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YALIN ÜRETİM TEKNİKLERİ İLE ÜRETİM VERİMLİLİĞİNİ ARTIRMA ÜZERİNE BİR ÇALIŞMA

A STUDY FOR INCREASING PRODUCTION EFFICIENCY WITH LEAN PRODUCTION TECHNIQUES

Hasan GÖKKAYA[1], Ömer DULKADİR[*2], Rüstem ÇİFTÇİ[3]

[*]**email: odulkadir@karabuk.edu.tr**

[1]Karabük Üniversitesi, Mühendislik Fakültesi, Karabük, Türkiye
[2]Karabük Üniversitesi, Safranbolu MYO, Karabük, Türkiye
[3]Karabük Üniversitesi, Lisansüstü Eğitim Enstitüsü, Karabük, Türkiye

ÖZET
Günümüz küresel pazarında, işletmelerin rekabet baskısı altında varlıklarını sürdürerek avantajlı duruma geçebilmeleri için, düşük maliyetle yüksek kalitede ürünler üretmesi gerekmektedir. Birçok sektörde en yüksek maliyet olan işgücü maliyetinin düşürülmesi için üretim hattının sürekli gözlemlenmesi ve iyileştirilmesi gerekmektedir. Bu kapsamda kullanılabilecek metotlardan biri de aksiyomatik tasarım ile iyileştirme parametrelerinin belirlenmesi ve belirlenen parametrelerin yalın üretim teknikleri kullanılarak gerçekleştirilmesidir. İşgücü verimliliğinde işletme hedeflerinin yakalanmasına yönelik yapılan bu çalışma, ticari soğutucu üretimi yapan bir işletmedeki dört üretim hattından verimliliği en düşük olan hatta yapılmıştır. Yapılan iyileştirmeler ve hat dengeleme çalışmaları sonrası, %74 olan hat verimliliği %81'e yükseltilmiş ve operatör sayısı 108'den 99'a düşürülmüştür. Böylece temel işletme hedeflerinden olan birim ürün maliyetinin azalması sağlanmıştır. Ayrıca işgücü kapasite kullanımı artırılmış ve operatörlerin iş yükü daha adil şekilde dağıtılmıştır.
Anahtar Kelimeler: Yalın Üretim, Aksiyomatik Tasarım, Montaj Hattı Dengeleme, Geleneksel Montaj Hattı.

ABSTRACT
In today's global market, businesses need to produce high quality products at low cost to maintain their existence and gain advantage under competitive pressure. To reduce the labor cost, which is the highest cost in many sectors, the production line must be constantly monitored and improved. One of the methods that can be used is; determining the improvement parameters with axiomatic design and realization of determined parameters by using lean manufacturing techniques. This study, which is aimed to achieve business targets in labor productivity, was carried out in the line with the lowest efficiency out of four production lines in a commercial cooler production enterprise. After the improvements and line balancing studies the line efficiency, which was 74%, was increased to 81% and the number of operators was reduced from 108 to 99. Thus, the unit product cost, which is one of the main business objectives, was reduced. In addition, workforce utilization was increased and the workload of operators was distributed more equitably.
Keywords: Lean Manufacturing, Axiomatic Design, Assembly Line Balancing, Conventional Assembly Line.

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INTRODUCTION

In today's competitive conditions, the businesses those aim to continue their activities should consider the value concept for the production of services and products. They also have to pay attention to parameters that directly affect production such as quality, time and cost. Businesses are aiming to gain competitive advantage by establishing their service or production structures at optimum level. For this purpose, they are implementing lean transformation projects that include techniques, systems and concepts which reveal business processes in the simplest way, in order to eliminate all kinds of waste and thus increase business profit (Duman, 2019).

According to lean thinking, the concept of waste refers to everything that does not present any value to the consumer and the consumer does not wish to pay a price in return. It is aimed to eliminate all kinds of waste (errors, production more than necessary, excess stock, unnecessary waiting, transfer time, movement time, working times and etc.) in all production activities from service/product design to transportation (Dolgun, 2012).

The basic condition of preventing waste in enterprises is to ensure the optimum use of existing capacity. Due to high labor costs, one of the important units in achieving this aim is assembly lines. The basic element of assembly line balancing is the minimization of idle times at the assembly line stations and therefore the use of the assembly line with the highest possible capacity. In this context, the coordination and assignment of work elements within a number of constraints is called "Assembly Line Balancing". The main purpose of the process is to produce products rapidly in each unit and deliver them to the next units as soon as possible (Altunay, Özmutlu & Özmutlu, 2017 and Özkan, 2003).

