STATISTICAL ANALYSIS IN ASSEMBLY LINE BALANCING: LEAN MANUFACTURING APPLICATION IN ENERGY SECTOR

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Abstract

The elimination of non-value added activities, maximizing the use of resources, reducing costs, ensuring continuity of these efforts, increasing quality and productivity are essential for firms. The lean manufacturing technique developed for this purpose is based on statistics data. Statistical analysis provides an improvement by presenting the current situation and future situation. The lean manufacturing operation was carried out in the "Qatar Breaker" assembly line, which operates in the energy sector. Circuit breakers are switchgears which are used to cut off the load current and short-circuit currents occur in high voltage and high-current switches. In this study, The Lean Production Activity Plan is conducted. Throughout this plan, process data collection, process analysis, process fluctuation and then standardization with kaizen have been applied in this order. Due to the fact that the use of automation is not widespread in the production system of the factory and manual labor is of first priority, process analyses were made with video records. Then standard operation tables were prepared and new process design was created according to the combination of these tables and sales planning departments' data. As a result, assembly line balancing was performed by creating work flow according to this new process design.

Keywords: Assembly Line Balancing, Lean Manufacturing, Statistical Analysis, Improvement

1. Introduction

Production is the activity of converting the scarce raw material available in nature into various final goods and services through various processes to meet the unlimited needs of individuals. The production systems include the presentation of these products to the customers by producing them on the basis of a certain system and producing higher quality products. The production systems must operate with a specific plan and program in order to be able to function in a disciplined manner. It is important for the company to prevent unnecessary production, to reduce excess waste, to increase the efficiency of the system. Lean production goes into effect here and the most important of the lean production principle is

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that the increase in efficiency is realized at low cost. The lean manufacturing technique is well known with the Toyota Production System, and today it is a technique that companies can not give up. In 1950, basic principles were first introduced by engineer Eiji Toyoda and engineer Taiichi Ohno, who worked with Toyota in Japan. This technique is used to perfect the value of the company and increase the profitability of the companies. Lean production means using less than everything to get more output and this means less production, fewer workers and less area to produce. This term is also used to refer to the Just-in-Time Production System (JIT), also known as the most efficient production system in the world, the Toyota Production System. Lean production mainly focuses on the elimination of all kinds of waste in production. Lean production tries to use all production factors in the most flexible manner, with minimal resources, the shortest time, the lowest cost and error-free production, and the ability to respond to individual customer requests [1]. This system developed at Toyota can be used to remove or at least reduce these waste sources [9]. Lean production is a holistic approach based on removing system wastes and increasing system efficiency on a continuous basis. Taiichi Ohno (1988) defined waste as an activity that consumes resources but does not create value. In other words, waste is an activity that does not add value but creates cost. Henry Ford, on the other hand, "defined everything that does not add value as wastage." The two points need to be kept in mind to remove waste and losses altogether. To increase activity is only meaningful when you lower the cost. To achieve this end, you only need to produce what you need and use labor at the minimum level possible. Secondly, the effectiveness of each worker and each production line should be observed. Then the parts and the efficiency of the whole facility should be evaluated [3]. The Lean Enterprise Research Center (LERC, 2004), Cardiff Business School emphasized the following for most production; For operations: 5% of activities add value; 35% are non-value activities; 60% does not add any value. For this reason, the removal of wastes is undoubtedly a great development potential for production [10]. Managing the value stream involves an understanding process. Developing, measuring, interacting with information and all tasks, company costs, services and quality products are as competitive as possible [12].

2. Lean Manufacturing Techniques

Lean Manufacturing constitutes a milestone in production systems in terms of time, customer and quality. Lean thought; it is important to think about product lines that are strong, focused teams, ignoring existing assets and technologies. This also requires redefining the role of the technical experts of the company and rethinking where it will create value only. When it becomes realistic, no manager can really apply all of these changes immediately, but it is necessary to create a clear picture of what is necessary [4]. There are five basic principles for the application of lean thinking in a firm. These principles are: [5]

1- Determining what customer values are in a product service (Costumer value)

2- Determination of value flows for a specific product and elimination of non-value-added activities (Value flow)

3- Continuous flow for value adding activities (Flow)

4- Creating of a pulling mechanism which is initiated by the customer, with the customer's requests, the arrangement of the stocks and the determination of the time of customer request. (Pulling system)

5- To work for excellence (Excellence)

The studies carried out in recent years in the field of lean production have been examined.

