasını eğ) | 1 | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-2 | 2 | fix left and right pillars to the cabin (Sağ ve sol dikmeleri kabine sabitle) | 1-2 | | 25 | 25 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-2 | 3 | fix external cabins support to the cabin (Kabin iç destek çıtasını kabine sabitle) | 1-2 | | 10 | 10 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-2 | 4 | assembly wheels to the shaft (Tekerlekleri tekerlek şaftına monte et) | 2 | | | 18 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-2 | 5 | screw wheels to the cabin's base (Tekerlekleri kabinin tabanına vidala) | 1-2 | | 22 | 22 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-2 | 6 | fixing 2 legs bases (2 ayağı kabinin alt kısmına sabitle) | 1-2 | | 12 | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-2 | 7 | assemby handle (sac tutamağını monte et ) | 1-2 | | 13 | 13 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-2 | 8 | screw (2+2) back cabin metal to the back side (arka gövde sacını vidala | 1-2 | | 30 | 15 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-2 | 9 | move wooden pallet to the line (Tahta paleti hatta koy) | 2 | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-2 | 10 | move cabin on wooden pallet (Kabini tahta palet üzerine koy) | 1-2 | | 6 | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-2 | 11 | screwing plate to the cabin's base (Alt gövde sacını kabinin temeline vidala) | 1-2 | | 27 | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-2 | 12 | turn over cabin (Kabini çevir) | 2 | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-2 | off | preparing legs (ayak hazırlama) | 1 | | 15 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 1 | place copper tubes and plastic hoses to the plate (4+4) (Bakır boruları ve plastik boruları alt gövde sacına yerleştir) | 3 | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 2 | assy evap. Box+compr. Drip tray (Evaporatör kutusunu ve kompresör su tasını birbirine monte et) | 3 | | | | 20 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 3 | place (Evap. Box+Compr.drip tray) onto the plate (Evap kutusu+kompresör su tasını kabin tabanına yerleştir) | 3 | | | | 12 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 4 | enlarge evap.'s hangers (evap'ın kancalarını genişlet) | 3 | | | | 10 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 5.1 (off) | stick 1 sponge to evap. motor (1. süngeri evap. motoruna yapıştır) | 3 | | | | 6 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 5.2 (off) | stick 1 sponge to evap. motor (2. süngeri evap. motoruna yapıştır) | 3 | | | | 6 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 6 (off) | put probe cable into macaron (Prob kablosunu makaronun içinden geçir) | 3 | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | |

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| | 7 (off) | place probe sensor into evaporator (Prob sensörünü evap.'ın içine yerleştir) | 3 | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 8 | place evap in to evap box (Evaporatörü evap kutusuna yerleştir) | 3 | | | | 14 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 9 (off) | cut and stick 2 pieces sponges to evap top side (2 adet süngeri kes ve evap.ın tavanına yapıştır) | 3 | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 10 | place evap top side (Evaporatörün üst metal parçasını evaporatöre yerleştir) | 3 | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 11 | screw evap top side (2screws) (Evap.'ın üst metal parçasını vidala (2 vida) | 3 | | | | 14 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 12 | stick dryer tube with mastich to evap box's hole (Dryer borularını macunla evap kutusunun deliğine yapıştır) | 3 | | | | 10 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 14 | place evaporation tube into drip tray (to eliminate water) (buharlaştırma borusunu su tasına yerleştir) | 3 | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 15 | put 2 evaporator tube fix metal onto the evaporator tube (2 adet buh. borusu sabitleme sacını buh. borusu üzerine koy) | 3 | | | | 6 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | cut white plastic hose in 4 pcs (Beyaz plastik tüpleri kes (4 pcs) | 3 | | | | 4 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | bring evap box(4 adet evap kutusu getir) | 3 | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | bring compressor drip tray (black 10pcs/time) (Kompresör su tasını getir) | 3 | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | bring evap. (20pcs/each time) (Evaporatör getir) | 3 | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | stick sponge to the 2 evaporator fix metals (2 buh. borusu sabitleme sacına sünger yapıştır) | 3 | | | | 10 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | cut macaron (Makaronu kes) | 3 | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | off | cut prob cable's fastening material (Prob kablosunun kablo tutucusunu kes) | 3 | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | 1 | place compressor into the drip tray (kompresörü su tasına yerleştir) | 4 | | | | | 12 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | arrange tubes and put compressor's cable into the oring (boruları düzenle ve kompresörün kablosunu oringten geçir) | 4 | | | | | 6 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | place spacer and washer and screw them (set from 4) (pul, civata ve vidayı yerleştir ve vidala) | 4 | | | | | 35 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | put the cooler on the green pallet (soğutucuyu yeşil paletin üzerine koy) | 4 | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | eject stickers from compressor tubes (kompresör borularının etiketilerini çıkar) | 4 | | | | | 7 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 6 | eject cap from evaporation tube (buharlaştırma borusundan kapağı çıkar) | 4 | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 7 | eject cap from compressor tube (kompresör borusundan kapağı çıkar) | 4 | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 8 | enlarge compressor tubes (Kompresör borularını genişlet) | 4 | | | | | 10 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 9 | fix 1.compressor tube to evap.'s tube (1.kompresör borusunu evap.'ın borusuna tak) | 4 | | | | | 13 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 10 | fix 2.compressor tube to evaporation tube (2.kompresör borusunu buharlaştırma borusuna tak) | 4 | | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 11 | put soldering metal (lehimleme metalini koy) | 4 | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 12 | bring solder gun (lehim tabancasını getir) | 4 | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 13 | solder 1. compressor tube to the evap's tube (1. kompresör borusunu evap'ın borusuna lehimle) | 4 | | | | | 22 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 14 | solder 2. compressor tube to the evaporation tube (2. kompresör borusunu buharlaştırma borusuna lehimle) | 4 | | | | | 15 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 15 | take the soldering metal (lehimleme metalini al) | 4 | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | |

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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | 1 | make colder solder area (lehim yapılan bölgeyi soğut) | 5 | | | | | | 15 | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | fix insulation sponge (izolasyon süngerini tak) | 5 | | | | | | 7 | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | fix first fastening material to the isolation sponge (İzolasyon süngerine 1. kablo bağını tak) | 5 | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | fix second fastening material to the isolation sponge (İzolasyon süngerine 2. kablo bağını tak) | 5 | | | | | | 7 | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | cut end of fastening materials (kablo bağlarının ucunu kes) | 5 | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | |
| | 6 | screw condenser blower metal to the cabin (6 screws) (kondenser fan sacını kabine vidala) | 5 | | | | | | 40 | | | | | | | | | | | | | | | | | | | | | | | |
| | 7 | put condenser blower cable inside clip (kondenser fan kablosunu klipsin içinden geçir) | 5 | | | | | | 13 | | | | | | | | | | | | | | | | | | | | | | | |
| | 9 | stick 2 sponges to the pillars (2 süngeri sağ ve sol dikmelere yapıştır) | 6 | | | | | | | 25 | | | | | | | | | | | | | | | | | | | | | | |
| | 10 | take compressor and evap blower cable from front side to the back side (komp. ve evap fan kablosunu ön taraftan arka tarafa al) | 5-6 | | | | | | 12 | 12 | | | | | | | | | | | | | | | | | | | | | | |
| | 11 | put prob cable through evap. box's hole (prob kablosunu evap'ın deliğinden geçir) | 6 | | | | | | | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | 12 | take the display and compressor cable from back side to the front side display ve komp. kablosunu arka taraftan ön tarafa al) | 5-6 | | | | | | 15 | 15 | | | | | | | | | | | | | | | | | | | | | | |
| | 13 | screw blower to the blower metal (2+2 screws) (fanı fan sacına vidala) | 5 | | | | | | 18 | | | | | | | | | | | | | | | | | | | | | | | |