Line balancing is a complex problem in which many combinations are used, because it is affected by many parameters such as purpose, constraints, product, system, product variety, flexibility. One of the systematic methods that can be used to achieve the aim of eliminating waste in all combinations is axiomatic design. Axiomatic design is used in areas such as product-process development, supply chain, product-system design and solution of environmental problems. The main objectives of the technique are to make designers more creative, to reduce random scanning processes, to minimize trial & error processes and to select the best design (Gönen, 2014 and Suh, 2001).

In this study, improvements are made by using axiomatic design and lean manufacturing methods in a factory which is producing commercial refrigerators & freezers and the efficiency results are presented comparatively.

MATERIAL and METHOD

In this section, the enterprise where the study is carried out, the state of the enterprise before the study, the usage of axiomatic design and used lean production methods are explained.

Enterprise and Current Situation

The study is carried out on one of 4 assembly lines in an enterprise that has a comprehensive range of production-solutions in the world commercial refrigeration market and has an annual production capacity of 450 thousand refrigerators (beverage coolers, freezer cabinets, vertical and horizontal freezers with sliding glass, etc.). According to the business working principles, the efficiency target is 80% and it was determined that 80% efficiency could not be reached in 6 of the 13 stations on the line by examining the work-time study schedule. The operators at 6 stations had high idle times and it was decided to rebalance the line by improving, without affecting the harmony of production lines.

The efficiency of all stations in the production line and the stations where improvements were made are shown in Table 1.

Table 1. Station efficiency percentages and stations where improvement works are carried out

Station Number	Station Name	Station Efficiency (%)	Stations Where The Study Is Carried Out
1	External body roof assembly station	83	
2	Inner body roof assembly station	77	✔
3	Indoor-outdoor jointing assembly station	72	✔
4	Polyurethane printing station	79	✔
5	Chassis connection assembly station	63	✔
6	First vertical preparation station	81	
7	First vertical assambly station	83	
8	Horizontal assembly station	80	
9	Group preparation station	83	
10	Group assembly station	82	
11	Second vertical assembly station	81	
12	Vacuum & performance station	74	✔
13	Packing station	64	✔

In the enterprise, if the operators are used at full capacity, the cycle time, which refers to the time between the entry and exit of a product, is 150 seconds. However, since it is not possible to work with 100% occupancy rate due to factors such as rest, fatigue, etc., the target is determined as 80% efficiency. For this reason, it is essential for each operator to spend 120 seconds on each product, but it is not possible to create a standard because every job is not same. In the study, it is aimed to bring the occupancy rate of the operators to the target of 120 seconds, which corresponds to 80%, as much as possible. To achieve this aim, the following principles have been used:

- **a)** Making new assignments to the operators in addition to their current duties and ensuring that all of their current time is used,
- **b)** Trying different combinations for balancing working time per operator until the best probability is found,
- **c)** Ensuring that the working time of the operator does not exceed the available cycle time.

In the line balancing process, the pre-operation situation was first considered. Each operation on the production line has been defined and the line balancing table has been prepared by performing the time process with the stopwatch. While selecting the operators in the time study application, the operators who have analyzed the line, station, operation, product well and completed the necessary training on production were selected. In the time measurements, it has been taken into account that the operators will get tired and slow down as the day progresses due to the effort spent. For this reason, the waiting time and rest share were gradually added to all jobs according to the type of job within the framework of the business working policy. In total, 20 measurements were observed for each operator.

Axiomatic Design and Lean Manufacturing Application

Axiomatic design is used in areas such as product-process development, supply chain, product-system design and solution of environmental problems. Its main objectives are to make designers more creative, to reduce random scanning processes, to minimize trial & error processes and to select the best design. The first step of axiomatic design is to identify the

basic functional requirements (FRs) that are important for the design process. Next, basic design parameters (DPs) that show how to obtain basic FRs are defined. After the basic FR and DP definitions are completed, the second, third and subsequent FRs and DPs must be defined step by step (Gönen, 2014 and Suh, 2001).
The main problem of this study is "the high number of personnel who are working to produce the demanded production volume within the desired time". Therefore, the line needs to be balanced in order to minimize the number of personnel to meet the required production volume. The FRs and DPs of the study are given in Table 2 together with their sub-levels.