Alhuraish argued that defining and understanding critical success factors is crucial for companies to successfully implement six sigma or lean manufacturing in his study. Lean production and six sigma were examined comparatively and success factors related to these two methodologies were determined. The most important success factors have been found to differ for six sigma and lean production [15]. The aim of Botti's study is to design an efficient assembly line that lean manufacturing principles and ergonomic requirements. A linear programming mathematical model was used to the effect of ergonomics on the lean production process [16]. Marodin's study focuses on the fact that many companies allocate less resources for lean implementation in product development processes. Survey method and hypothesis tests were used [17]. Deshkar has implemented value flow mapping in a small and mid-sized group of plastic manufacturing companies. It has proposed a solution for seven wastes in lean manufacturing. Lean philosophy emphasized that the value added increased by 74.5%, and that this methodology could be applied to small and medium scale [18]. Santos reveals the results of the analysis of improving efficiency and ergonomic conditions as a result of the elimination of wastes in his study [19]. Bauer emphasizes how various topics in Industry 4.0 (such as Big data, data analytic ...) will be adapted to lean manufacturing systems and optimization projects in his study [20].

5S: 5S is a systematic approach that ensures the participation of employees in the workplace cleanliness and order, creates a quality working environment in organizations and maintains its continuity. The greatest feature of the 5S approach is that it is simple, so it is easy to find an application area. 5S, which forms the basis for other improvement works, is the basic concept that prioritizes workplace improvement in this context [6]. The definition of five terms are given below [14]:

- SEIRI – Sort
- SEITON – Set in order/Simplify
- SEISO – Shine/Sweeping Work areas/Equipment will be clean.
- SEIKETSU – Standardize
- SHITSUKE – Sustain

Kaizen: Development, continuous improvement, better. The main goal here is to reduce the cost of production by reducing waste and raising productivity. Every proposal, small or large, brought to improve a stage of production or business is "Kaizen" [7].

Poka-Yoke: This method is used to prevent mistakes made by the operator or other reasons during the production and to use some warning devices to prevent such mistakes from occurring. This concept was used by the Japanese Engineer Shigeo Shingo in 1986. Poka-Yoke means fault isolation in Japan. Shingo has continued to develop the issue of error prevention for thirty years. The most important invention he made is to distinguish between error and defect [6]. Every

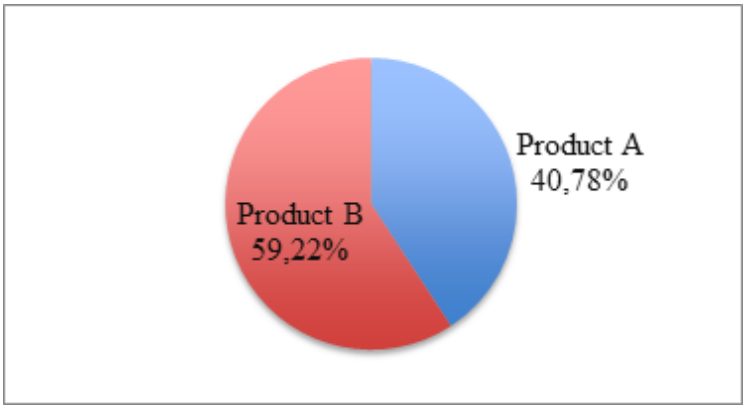
step of the product lifecycle, every process and every operation can have an error. As a result, the final product leads to imperfections and customer dissatisfaction and frustration. Even if the number of minor errors in the Poka Yoke base is small, it is unacceptable [13].

Quality Circles: The pioneer of the Japanese quality control movement, according to Dr. Kaoru Ishikawa, the enterpriseÔÇÖs quality control approach has three main characteristics. All departments participate in the quality control function. All employees participate in the quality control function. Quality control is fully integrated into other business functions [8].

3. Lean Manufacturing Application In Energy Sector

The study section contains studies for the theoretical information described in the previous chapters. The application sequence followed the sequence in the theoretical information. Firstly, the five basic principles of lean production came out, and later they were passed by lean techniques to achieve them. As a result, in assembly line process, seven orders of breaker per day were produced with five operators in comparison with twelve orders of plan in the current situation. Lean operations and planning can take twenty four orders and it can be done with two operators at a rate of 77.98%. There are two main specs production of twelve KV breakers. Two different types of breakers, Product A and Product B, differ from each other in that Product B has wheels located under the breaker. The spec productions rates are according to 2017 data are shown below in Figure 1.