| | 14 | fix 2 cables (blue and yellow) to the blower (2 kabloyu fana tak) | 5 | | | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | |
| | 15 | screw ground cable to the blower motor (topraklama kablosunu fan motoruna vidala) | 5 | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | |
| | off | cut isolation sponge (izolasyon süngerini kes) | 5 | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | 1 | screw notr cable (nötr kablosunu vidala) | 6 | | | | | | | 14 | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | screw phase cable (faz kablosunu vidala) | 6 | | | | | | | 14 | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | screw 2 ground cable to blower metal (2 topraklama kablosunu fan sacına vidala) | 6 | | | | | | | 17 | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | fix 2 prob sockets to the thermostat (2 prob soketini fan termostata tak) | 6 | | | | | | | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | fix 3 compressor cables to the thermostat (3 kompresör kablosunu thermostata tak) | 6 | | | | | | | 25 | | | | | | | | | | | | | | | | | | | | | | |
| | off | cut adhesive sponges (yapışkan süngerleri kes) | 6 | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | |
| | off | bring green pallet (yeşil paleti getir) | 6 | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| | off | put green pallet (yeşil paleti koy) | 6 | | | | | | | 6 | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | 1 | screw internal condenser to the cabin (2+2) | 7 | | | | | | | | 55 | | | | | | | | | | | | | | | | | | | | | |
| | 2 | screw external condenser to the cabin (2+2) | 7 | | | | | | | | 55 | | | | | | | | | | | | | | | | | | | | | |
| | 3 | take internal condenser (İç kondanserin istiften alınarak tezgaha getirilmesi) | 7 | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | |
| | 4 | take external condenser (Dış kondanserin istiften alınarak tezgaha getirilmesi) | 7 | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | |
| | 5 | take conders' cap (Kondanser tapalarının çıkartılması) | 7 | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | |
| | 6 | combine internal and external condensers (iç ve dış kondanser arasına ilave boru takılarak birleştirilmesi) | 7 | | | | | | | | 20 | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | 1 | turn the pallet (paleti çevir) | 5 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | |

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| | 2 | arrange tubes (boruları düzenle) | 5 | | | | | | | | | 6 | | | | | | | | | | | | | | | | | | | | |
| | 3 | eject condenser tubes' cap (kondenser borularının şapkasını çıkar) | 5 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | |
| | 4 | fix condenser tube to the dual dryer tube (kondenser borusunu ikili dryer borusuna tak) | 5 | | | | | | | | | 20 | | | | | | | | | | | | | | | | | | | | |
| | 5 | fix condenser tube to the evaporation tube (Kondanser borusunu buharlaştırma borusuna tak) | 5 | | | | | | | | | 7 | | | | | | | | | | | | | | | | | | | | |
| | 6 | fix service tube to the dryer (servis borusunu dryer'e tak) | 5 | | | | | | | | | 8 | | | | | | | | | | | | | | | | | | | | |
| | 8 | take the solder gun (lehim tabancasını al) | 5 | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | |
| | 9 | solder this tubes (bu boruları lehimle) | 5 | | | | | | | | | 25 | | | | | | | | | | | | | | | | | | | | |
| | 10 | fix again service tube to the dryer (servis borusunu tekrar dryer'a tak) | 5 | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | |
| | 11 | take the solder gun (lehim tabancasını al) | 5 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | |
| | 12 | solder this tube (bu boruyu lehimle) | 5 | | | | | | | | | 25 | | | | | | | | | | | | | | | | | | | | |
| | 13 | soldering condenser's addition points (kondanserin ek noktasının kaynak teli yardımı ile sert lehimlenmesi) | 5 | | | | | | | | | 28 | | | | | | | | | | | | | | | | | | | | |
| | 14 | leave solder gun (şalamanın yerine bırakılması) | 5 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | 1 | put evap. fan cable (blue cable) into the evap box and press it's end (evap fan kablosunu evap kutusundan geçir ve ucunu ez) | 9 | | | | | | | | | | 12 | | | | | | | | | | | | | | | | | | | |
| | 2 | fix evap fan cable (blue) to the evap blower (evap fan kablosunu evap fanına tak) | 9 | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | |
| | 3 | press end of evap fan cable and fix it to the evap. blower-brown cable (evap fan kablosunun ucunu ez ve evap.fanına tak) | 9 | | | | | | | | | | 12 | | | | | | | | | | | | | | | | | | | |