Table 2. Axiomatic design table used in the study

FUNCTIONAL REQUIREMENTS		DESIGN PARAMETERS	
FR_1:	Operator times should be made shorter or equal to the production cycle time.	DP_1:	Check operator times.
FR_{11}:	Operation steps should be defined.	DP_{11}:	Create a method study.
FR_{12}:	Operation times should be defined.	DP_{12}:	Create a time study.
FR_{13}:	Operations with high occupancy rate should be determined.	DP_{13}:	Calculate the cycle time for one product.
FR_{14}	Operations should be assigned to the operators in a balanced manner without exceeding the cycle time.	DP_{14}:	Apply line balancing.
FR_2	Be sure operators know the operations they are doing.	DP_2:	Check the knowledge level of the operators.
FR_{21}:	Transactions must be defined.	DP_{21}:	Follow standard operating procedures.
FR_{22}:	The current knowledge level of the operators should be defined.	DP_{22}:	Apply a practical exam.
FR_{23}:	Necessary trainings should be defined.	DP_{23}:	Build the training matrix.
FR_{24}:	Operational trainings should be provided.	DP_{24}:	Provide theoretical and practical training in operational steps (screwing, pressing PU, welding, etc.).
FR_{25}:	The knowledge level sufficiency of the operators should be analyzed.	DP_{25}:	Apply a practical exam.
FR_{26}:	Results should be visualized.	DP_{26}:	Build the skill matrix.
FR_{27}:	Operation instructions should be prepared.	DP_{27}:	Train operators to apply the operating instruction.
FR_3:	Transactions that do not add value should be optimized.	DP_3:	Apply improvements with ECRS analysis.
FR_{31}:	Improvement work should be done at the stations.	DP_{31}:	Apply lean manufacturing techniques.
FR_{311}:	Waste should be reduced.	DP_{311}:	Apply just in time production.
FR_{312}:	Improvements should be made in product design.	DP_{312}:	Apply kaizen.
FR_{3121}:	Material handling in the production line should be reduced.	DP_{3121}:	Assign responsible people who have a long idle time and can transfer the material to production in certain periods.
FR_{3122}:	Walking time should be shortened.	DP_{3122}:	Organize the workspace, taking into account ergonomics and productivity.
FR_{313}:	Problems that will prevent reaching the aims should be identified.	DP_{313}:	Practice problem solving technique.
FR_{32}:	Operators should be informed about the changes made.	DP_{32}:	Apply a visual-based one-point lesson.
FR_{33}:	Waitings should be avoided.	DP_{33}:	Combine operations.
FR_{34}:	Transactions should be assigned to operators in a balanced way.	DP_{34}:	Apply line balancing.
FR_{35}:	The operations that are eliminated and combined must be defined in the operation instruction.	DP_{35}:	Update the operating instructions.
FR_4:	It should be ensured that the real flow of information continues.	DP_4:	Design a system that strengthens the communication information network.
FR_{41}:	Continuity of information flow between departments should be ensured.	DP_{41}:	Apply report system.

The process of creating basic FRs and DPs within the scope of applying axiomatic design is as follows:

- **Step 1:** In the field of functional information, the highest level of FR is defined: " Provide the required production quantity in the assembly line by the most efficient way according to customer demand".
- **Step 2:** The DP that meets the FR in the first step is defined: “Balance the assembly line with the minimum number of operators according to the required production quantity”.
- **Step 3:** FRs defined in the first step are parsed. These are lower level FRs of the previous FRs.
- **Step 4:** DPs that meet each lower level FR are matched.
- **Step 5:** The design matrix is defined between lower-level FRs and DPs. If there is a relationship between FRs and DPs, X is written, if not, 0 is written.
- **Step 6:** The cycle continues according to the need (Gönen, 2014 and Suh, 2001).

After determining the design table, the design matrix showing the relationship between FRs and DPs for FR_1 is determined and shown in Equation 1.

$$\begin{bmatrix} FR_{11} \\ FR_{12} \\ FR_{13} \\ FR_{14} \end{bmatrix} = \begin{bmatrix} X & 0 & 0 & 0 \\ 0 & X & 0 & 0 \\ 0 & 0 & X & 0 \\ 0 & 0 & 0 & X \end{bmatrix} \begin{bmatrix} DP_{11} \\ DP_{12} \\ DP_{13} \\ DP_{14} \end{bmatrix} \quad (1)$$

The obtained design matrix is a decomposed matrix and shows that the ideal approach is obtained for FR_1 which is determined as "Operator times should be made shorter or equal to the production cycle time". In this context, the FR_1 target will be achieved when the following determined DPs are applied; defining operation steps, defining durations, determination of occupancy times and balanced reorganization of processes.
The design matrix showing the relationship between FRs and DPs for FR_2 is determined and shown in Equation 2.