Figure 1. 12 KV Breaker Production Rates in 2017.



The number of videos, time, analysis status, anomalies and kaizen numbers according to the information are analyzed according to Table 1. Video shooting, analysis, evaluation, kaizen identification procedures were followed respectively.

While performing video analysis, jobs that provide added value and jobs that do not provide added value have been identified. Net work, Compulsory wastage, Periodical work providing added value, wasted works are that do not provide added value. Kaizen was determined for the wasteful work steps identified as abnormal.

Table 1. Lean Work Progress Table

Spec	Assembly Group	Assembly Name	Video Status	Analysis Status %	Number of Abnormalities	Number of Kaizen
PRODUCT A	Assembly	Harness Pre-Assembly	Viewed	100	28	4
PRODUCT A	Assembly	Pole Assembly	Viewed	100	21	6
PRODUCT A	Assembly	Harness Final Assembly	Viewed	100	18	5
PRODUCT A	Test	Electrical Test	Viewed	100	5	3
PRODUCT A	Test	Mechanical Test	Viewed	100	4	2
PRODUCT A	Preliminary	Preliminary	Viewed	100	12	6
PRODUCT B	Assembly	Harness Pre-Assembly	Viewed	100	28	3
PRODUCT B	Assembly	Pole Assembly	Viewed	100	21	6
PRODUCT B	Assembly	Harness Final Assembly	Viewed	100	18	5
PRODUCT B	Test	Electrical Test	Viewed	100	5	3
PRODUCT B	Test	Mechanical Test	Viewed	100	5	2
PRODUCT B	Preliminary	Preliminary	Viewed	100	26	6
PRODUCT B	Preliminary	Physical Quality Control	Viewed	100	2	1

As can be seen in Table 2, these anomalies are separated into quality problems and other assembly problems. Analysis of the current situation is completed with this process index.

Table 2. Standard Worksheets

Spec	Proses Name(1)	Work Item Name	Total 1. Status Duration
Product A	**Pole Assembly**	Bottom support assembly	245
		Electrical Bus Assembly	105
		Contact Assembly	32
		Pole Assembly	387
	Preliminary	Back Cover Preparation	36
		Back Cover Assembly	39
		Electrical Bus Preparation	229
		Contact Preparation	1266
	Harness Pre- Assembly	Open breaker case	47
		Take the breaker chassis from the pallette	8
		Take the harness equipment box	0
		Take the spare equipments from inside the box	27
		Throw away the moisture preventer bags from the box	8
		Assembly the harness	360
		Assembly the motor cables	82
		Disassembly the rear cover	18
		Disassembly the breaker from the pallette	108
		Disassembly the X01 socket from the breaker	32
		Assembly the breakerÔÇÖs internal switch support sheet metal	62
		Assembly the clamp rail	75
	Harness Final-Assembly	Labeling	92
		Assembly of the switch of movement end	87
		Assembly of S1-ABC, S2-S3 Switches	266
		Preparation of S2-S3 Switches	59
		Assembly of S8-S9 Switches	299
	Test	Electrical Test	129
		Mechanical Test	442
Grand Total			4540

The standard worksheet is used to record every step during work analysis, track number used, duration, assembly pattern, and to record improper or abnormal situations and suggestions for improvement.

It is a form that has created for the Standard Operations Table, which is used to standardize the work For product A,process name is Harness Pre-Assembly and work name is assembly is shown in Table 3