| | 4 | screw grounding cable which comes from clemens to the evap. blower (klemensten gelen topraklama kablosunu evap. fanına vidala) | 9 | | | | | | | | | | 25 | | | | | | | | | | | | | | | | | | | |
| | 5 | arrange fan cables and prob (fan kablolarını ve prob kablosunu düzenle) | 9 | | | | | | | | | | 8 | | | | | | | | | | | | | | | | | | | |
| | 6 | fix fastening material to cables and prob cable onto the evap (kabloları ve prob kablosunu kablo bağı ile evap üstüne bağla) | 9 | | | | | | | | | | 18 | | | | | | | | | | | | | | | | | | | |
| | 7 | cut end of fastening material (kablo bağının ucunu kes) | 9 | | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | |
| | 8 | sealing into the evap box hole which evap blower cables comes from there with mastich (evap. box'da evap fan kabloların geçtiği deliğin içine mastikle kapat) | 9 | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | |
| | 9 | sealing out of the evap box hole with mastich (evap. Box'da kabloların geçtiği deliğin dışını mastikle kapat) | 9 | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | |
| | 10 | press end of compressor blower cable-brown and fix it to the comp. blower(kompresör fan kablosunun ucunu ez ve komp. fanına tak) | 9 | | | | | | | | | | 7 | | | | | | | | | | | | | | | | | | | |
| | 11 | press end of compressor blower cable-blue and fix it to the comp. blower (kompresör fan kablosunun ucunu ez ve komp. fanına tak) | 9 | | | | | | | | | | 7 | | | | | | | | | | | | | | | | | | | |
| | 12 | screw grounding cable to the compressor blower metal (topraklama kablosunu kompresör fan sacına vidala) | 9 | | | | | | | | | | 22 | | | | | | | | | | | | | | | | | | | |
| | 13 | arrange compressor blower metal cables (kompresör fan metali kablolarını düzenle) | 9 | | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | |
| | 14 | fix pineed fastening material to the cables (kabloları iğneli kablo bağı ile bağla) | 9 | | | | | | | | | | 12 | | | | | | | | | | | | | | | | | | | |
| | 15 | cut end of fastening material (kablo bağının ucunu kes) | 9 | | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 16 | place evap. blower cables between compress and evap.box (evap fan kablolarını kompresör ile evap. box'ın arasına yerleştir) | 9 | | | | | | | | | | 5 | | | |
| | 17 | cut end of fastening material (kablo bağının ucunu kes) | 9 | | | | | | | | | | 3 | | | |
| 10 | 1 | screw blue cable to the clemens (Mavi kabloyu klemense vidala) | 10 | | | | | | | | | | | 12 | | |
| | 2 | screw ground cable to the clemens (Topraklama kablosunu klemense vidala) | 10 | | | | | | | | | | | 12 | | |
| | 3 | put cables into the black box (kabloları karakutudan geçir) | 10 | | | | | | | | | | | 10 | | |
| | 4 | screw red cable to the digital thermostat (Kırmızı kabloyu dijital termostata vidala) | 10 | | | | | | | | | | | 12 | | |
| | 5 | screw 3 cables which come from compressor (kompresörden gelen kablonun 3 ucunu dijital termostata vidala) | 10 | | | | | | | | | | | 30 | | |
| | 6 | divide black prob's end (siyah probun ucunu ikiye ayır) | 10 | | | | | | | | | | | 8 | | |
| | 7 | screw black prob's one end (siyah probun 1 ucunu vidala) | 10 | | | | | | | | | | | 12 | | |
| | 8 | screw black prob's other end with white prob's one end to the digital thermostat (siyah probun diğer ucunu beyaz prob'un bir ucuyla dijital termostata vidala) | 10 | | | | | | | | | | | 14 | | |
| | 9 | screw white prob's other end (beyaz probun diğer ucunu vidala) | 10 | | | | | | | | | | | 12 | | |
| 11 | 1 | mount the valves to the cooler and connect machine (vanaları yerleştir ve makinayla bağlantı kur) | 11 | | | | | | | | | | | | 16 | |
| | 2 | pressure control (basınç kontrolü) (machine time) | M | 90 | | | | | | | | | | | 90 | |
| | 3 | detect gas leak with hellium (helyumla gaz kaçağını kontrol et) | 11 | | | | | | | | | | | | 25 | |
| | 4 | empty the gas (gazı boşalt) (machine time) | M | 12 | | | | | | | | | | | 10 | |
| | 5 | removing the hose and valves of the helium station from the cooling unit (helyum makinasının hortumunu ve valflerini soğutucudan çıkar) | 11 | | | | | | | | | | | | 16 | |
| | 6 | plug cooler and control electric leak (soğutucunun fişini prize tak ve elektrik kaçağını kontrol et) | 11 | | | | | | | | | | | | 10 | |
| 12 | 1 | place back eps to the metal (arka straforu saca yerleştir) | 12 | | | | | | | | | | | | | 6 |
| | 2 | stick 2 armouflex to the back eps (arka starafora 2 adet armaflex yapıştır) | 12 | | | | | | | | | | | | | 12 |
| | 3 | place evap. box eps cover to the evap. box (evap box strafor kapağını evap box kutusuna yerleştir) | 12 | | | | | | | | | | | | | 5 |