$$\begin{bmatrix} FR_{21} \\ FR_{22} \\ FR_{23} \\ FR_{24} \\ FR_{25} \\ FR_{26} \\ FR_{27} \end{bmatrix} = \begin{bmatrix} X & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & X & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & X & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & X & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & X & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & X & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & X \end{bmatrix} \begin{bmatrix} DP_{21} \\ DP_{22} \\ DP_{23} \\ DP_{24} \\ DP_{25} \\ DP_{26} \\ DP_{27} \end{bmatrix} \quad (2)$$

The obtained design matrix is a decomposed matrix and shows that the ideal approach is obtained for FR_2, which is determined as "Be sure the operators know the operations they are doing". In this context, the FR_2 target will be achieved when the following determined DPs are applied; defining the operations, determining the knowledge level of operators, improving abilities with trainings and visualizing the analyzed results. The design matrix showing the relationship between FRs and DPs is determined for FR_3 and shown in Equation 3.

$$\begin{bmatrix} FR_{31} \\ FR_{32} \\ FR_{33} \\ FR_{34} \\ FR_{35} \end{bmatrix} = \begin{bmatrix} X & 0 & 0 & 0 & 0 \\ 0 & X & 0 & 0 & 0 \\ 0 & 0 & X & 0 & 0 \\ 0 & 0 & 0 & X & 0 \\ 0 & 0 & 0 & 0 & X \end{bmatrix} \begin{bmatrix} DP_{31} \\ DP_{32} \\ DP_{33} \\ DP_{34} \\ DP_{35} \end{bmatrix} \quad (3)$$

The obtained design matrix is a decomposed matrix and shows that the ideal approach is obtained for FR_3, which is determined as “transactions that do not add value should be optimized”. In this context, the FR_3 target will be achieved when the following determined DPs are applied; reducing waste by making improvements in stations, making improvements in product design, determining the root cause of problems, informing operators about changes, avoiding waiting, assigning new operations to operators in a balanced way and making new job definitions.

The design matrix for FR_4 is showing the relationship between FRs and DPs is the identity matrix. Since it is an unit matrix, the design matrix is a decomposed matrix and shows that the ideal approach is obtained for FR_4, which is determined as "it should be ensured that the real flow of information continues ". In this context, when the DPs determined to ensure the continuity of information flow between departments are applied, FR_4 target will be achieved.

After the development of the axiomatic design, observation and application studies were carried out to improve the assembly line. In line balancing, it is aimed to produce the desired amount of product with the minimum number of operators by using DPs that meet the FRs determined by axiomatic design.

In the implementation of axiomatic design, DPs that meet FRs are produced by using lean manufacturing techniques. The opinions of the white-collar employees in the enterprise were taken in the selection of lean production methods for DPs. All lean production methods were evaluated with the brainstorming method and the methods to be used were determined on station basis. In this context; the FRs, DPs and lean production methods used in 6 stations where improvements are aimed are shown in Table 3.

Table 3. FRs and DPs applied in stations

Stations Where Improvements are Done	FRs	Lean Production Techniques Used in DPs
Inner body roof assembly station	Improving product design Reduce waste	Problem solving techniques (brainstorming)
Indoor-outdoor jointing assembly station	Improving product design	Problem solving technique (process improvement)
Polyurethane printing station	Improving product design	Problem solving technique (process improvement)
Chassis connection assembly station	Material handling should be reduced	Just in time production
Vacuum & performance station	Operational workload should be reduced	Kaizen (suggestion system and benchmark)
Packing station	Operational workload should be reduced	Problem solving technique (process improvement)

The ability of the operator to perform one more work must be developed Reduce waste	Kaizen (process development)

FINDINGS

In the business where the study is conducted, it is important that the efficiency of the assembly lines is 80% or above, in order to meet the order quantity requested by the customers and to reach the minimum cost targets. However, the time differences in assembly cause differentiation in the work times of the operators, thus it occurs an increase in idle waiting times and the operators wait the previous work units. Excessive waiting times cause a decrease in the occupancy rates of the operators and the efficiency values of the line. Depending on this situation, it becomes necessary to increase the number of employees. In this section, information will be given the improvement studies and findings in 6 stations whose efficiency values have fallen below the 80% operational efficiency target and also comparisons will be made with previous scientific studies.