Table 3. Standard Operations Table

	Work Step Sequence Number	Group Sequence	Work Item Name	Work Step (Verbs)	Work Item Steps	Video Duration	Waste Duration	1. Status Duration	2. Status Duration	Seperation Auto	Seperation Manual	Kaizen Number
Product A, process name is Harness Pre-Assembly and work name is assembly	1	1	Opening breaker box	Get	Get pallet truck	4	4	0	0	Wrong	Waste	A1
	2	1	Opening breaker box	Get	Get box	39	39	0	0	Wrong	Waste	A1
	3	1	Opening breaker box	Release	Release pallet truck	16	16	0	0	Wrong	Waste	A1
	4	1	Opening breaker box	Get	Get claw hammer	1	0	1	1	Compulsory Waste	Compulsory Waste	
	5	1	Opening breaker box	Open	Open pallet truck	45	0	45	45	Waste	Compulsory Waste	
	6	1	Opening breaker box	Release	Release claw hammer	1	0	1	1	Compulsory Waste	Compulsory Waste	
	7	2	Take the spare equipments from inside the box	Get	Get Set-up arm support bracket, side bracket	5	0	5	5	Compulsory Waste	Compulsory Waste	
	8	2	Take the spare equipments from inside the box	Release	Leave Set-up arm support bracket, side bracket	3	0	3	3	Compulsory Waste	Compulsory Waste	
	9	2	Take the spare equipments from inside the box	Get	Get 90 degree elbow	2	0	2	2	Compulsory Waste	Compulsory Waste	P1
	10	2	Take the spare equipments from inside the box	Leave	Leave 90 degree elbow	3	0	3	3	Compulsory Waste	Compulsory Waste	
	11	2	Take the spare equipments from inside the box	Disassembly	Disassembly nylon packaging	15	5	10	10	Waste	Compulsory Waste	A2
	12	2	Take the spare equipments from inside the box	Throw away	Throw away nylon waste	1	0	1	1	Waste	Compulsory Waste	
	13	2	Take the spare equipments from inside the box	Get	Get silica gel	2	0	2	2	Compulsory Waste	Compulsory Waste	
	14	2	Take the spare equipments from inside the box	Throw away	Throw in the silica gel waste box	1	0	1	1	Waste	Compulsory Waste	A2
	15	3	Get the breaker from pallette	Get	Get open end wrench	1	0	1	1	Compulsory Waste	Compulsory Waste	
	16	3	Get the breaker from pallette	Disassembly	Release the nuts	180	74	106	106	Waste	Compulsory Waste	A3
	17	3	Get the breaker from pallette	Leave	Leave the open end wrench	1	0	1	1	Compulsory Waste	Compulsory Waste	
	18	4	Get the breaker chassis from the pallette	Get	Get the beraker to the table from the box	8	0	8	8	Compulsory Waste	Compulsory Waste	
	19	5	Get the tool case	Get	Get the tool case	58	58	0	0	Wrong	Waste	A1
	20	6	Disassembly the rear cover	Get	Get the allen wrench	3	0	3	3	Compulsory Waste	Compulsory Waste	

Editing is made with the standard work sheet, the determined steps were analyzed and the Standard Operation Table was created. Steps are grouped into net work, compulsory waste, waste, periodic work. Process number, work step group number is determined. For every question that can be asked during the process design, the work step, cause, process, group, analysis are determined by this table and standardized. The Standard Operation Table created is standardized in two different specs (Product A-Product B), 854 work steps and divided into five processes. In Table 4 Job analysis is shown.

Table 4. Job Analysis

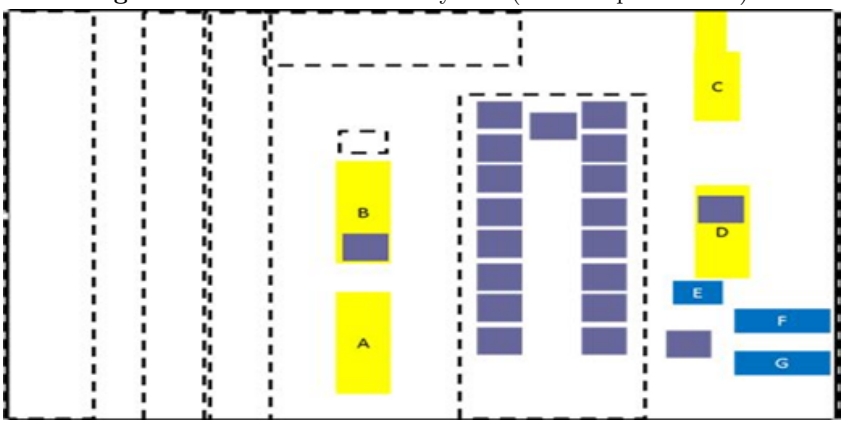
Spec	Seperation Manuel	Total Video Duration	Total 1. Status Duration	Total 2. Status Duration
Product A	Waste	480	0	0
	Net Work	1915	1788	1746
	Compulsory Waste	3271	2752	2672
Total Product A		**5666**	**4540**	**4418**
Product B	Waste	491	0	0
	Net Work	2601	2280	2238
	Compulsory Waste	4405	3528	3448
Total Product B		**7497**	**5808**	**5686**
Grand Total		**13163**	**10348**	**10104**

It is aimed to create a summary table by determining the processes for the work steps. It determines which of the improvement groups can be implemented and what requirements contain.