| | 4 (off) | cut a part from evap box eps cover (evap box strafor kapağından bir parça kes) | 12 | | | | | | | | | | | | | 5 |
| | 5 | stick aluminium tape on evap box eps cover (aliminyum bantı evap box strafor kapağına yapıştır) | 12 | | | | | | | | | | | | | 24 |
| | 6 | place compressor eps cover on the compressor (kompresör kapama straforunu kompresör üzerine yerleştir) | 12 | | | | | | | | | | | | | 4 |
| | 7 | squeeze silicon on the compressor eps cover (kompresör kapama staraforu üzerine silikon sık) | 12 | | | | | | | | | | | | | 5 |
| | 9 | place and stick internal base metal on the evap. eps cover (iç taban sacını evap strafor kapağına yerleştir ve yapıştır) | 12 | | | | | | | | | | | | | 16 |
| | 8 | place internal back metal to the back metal (iç arka sacı arka saca yerleştir) | 12 | | | | | | | | | | | | | 10 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | put drainage tube's end into the drip tray (su tahliye borusunun ucunu su tasına koy) | 12 | | | | | | | | | | | | | 6 | | | | | | | | | | | | | | | | |
| | 11 | screw internal back metal to the cabin from the back side (2 screws) (iç arka sacı kabine vidala, vidalar kabinin arkasına vidalanacak) | 12 | | | | | | | | | | | | | 5 | | | | | | | | | | | | | | | | |
| | 12 | screw internal back metal to the cabin from the front right side (3 screws) (iç arka sacı kabine vidala, vidalar kabinin sağ ön tarafına vidalanacak) | 12 | | | | | | | | | | | | | 13 | | | | | | | | | | | | | | | | |
| | 13 | screw internal back metal to the cabin from the front left side (3 screws) (iç arka sacı kabine vidala) (vidalar kabinin sol ön tarafına vidalanacak) | 12 | | | | | | | | | | | | | 13 | | | | | | | | | | | | | | | | |
| | 14 | screw mounting chanel for glass to the left side of internal back metal (cam yerleştirme kanalını iç arka metalin sol tarafına vidala) | 12 | | | | | | | | | | | | | 17 | | | | | | | | | | | | | | | | |
| | 15 | screw mounting chanel for glass to the right side of internal back metal (cam yerleştirme kanalını iç arka metalin sağ tarafına vidala) | 12 | | | | | | | | | | | | | 17 | | | | | | | | | | | | | | | | |
| | off | bring evap. box eps cover, insulation eps and compressor cover eps (40-50 tane/each) (Evap üzeri strafor kapak, izolasyon straforu (arka sac üzerindeki) ve kompresör kapama straforunu getir) | 12 | | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | | |
| | off | cut armaouflex (armaflexiler elle kesilip hazırlanır) | 12 | | | | | | | | | | | | | 3 | | | | | | | | | | | | | | | | |
| | off | cut aliminium tape (aliminyum bant kes) | 12 | | | | | | | | | | | | | 3 | | | | | | | | | | | | | | | | |
| 13-new operator | 1 | screw adaptor (1 screw) (adaptörü vidala) | 13 | | | | | | | | | | | | | | 10 | | | | | | | | | | | | | | | |
| | 2 | arrange cables and fix fastening material (kabloları düzenle ve kablo bağını tak) | 13 | | | | | | | | | | | | | | 67 | | | | | | | | | | | | | | | |
| | 3 | fix 2 latches to the electronic thermostat (elektronik termostat 2 adet kelepçe tak) | 13 | | | | | | | | | | | | | | 24 | | | | | | | | | | | | | | | |
| | 4 | place black thermostat box (siyah termostat kutusunu yerleştir) | 13 | | | | | | | | | | | | | | 25 | | | | | | | | | | | | | | | |
| | 5 | screw black thermostat box (siyah termostat kutusunu vidala) | 13 | | | | | | | | | | | | | | 27 | | | | | | | | | | | | | | | |
| 14-15 | 1 | squeeze silicon into the internal base metal (iç taban sacının içine silikon sık) | 14 | | | | | | | | | | | | | | | 25 | | | | | | | | | | | | | | |
| | 2 | bring the internal glass (iç camı getir) | 15 | | | | | | | | | | | | | | | | 5 | | | | | | | | | | | | | |
| | 3 | stick internal glass to the cabin (iç camı kabine yapıştır) | 14 | | | | | | | | | | | | | | | 30 | | | | | | | | | | | | | | |
| | 4 | screw internal glass from right side (2 screws) (iç camı iç arka metal saca sağ taraftan vidala | 14 | | | | | | | | | | | | | | | 17 | | | | | | | | | | | | | | |
| | 5 | screw internal glass from left side (2 screws) (iç camı iç arka metal saca sol taraftan vidala) | 14 | | | | | | | | | | | | | | | 17 | | | | | | | | | | | | | | |
| | 6 | bring the external glass (dış camı getir) | 15 | | | | | | | | | | | | | | | | 5 | | | | | | | | | | | | | |
| | 7 | place external glass (dış camı yerleştir) | 15 | | | | | | | | | | | | | | | | 12 | | | | | | | | | | | | | |
| | 8 | screw internal base metal (3 screws) (iç taban sacını vidala) | 14 | | | | | | | | | | | | | | | 23 | | | | | | | | | | | | | | |
| | 9 | screw external glass (dış camı vidala) | 14 | | | | | | | | | | | | | | | | 33 | | | | | | | | | | | | | |