Inner Body Roof Assembly Station

In the inner body roof assembly station the processes of clamping the inner body materials, frame joining, inox sheet stretch peeling, fastening and masking the clips to the ceiling sheet are performed. When the operations with 77% efficiency are examined, it was observed that the idle time of the operators is high at the points where the operator occupancy rates are low. Within the scope of improvement works, it is aimed to reduce the count of operators with 2 separate studies. In the process of improving operations problem solving technique was applied as lean manufacturing method. The current situation was evaluated with the white collar employees of design R&D department and production department by brainstorming method. The solutions were developed for identified works which could be improved.

The first study was carried out in the unit, where 3 different cabinet sheets are prepared with the same dimensions but differentiated by customer demands. Before the study, in order to prevent the use of incorrect components that may be caused by the production of different cabinets at the same time, the discharges required by all models are carried out at once instead of making a model-based discharge (drilling for cable, pipe, etc.) in the inner body sheet. For this reason, a large number of discharges are done in different regions of product and during the production process, the discharges required by the model are used, others are closed by masking method. It has been observed that there is extra labor and waste for this process. As a result of the design improvements made to prevent waste, due to the fact that the production transition between models is not very frequent, it was ensured that the extra discharges were canceled and each model was discharged for its own needs. All the operators working at the station were trained about the improvement and it was observed that the operators adapted after the trial. Moreover; it has been observed that the possibility of mixing the models with each other is eliminated due to the understanding of what the model is according to the type of discharge opened. Masking, in which extra holes were covered, was also eliminated by canceling the holes.

It has been observed that another improvement can be made in the peeling of the stretch films on the right-left pre-painted sheets. It has been determined that the long duration of peeling stretch film increases the workload of the operation and consequently causes extra power lost for the operator. During the day, depending on the force consumed, the performance of the operator decreases and the low performance causes an increase in cycle times. Pre-painted and stretched inner body left/right sheets come ready from the supplier and are transferred to the station for assembly after they are processed in metal works. A request was made to the supplier to reduce the peel strength without changing the micron thickness of the stretch (50 μm). In this context, the amount of chemical substance that allows the stretch to adhere to the sheet is reduced, the stretch peeling strength is decreased from 330.5 gf to 110.5 gf and the processing time is reduced. The force values measured during the peeling of the stretch film on the pre-painted sheet are shown in Figure 1.

Figure 1. Photo image showing the strength values measured during the peeling of the stretch film on the pre-painted sheet

By means of improvements made, a total improvement of 185 seconds is achieved in the work times of four operators. In addition to the low occupancy rates, it was tried to distribute the existing operations to two operators and to take the other two operators off the line to be used in other lines. When it was determined that there is no quality problem at the end of the trial, two operators were permanently taken off the line. Thus, the efficiency of the inner body roof assembly station is increased from 77% to 81% and the number of operators is reduced from 10 to 8. In the literature, it was seen that businesses make improvement studies using the brainstorming method. By applying the brainstorming method in a ready-wear factory, the reasons for delaying contract yarn manufacturing deadlines were revealed and an improvement of 17.3% was achieved in the deadline by applying the improvement suggestions (Örgerin, 2008). The findings overlap with the literature, as it shows that improvements made by the application of brainstorming reduce work times.

Indoor-Outdoor Jointing Assembly Station

In the indoor-outdoor joining assembly station, double-door cooling cabinet components are combined and station efficiency was 72% before study. In order to reach the business efficiency target of 80%, complex and continuing problem details have been studied with problem solving technique.

As a result of the analyses, it has been determined that the time losses in the masking of the corners can be reduced. Since the masking process is mostly carried out at the assembly stations before the polyurethane printing station, the analysis of the outer body sheet production process has been carried out in order to prevent loss of time in the inner-outer joining assembly station. In the analysis of the technical drawing specs, it has been observed that there are gaps with undesired criteria at the joints of the sheet metal and these gaps increase polyurethane leakage. Problem solving techniques were used to minimize gaps and a new design is developed with process improvement. In the new design, the masking process times are improved by minimizing the gaps. The visuals of the design changes are given in Figure 2. In the 1st photo, the masking density at the corner points is seen before the improvement studies. In the 2nd photo, the final form of the product is given and the masking density has been reduced since leaks are prevented by the bend given to the edge and the process has been made in shorter time.