•The first optimization phase contains the elimination of wasteful abnormal work steps.

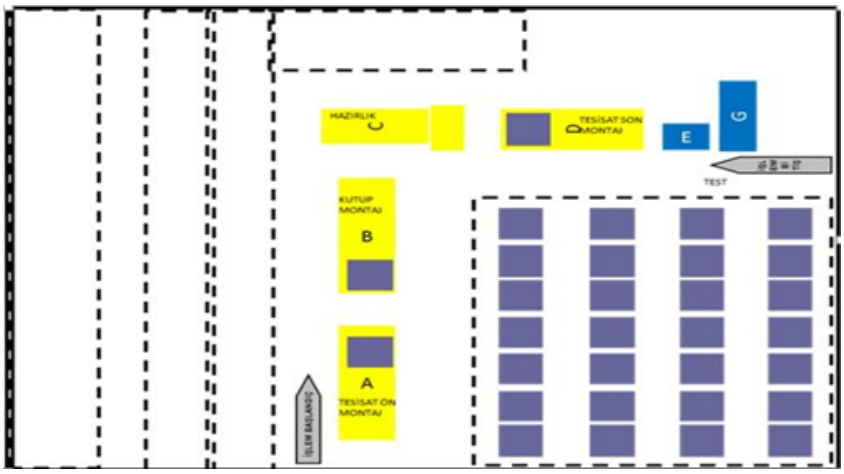
•In the second optimization phase contains net work, abnormalities in steps designated as waste, kaizen, poke yoke, etc. including the reduction of time by improving with tools. Current Situation Lay-Out (Before Optimization)is seen in Figure 2.

Figure 2. Current Situation Lay-Out (Before Optimization).



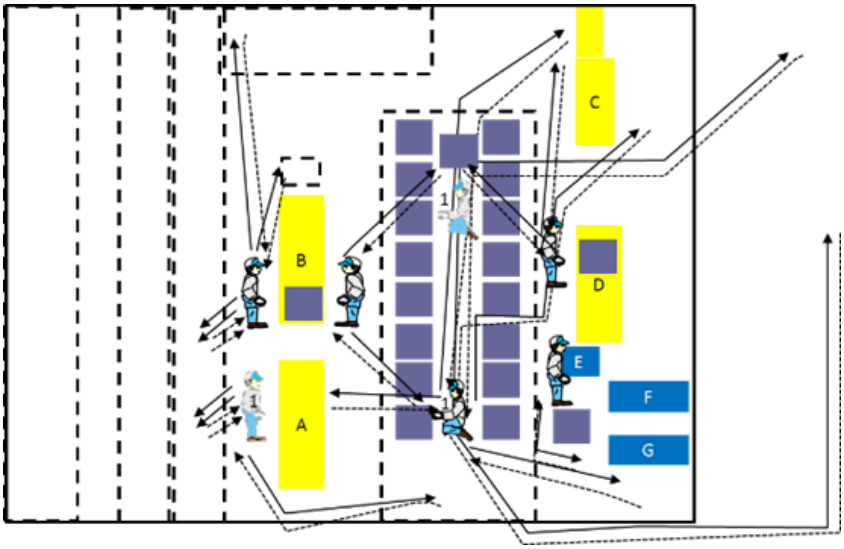
It is removed unnecessary tools as table, shelf, equipment in 12 KV Breaker assembly line. Due to the fact that lay-out is editing based on necessary equipment etc. for specs. As a result, two processes are enough for new lay-out. New Situation Lay-Out (After Optimization) is shown in Figure 3.

Figure 3. New Situation Lay-Out (After Optimization).