| | 10 | stick aluminium tape out of external glass (dış camın alt kısmına aliminyum bant yapıştır) | 15 | | | | | | | | | | | | | | | 28 | | | | | | | | | | | | | | |
| | 11 | take internal glass foil (dış cam koruyucu folyoyu çıkar) | 15 | | | | | | | | | | | | | | | | 25 | | | | | | | | | | | | | |
| | 12 | take external glass foil (dış cam koruyucu folyoyu çıkar) | 15 | | | | | | | | | | | | | | | | 65 | | | | | | | | | | | | | |
| 16 | 1 | stick sticker to the grey top cover with mastar (gri üst kapağa mastarla etiketi yapıştır) | 16 | | | | | | | | | | | | | | | | | 32 | | | | | | | | | | | | |

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| | 2 | clean front cover metal and soap with sponge (ön kapama sacını sil ve süngerle sabunla) | 16 | | | | | | | | | | | | | | | | | 13 | | | | | | | | | | | | |
| | 3 | open sticker and stick it (etiketi aç ve yapıştır) | 16 | | | | | | | | | | | | | | | | | 37 | | | | | | | | | | | | |
| | 4 | stick sticker to the front cover metal (etiketi ön kapama sacına yapıştır) | 16 | | | | | | | | | | | | | | | | | 42 | | | | | | | | | | | | |
| | 5 | dry the stick (etiketi kurula) | 16 | | | | | | | | | | | | | | | | | 9 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | 1 | stick max load label into the cooler (max load etiketiketini kabinin içine yapıştır) | 17 | | | | | | | | | | | | | | | | | | 6 | | | | | | | | | | | |
| | 2 | place 1. shelf into the cooler (1. rafı kabinin içine yerleştir) | 17 | | | | | | | | | | | | | | | | | | 5 | | | | | | | | | | | |
| | 3 | screw 2. shelf into the cooler (2. rafı kabinin içine vidala) | 17 | | | | | | | | | | | | | | | | | | 45 | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | 1 | screw left decorative part (sol dekoratif parçayı vidala) | 18 | | | | | | | | | | | | | | | | | | | 18 | | | | | | | | | | |
| | 2 | screw right decorative part (sağ dekoratif parçayı vidala) | 18 | | | | | | | | | | | | | | | | | | | 18 | | | | | | | | | | |
| | 3 | stick 2 armouflex top of the cabin (kabinin üstüne 2 armaflex yapıştır) | 18 | | | | | | | | | | | | | | | | | | | 20 | | | | | | | | | | |
| | 4 | place top cover eps (üst kapama starforunu yerleştir) | 18 | | | | | | | | | | | | | | | | | | | 25 | | | | | | | | | | |
| | 5 | place grey top cover on the cabin (gri üst kapağı kabine yerleştir) | 18 | | | | | | | | | | | | | | | | | | | 15 | | | | | | | | | | |
| | 6 | screw grey top cover to the cabin (gri üst kapağı kabine vidala-3 vida) | 18 | | | | | | | | | | | | | | | | | | | 20 | | | | | | | | | | |
| | off | cut armouflex tape (armaflex bandı kes) | 18 | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | 1 | cooler comes to the vacuum by caroser (soğutucu karoserle vakuma gider (machine time) | M | 22 | | | | | | | | | | | | | | | | | | | 22 | | | | | | | | | |
| | 2 | mounting 2 vacuum valves to the compressor and service tubes (vakum vanalarını kompresör ve servis borularına bağla) | 19 | | | | | | | | | | | | | | | | | | | | 6 | | | | | | | | | |
| | 3 | mounting 2 hoses to the vacuum valves (hortumları vakum vanalarına bağla) | 19 | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | | | |
| | 4 | test (machine time) 12min*60=720 sec | M | 720 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | demount hoses from the vacuum valves (hortumları vakum vanasından sök) | 19 | | | | | | | | | | | | | | | | | | | | 6 | | | | | | | | | |
| | 6 | fix isolation sponge | 19 | | | | | | | | | | | | | | | | | | | | 7 | | | | | | | | | |
| | 7 | stick thermostat sticker | 19 | | | | | | | | | | | | | | | | | | | | 6 | | | | | | | | | |
| | 8 | cooler comes from caroser to the conveyor (soğutucu karoserden konveyöre gelir) | M | 22 | | | | | | | | | | | | | | | | | | | 22 | | | | | | | | | |
| | off | cut isolation sponge | 19 | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | 1 | mount gas gun to the valve (gaz tabancasını vanaya bağla) | 20 | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | | |
| | 2 | charging gas (machine time) (gaz doldur) | M | 43 | | | | | | | | | | | | | | | | | | | | 43 | | | | | | | | |
| | 3 | demount gas gun (gaz tabancasını sök) | 20 | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | | |
| | 4 | press end of cooler tube's with pinchoffs (soğutucu boruların ucunu pinchoff makasıyla ez) | 20 | | | | | | | | | | | | | | | | | | | | | 10 | | | | | | | | |
| | 5 | demount valves (vanaları sök) | 20 | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | |
| | 6 | solder end of compressor tube, service tube and melt corners of tube (kompresör borusunun ve servis borusunun ucunu lehimle ve köşeleri erit) (sert lehimleme) | 20 | | | | | | | | | | | | | | | | | | | | | 33 | | | | | | | | |
| | 7 | bend 1. tube from the melt corner (1. boruyu eritilen yerden eğ) | 20 | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | |
| | 8 | bend 2. tube from the melt corner (2. boruyu eritilen yerden eğ) | 20 | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | |

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| | 9 | write name and gas amount to the paper (sicilini ve gaz miktarını föy kağıdına yaz) | 20 | | | | | | | | | | | | | | | | | | | | | 10 | | | | | | | | |
| 21 | 1 | cut fastening material from the power cable and plug to the machine (güç kablosundaki kablo bağını kes ve makinaya fişi tak) | 21 | | | | | | | | | | | | | | | | | | | | | | 15 | | | | | | | |
| | 2 | plug power cable (güç kablosunu fişe tak) | 21 | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | |
| | 3 | read barcode (barkodu okut) | 21 | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | |
| | 4 | test high voltage and insulation test (yüksek gerilim ve izolasyonu kontrol et) | 21 | | | | | | | | | | | | | | | | | | | | | | 30 | | | | | | | |
| | 5 | control gas leak (gaz kaçağını kontrol et) | 21 | | | | | | | | | | | | | | | | | | | | | | 50 | | | | | | | |
| | 6 | stick barcode on the cabin (kabine etiketi yapıştır) | 21 | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | |
| | 7 | write number and seal to the paper (föy kağıdına sicilini yaz ve onay kaşesini bas) | 21 | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | |
| | 8 | arrange power cable (güç kablosunu düzenle) | 21 | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | |
| 22 | 1 | cooler comes to caroser (soğutucu karosere gelir) | M | 22 | | | | | | | | | | | | | | | | | | | | | | 22 | | | | | | |
| | 2 | plug power cable (güç kablosunu fişe tak) | 22 | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | |
| | 3 | check the condenser, blower, blower motor manually | 22 | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | | |
| | 4 | put prob cable into the cartoon hole and place cartoon to the top of the cabin (prob kablosunu kartonun deliğinden geçir ve kartonu kabinin üstüne koy) | 22 | | | | | | | | | | | | | | | | | | | | | | | 14 | | | | | | |
| | 5 | read barcode and start testing the machine (machine time) (barkodu okut ve makinayı teste başlat) | M | 36 | | | | | | | | | | | | | | | | | | | | | | 36 | | | | | | |
| | 6 | control performans and seal (performansını kontrol et ve kaşe bas) | 22 | | | | | | | | | | | | | | | | | | | | | | | 20 | | | | | | |
| | 7 | take the cartoon from top cover (test için soğutucu üzerine konulan kartonu al) | 22 | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | | |
| | 8 | cooler comes from caroser to the conveyor (soğutucu karoserden konveyöre gelir) | M | 22 | | | | | | | | | | | | | | | | | | | | | | 22 | | | | | | |
| 23-24 | 1 | take front metal cover and put the konveyor (ön kapama sacını al ve konveyöre koy) | 23 | | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | |
| | 2 | paint solder points (lehim noktalarını boya) | 24 | | | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | |
| | 3 | give the condenser cover metal | 23 | | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | |
| | 4 | place 1. screw with copper to the hole of the condenser cover metal and screw (1. vidayı bakırla kondenser kapama sacının deliğine yerleştir ve vidala) | 24 | | | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | |
| | 5 | place 2. screw with copper to the hole of the condenser cover metal and screw (2. vidayı bakırla kondenser kapama sacının deliğine yerleştir ve vidala) | 24 | | | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | |
| | 6 | place 3. screw with copper to the hole of the condenser cover metal and screw (3. vidayı bakırla kondenser kapama sacının deliğine yerleştir ve vidala) | 24 | | | | | | | | | | | | | | | | | | | | | | | | | 11 | | | | |
| | 7 | screw condenser cover metal near the thermostat (kondenser kapama sacını termostat yanından vidala | 24 | | | | | | | | | | | | | | | | | | | | | | | | | 8 | | | | |
| | 8 | screw compressor blower metal to the cabin (kompresör fan sacını kabine vidala) | 23-24 | | | | | | | | | | | | | | | | | | | | | | | | 24 | 19 | | | | |
| | 10 | stick aliminium tape on the compresor blower metal (aliminyum bantı kompresör fan sacının kenarına yapıştır) | 23 | | | | | | | | | | | | | | | | | | | | | | | | 6 | | | | | |