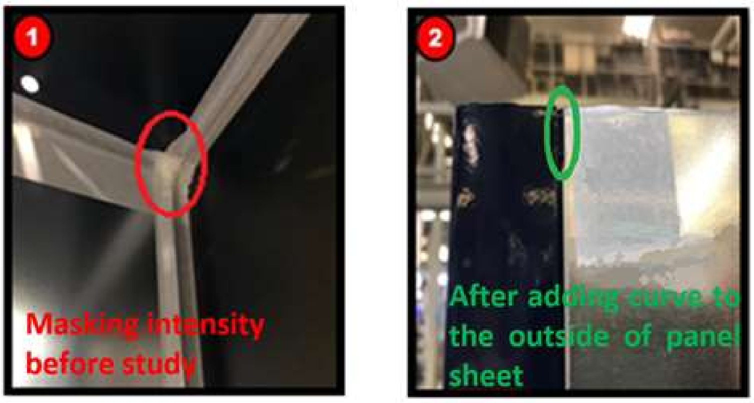

Figure 2. Masking density before study and folding that added to the sheet

The visuals regarding the reduction of polyurethane leakage after the improvement is given in Figure 3. In the 1st photo, the polyurethane leakage is seen despite the masking, before the improvement work. In the 2nd photo, although the polyurethane leakage could not be completely eliminated after the improvement, it is seen that the amount is reduced too much.

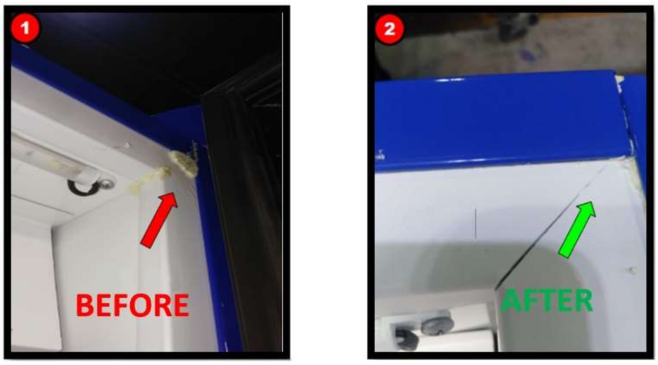

Figure 3. Photos before and after improvement

By the improvement, an operator's work time has been reduced by 40 seconds. In addition to the low occupancy rates, it was tried to give two of the existing operations to an operator and to take the other operator out of the line to be used in other lines. After trial, no quality problem occured and the operator is permanently taken off the line. Thus, the efficiency of the indoor-outdoor joining assembly station is increased from 72% to 80% and the number of operators is reduced from 7 to 6. When the literature studies are examined, it is seen that Bilgin applied the problem solving method in a company which is operating in the packaging sector and reduced the waiting time of the spinning machines from 53 minutes to 31 minutes with improvements (Bilgin, 2014).

Polyurethane Printing Station

In the polyurethane printing station; polyurethane pre-printing processes, polyurethane printing and polyurethane post-printing cleaning operations are performed. The station efficiency was 79% before the study. Although it is close to 80% target, the improvement applied in the inner-outer joining assembly station also directly affected the duration of the polyurethane printing station. As a result of preventing leaks by closing the corners of the cabinet, a reduction in the time of top and bottom cleaning processes has been achieved.

By the improvement, the work time of two operators is reduced by total of 90 seconds. With the addition of low occupancy rates, it was tried to give two operations to one operator and to take the other operator out of the line, to be used in other lines. When it was tried, no quality problem occured and the operator is permanently taken off the line. Thus, the efficiency of the polyurethane printing station is increased from 79% to 82% and the number of operators is reduced from 9 to 8.

Chassis Connection Assembly Station

In the chassis connection assembly station, which has a 63% efficiency value before the operation, the assembly of the chassis parts to the cabinets, the assembly of the chassis to the cooler cabinet and the assembly of the wooden pallet are performed. Compared to other stations, since the station efficiency value is much less than 80% and although the operations are examined in more detail, it has been determined that only one operation can be improved.
One of the operations in the station is taking the wooden pallets from the defined area. In the observations made, it was determined that the transportation process is carried out from a distant point by walking and this process, which does not contribute to production, causes loss of time. Improvement work was carried out with the aim of eliminating the walking process which is required by job description but don't provide added value to the product. For this wasteful process, a study was carried out within the scope of just in time production technique. For this purpose; it is planned to assign the work of transferring the material to production area in certain periods to another suitable employee. As a result of the observations made, it is seen that the material tracking employee, which works indirectly and does not affect the station time, goes back and forth between the area where the pallets are and the station. In the meantime, it has been determined that bringing the pallets will not affect the job performance much. As a result of the experiments, it is determined that it could be applied and the material tracking staff is provided to transfer regular pallet stock according to the number of cabinets per hour.