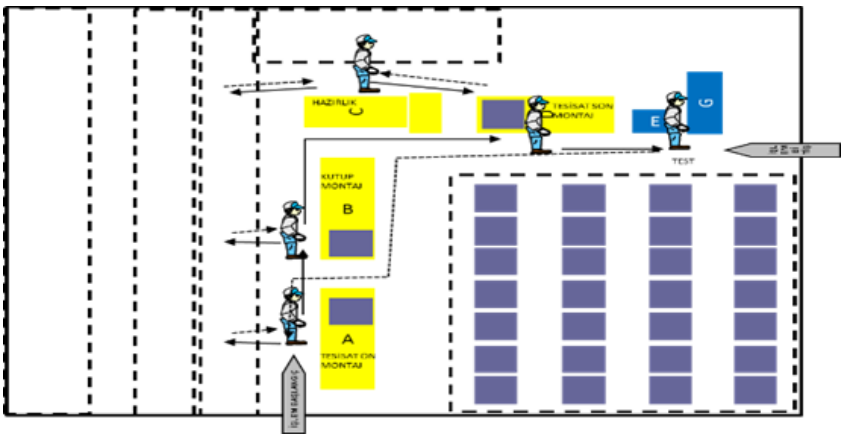
The total walking distance for a product assembly was 120 meters before lean operation, while the total effort was reduced by 48 meters as a result of optimizations made in the lean operation and 5S adjustments. Before The Optimization Walking Diagram is shown in Figure 4 .

Figure 4. Before The Optimization Walking Diagram.



Thus, a %60 gain was achieved in reducing the total walk. After The Optimization Walking Diagram is shown in Figure 5

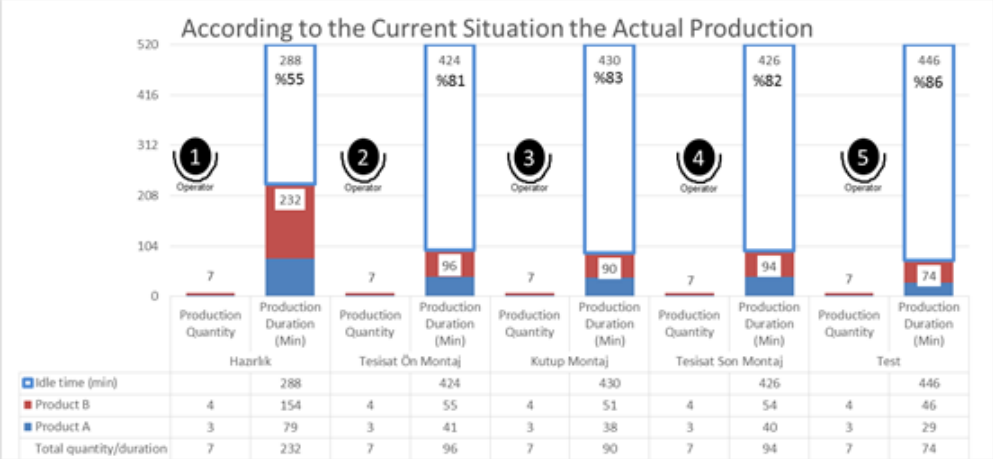
Figure 5. After The Optimization Walking Diagram.



3.1. Yamazumi and Workload Process. Yamazumi is that the work steps are arranged in a balanced manner with each other, thus sharing the work load in a straightened in the lean thinking.

The line balancing exercises are slightly different from the Yamazumi exercises. The most important point at Yamazumi is to distribute works to operators based on the concept of takt time, which relates customer demand. For an effective Yamazumi study, standard worksheets and work standards must be properly defined. It is used for balancing the workload of the processes determined according to the desired number of production.

Figure 6. The Actual Production According To the Current Situation.



In the current situation, the role of 5 operators in production is seen in the table. The white part in the table shows the vacancy rate of the operator and the red part shows the occupancy rate of the operator according to the current production name. The actual amount of production currently available is 7 breakers in total, including Truck 4 and Casette 3. The 12 production orders planned by the planning can not be met due to this irregular work distribution and this table shows that 12 orders can be produced. Productivity with 7 processes with 5 processes is productivity rate 22.54% and balancing loss is 77.46%.

With the 5 processes available according to the planned production, the number of production to be realized is 12 breakers. Productivity is 45.39% and loss of balancing is 54.61%. The high loss of balancing makes it possible to produce more products.

In the current situation, 7 orders produced with 5 operators are shown on the table which can be produced with 2 operators. In this case, the productivity is 56.35% and the balancing loss is 43.65%. The loss of balancing is 43.65%, which means that 2 operators can actually make more orders. If you want to produce with 2 operators, 3 workers gain will be provided.