| | 11 | screw front cover metal to the cabin (ön kapama sacını kabine vidala) | 23-24 | | | | | | | | | | | | | | | | | | | | | | | | 33 | 33 | | | | |
| | off | cut aluminium tape (aliminyum bant kes) | 23 | | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 (off) | squeeze adhesive to the left air flow fin and stick (sol hava akış kanatçığına yapıştırıcı sık ve yapıştır) | 23 | | | | | | | | | | | | | | | | | | | | | | | | | 21 | | | | | |
| | 2 (off) | squueze adhesive to the middle air flow fin and stick (orta hava akış kanatçığına yapıştırıcı sık ve yapıştır) | 23 | | | | | | | | | | | | | | | | | | | | | | | | | 16 | | | | | |
| | 3 (off) | squueze adhesive to the right air flow fin and stick (sağ hava akış kanatçığına yapıştırıcı sık ve yapıştır) | 23 | | | | | | | | | | | | | | | | | | | | | | | | | 18 | | | | | |
| 25 | 1 | clean inside and outside of the cooler with air (dolabın içini, camlarını havayla temizle) | 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | 15 | | | |
| 25 | 2 | clean outside of cooler with air (soğutucunun dışını havayla temizle) | 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | 8 | | | |
| 25 | 3 | clean inside and outside of cooler with alcohol (soğutucunun içini ve dışını alkolle temizle) | 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | 60 | | | |
| 26 (Quality Operator) | 1 | control cooler estetically (soğutucuyu estetik olarak kontrol et) | 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 100 | | |
| 26 (Quality Operator) | 2 | plug cooler for electric control (elektrik kontrolü için soğutucuyu fişe tak) | 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | |
| 26 (Quality Operator) | 3 | control breakdown, control gas and cooling seals (arıza kaşesi, gaz ve soğutma mühürleri varmı kontrol et) | 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 8 | | |
| 26 (Quality Operator) | 4 | read barcode (barkodu okut) | 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | | |
| 26 (Quality Operator) | 5 | take labels and user manual and go to the cooler (etiketleri ve kullanıcı el kitabını al ve dolaba git) | 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15 | | |
| 26 (Quality Operator) | 6 | stick stickers to the glass and put user manual into the cooler (etiketleri cama yapıştır ve kullanıcı el kitabını soğutucunun içine koy) | 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 10 | | |
| 27-28 | 1 | take grey top cover (gri üs kapaktan folyoyu al) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | |
| 27-28 | 2 | stick sticker to the condenser cover metal (arka kapama sacına etiket yapıştır) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | |
| 27-28 | 3 | unplug and wrap power cable (güç kablosunu sar) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 | |
| 27-28 | 4 | fix power cable to the handle with fastening material (güç kablosunu sac tutamağına kablo bağı ile bağla) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 17 | |
| 27-28 | 5 | put plastic bag on cooler (plastik poşeti soğutucuya geçir) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15 | |
| 27-28 | 6 | cut the top of the plastik pocket (plastik poşetin üstünü kes) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | |
| 27-28 | 7 | stick top of the cooler wtih band (soğutucunun üstünü 2 bantla yapıştır) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 26 | |
| 27-28 | 8 | stick plastic and cartoon angle with band to the cooler (carton ve plastik köşebentleri bantla soğutucuya yapıştır) | 27-28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 17 | 26 |
| 27-28 | 10 | put upper protective eps onto the box (kutunun üstüne üst koruyucu straforu koy) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | |
| 27-28 | 11 | put cartoon box on the cooler (karton kutuyu soğutucunun üzerine koy) | 27-28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 18 | 11 |
| 27-28 | 12 | stick label to the box (kutunun üstüne etiketi yapıştır) | 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | |
| 27-28 | 13 | punch cover of box (kutunun kapağını zımbala) | 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 12 |
| 27-28 | 14 | squeeze hot melt onto the 2 cartoon angles and stick onto the box (2 tane karton köşebente erimiş yapışkandan sık ve kutunun üzerine yapıştır) | 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 22 |
| 27-28 | 15 | take green pallet under the cooler (soğutucunun altından yeşil paleti al) | 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15 |
| 27-28 | 16 | wrap and fix stripes to the box (2 numbers) (şeritleri sar ve bağla) | 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 30 |