After the improvement, an operator's walking to the pallet area is canceled and the work time is reduced by 26 seconds. It has been observed that the operator with a final workload of 33% cannot be combined with another operation due to the fact that the station consists of less operations and that merging the operation with another station will lead to management weakness. The job allocation option is used due to the inability to combine work. In this context, the workload of the operator is distributed to 2 other operators with sufficient free time. After the training and trials, the operator is removed from the station and used on another line. However, even if an operator and an operation were removed from the station, efficiency increased to 78%, and the operating target of 80% could not be achieved. Despite new observations, productivity could not be increased further. Considering that the improvements in other stations have contributed to the line efficiency at a high rate, the station efficiency is left at 78%.

It is known that improvement studies are carried out by using the just in time production method in enterprises. Doyuran has made improvement activities in Turkish Locomotive and Engine Industry Corporation wagon factory by using just in time methods and has provided a saving in the amount of annual 5 wagon costs by reducing the costs of various units (Doyuran, 1990). The findings show that just in time production practices increase the labor force utilization rate in the enterprise and reduce the costs.

Vacuum & Performance Station

In the station with 74% efficiency; preparation of product related files (C-Pantene, product identification label, barcode label, inventory label, warranty certificate, etc.), vacuuming process by connecting the vacuum hose to the compressor, gas filling process after vacuuming, refrigerant pipe pinch off and welding process, gas leakage control, electrical leakage control with EST (Electronic System Test) device, assembly of the rear shutter and performance tests are performed. In order to bring the efficiency of station to the operating target of 80%; waste, irregularities and ergonomic errors have been investigated. As a result of the analyses, it has been determined that an improvement can be made in an operation.

Improvement studies were carried out during the painting of the welding points which is made after the welding of the cooler copper pipes. The kaizen method was applied in the improvement work to eliminate the painting process. By the suggestion system, an employee stated that the painting process was not performed in the company where he worked before and suggested that work time and cost savings could be achieved. Upon the suggestion, a benchmark was made and as a result of the comparisons, it became clear that there was no painting in other enterprises. In this context, it was observed that not dyeing did not affect the product and the dyeing process is canceled. Before and after of the work is given in Figure 4.

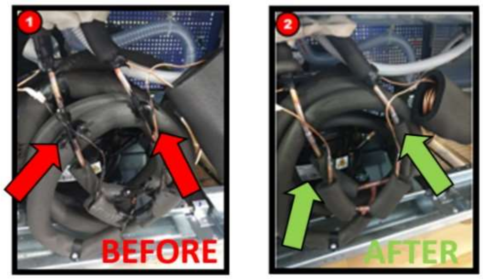

Figure 4. Painted and unpainted photos of copper pipe weld points

By the improvement made by using kaizen, 42 second reduction in operation is achieved. This operation is defined as an additional operation to another operation and two operations were attempted by one operatör. As a result of the improvement, the efficiency of the vacuum & performance station has been increased from 74% to 81% and the number of operators has been reduced from 8 to 7. Tekin et al., similarly received suggestions from employees and made improvements in the packaging machine by applying the suggestions, in their study in a flour factory. As a result of the study, the waiting time between product types, which was 30 minutes, is reduced to 5 minutes (Tekin at all, 2018). The findings obtained show that the suggestion system, which is one of the kaizen elements, increases the workforce utilization rate in the enterprise and decreases the cost.