Figure 7. The Planned Production According To The Current Situation .

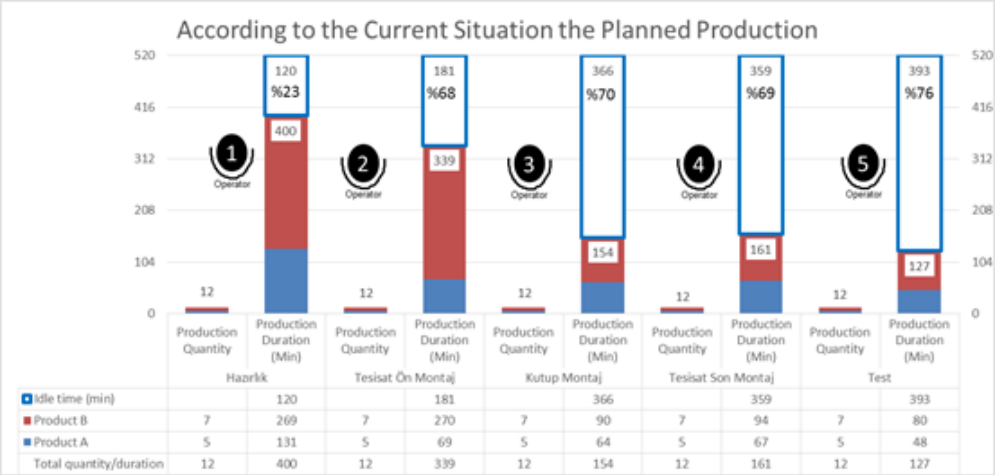
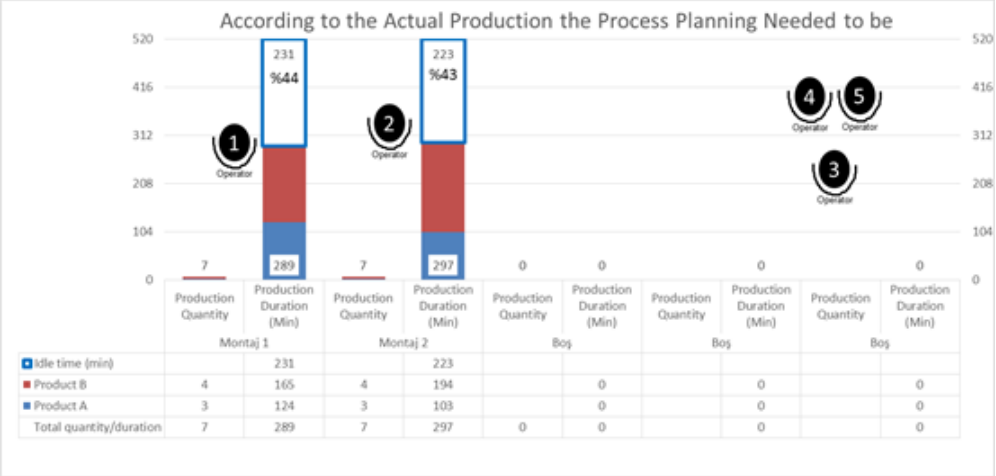


Figure 8. The Process Planning Needed To Be, According To The Actual Production.



It has been shown that the 12 product orders that the planning has given can actually be produced at maximum efficiency with 2 operators instead of 5 operators. The number of processes that should be compared to 12 planned productions is 2. In this case the productivity is 96.80% and the loss of balancing is 3.20%. There are 3 workers gains.

Since more production is preferred instead of operator removal, this table shows that a maximum of 24 units can be produced by reducing the balancing loss to 5

Figure 9. The Process Planning Needed To Be, According To The Planned Production.

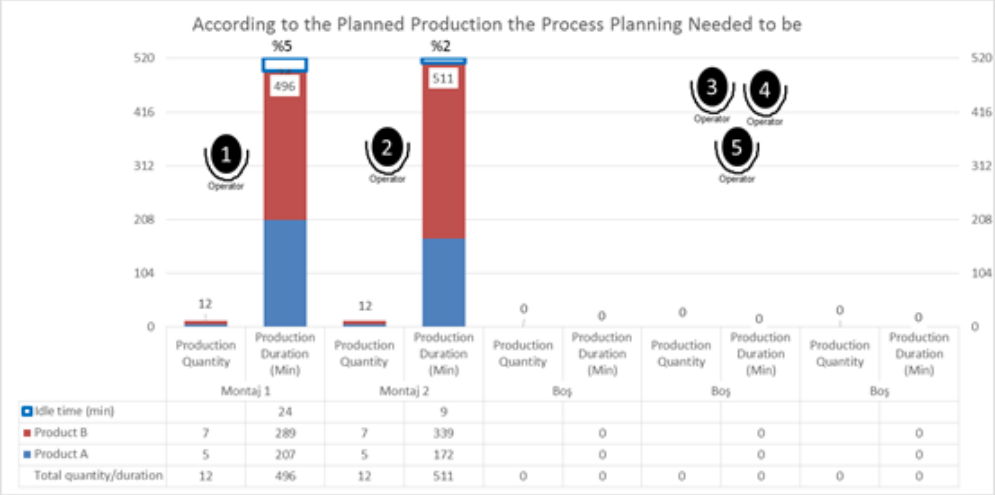
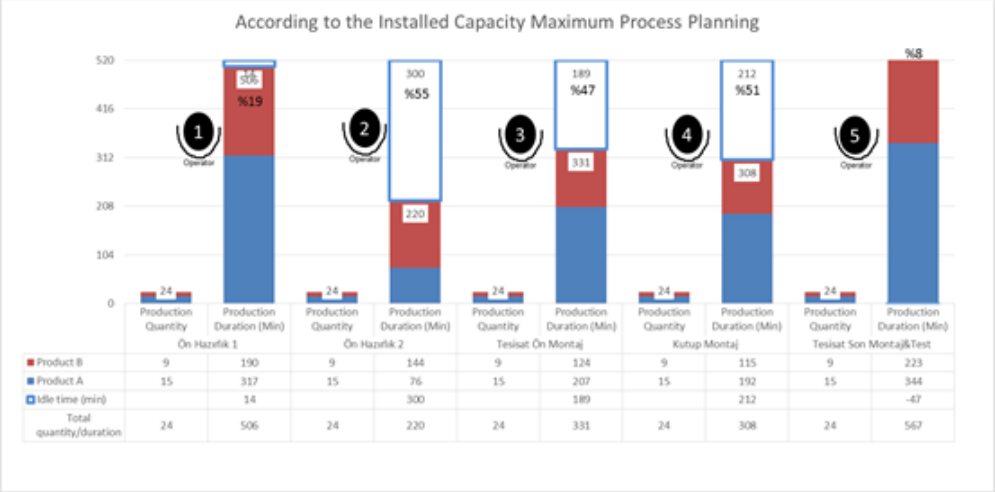


Figure 10. Maximum Process Planning According To The Installed Capacity .



operators and 5 processes available. Balancing loss is 22.02% while the production amount is 24, ensuring that the line is optimized.

4. Results And Conclusion

Lean thought approach, aiming at getting rid of all kinds of processes and losses that do not add value to the business, the strategy that enables them to do so. When the lean manufacturing application was started in the 12KV breaker section, there were five operators and one team leader as six staffs. Analyzes made and workload distributions according to the target production figures of the sales department were created. Process design for two processes, two operators and one team leader was determined to provide the number of production targeted in the near future with flexible production concept.

Table 5. Man Power Capacity Utilization After Lean Work According To Amount Of Product.

Spec	Current SAP Unit (min)	New SAP Unit (min)	Daily Production Spec Distribution Quantity	Production Quantity	Shift / Production (min)	Process Number	Operator Number	Man Power Capacity Utilization Rate(%)	Explanation
A	63	76	3	7	One Shift (520 min)	5	5	23%	According to the Current Situation the Planned
B	63	90	4						
A	63	76	5	12	One Shift (520 min)	5	5	45%	According to the Current Situation the Planned
B	63	90	7						
A	63	76	3	7	One Shift (520 min)	2	2	56%	According to the Actual Production the Process
B	63	90	4						
A	63	76	5	12	One Shift (520 min)	2	2	97%	According to the Planned Production the Process
B	63	90	7						
A	63	76	9	24	One Shift (520 min)	5	5	74%	According to the Planned Capacity Maximum Process Planning
B	63	90	15						

In the Table 5. the previous period, the new period, the number of processes, the number of operators and the man power capacity utilization rate were given to SAP according to target production numbers.

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