Packaging Station

In the packaging station, the short circuit control process with the EST method, the internal body cleaning of the refrigerator cabinet, the process of matching the inventory label of the refrigerator with the barcode reader, the process of leaving the wire shelves in the cabinet and the packaging of the refrigerator cabinet are performed. The efficiency value of the station was 64% before the study. Since it has a lower efficiency value compared to other stations, it has been tried to reach 80% target with 3 improvements after more comprehensive examination.
The first improvement occurred spontaneously by facilitating the stripping of the inox base sheet stretch at the inner body roof assembly station. As the stretch, which prevents the sheet from deforming due to scratches, contact, impact, etc. during operations, is removed more easily and an operator's work time is reduced by 40 seconds. By the time reduction, it is decided to remove one of the operators after trying to combine the two operations at the station for a while.
In the operation where the second study is carried out is the inner body sheet which is cleaned with a dry fabric. Before the study, this operation is performed by a male operator. With the help of kaizen, the operation, which does not require much training, was commissioned by the female cleaning staff in the enterprise and as a result of the detailed analysis it was seen that the female personnel completed the process in 75 seconds, which was 90 seconds. In this context, it has been decided that the operation will be carried out by female personnel. A multi-functional operator training program was implemented for female personnel in order to complete the reduced time with additional operations. Basic skills development training on DOJO, which is a close and convenient operation, was provided in the training program. The job training, in which matches such as fixture tag reading and barcode scanning was performed, was easily implemented as it did not require intensive personal skills and adaptation to the working environment was achieved in a short time. Thus, an operator is taken off the line.
The third improvement was made in the process of placing the components in the cabinet before packaging. There are 6 shelves in a cabinet and the shelves come in packs of three before study. Since the shelve packages are triple, the operator has to do the shelve retrieval and shelve transport process twice for a cabinet. By applying process development with the help of kaizen, the weight of the shelves and carrying ergonomics were analyzed and it was determined that there was no obstacle to the operation at once. Within the scope of the improvement, the supplier company was provided to pack the shelves in 6 pieces and the second shelf purchase, which did not add value, was canceled. In addition, as a single pack of stretch film was peeled instead of two packs, the peeling time was reduced. By the improvement, work time is reduced by 37 seconds. It has been determined that the operator can perform another operation as a result of the trainings given. Working with a single operator was tried for a while, it is determined that it did not cause a problem in quality and it is decided to remove one of the operators.

After the improvement, although the number of operators in the station is reduced by three, the efficiency increased to 78% and the 80% target could not be achieved. Despite new observations are done, productivity could not increased further. Considering that the improvements in other stations have contributed to the line efficiency at a high rate, the station efficiency is left at 78%. Berber has made improvements in various issues such as occupational safety, material, environment and process improvement by applying kaizen in a factory that produces cylinder liners with centrifugal casting and machining. As a result of the work, the company gained 5832 kg of boron oil. Also the environmental pollution caused by the oil was prevented. In addition, the cleaning of the loom has been made functional and the daily cleaning time has been reduced from 50 minutes to 16 minutes (Berber, 2013). The findings are consistent with the labor&material savings and the increase in operational efficiency.

DISCUSSION and RESULTS

In this study, the assembly line is rearranged as a result of improving the FRs determined by axiomatic design and by use of kaizen, just-in-time production and problem solving techniques.

In the commercial refrigerator production line consisting of 13 stations, where the study was conducted, all processes were defined and examined first in order to see the current waste. The determined wastes were evaluated according to the current-future situation and estimated numerical data were obtained. Those that seem to give positive results have been put into practice. With the axiomatic design applied to balance the assembly line by eliminating waste; some operations have been combined, simplified or eliminated by distributing tasks.

In the production line, where the operating target efficiency is 80%, the number of operators before the study was 108 and the line efficiency was 74%. Improvement works were carried out in 6 stations, those are below the 80% target, out of the 13 stations on the line. As a result of various improvements, 9 operators were taken off the production line and the number of operators is reduced to 99. With the increase in efficiency at 6 stations, the line efficiency, which was 74%, is increased by 7% and reached 81%. Thus, the line efficiency has been raised above the 80% target. On the basis of stations, the target of 80% is achieved or exceeded in 4 of the 6 stations where improvements were made. In the chassis connection assembly station and packing station, efficiency remained at 78% despite all efforts. It has been decided not to do any other work due to the fact that no other improvement could be found and the line efficiency is increased above 80%. With the decrease in the number of workers and the increase in productivity, the product cost which is one of the main business objectives, has been reduced.

With the study, the workload rate of the operators is distributed more equitably. Although it is not possible to equalize all employees, the difference between them has been closed as much as possible and employee satisfaction has been increased with the policy of equal pay for equal work. In the time distribution, more waiting time is used in operations that require force and caused a decrease in performance especially after the middle of the day.

Because the limited capital, labor and other costs are high in Turkey, the way of growth is passing through efficient production on private and public sectors. The most comprehensive application to ensure efficient production is lean production. In order to implement lean production systems, all employees and suppliers of the enterprise from top to the lowest level must act together. As a result of the applications, the main purpose is to minimize or eliminate waste and reach the business targets. In order to ensure efficient production and therefore growth, the lean production philosophy which is partially applied by very few enterprises throughout the Turkey, should be examined by selecting and applying appropriate methods comprehensively in all enterprises.

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