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# IMPROVING MANUFACTURING PROCESS BY OPTIMIZING TIME PARAMETERS

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***Abstract:*** *Lean methodology as one of the most modern ways of working, uses a variety of methods and tools that are aimed at continuous improvement and functioning of a single system. Due to its growing use in the manufacturing and service sector, Lean methodology is the subject of this paper. First, a series of Lean methods and tools will be presented to help analyze the current state of the selected production process, from raw materials to finished product. Then, with the help of the obtained data from the monitoring, it will be determined whether it is possible to improve the production process, by calculating the required number of operators in relation to the number of machines operated by one operator and the required number of operators in relation to the takt time, which in turn is related to the volume. Finally, a comparison of these data will be made to determine the future state of the process.*

***Key words:*** *Lean methodology, production process, takt time.*

**Unapređenje proizvodnog procesa optimizacijom vremenskih parametara.** *Lean metodologija koristi različite metode i alate koji imaju za cilj stalno unapređenje funkcionisanja proizvodnog sistema. Zbog sve veće upotrebe u proizvodnom i uslužnom sektoru, Lean metodologija je predmet ovog rada. Prvo, biće predstavljena serija Lean metoda i alata koji se koriste u analizi trenutnog stanja odabranog proizvodnog procesa, od pripremaka do gotovih proizvoda. Zatim će se, uz pomoć dobijenih podataka iz monitoringa, utvrditi da li je moguće poboljšati proizvodni proces, izračunavanjem potrebnog broja radnika u odnosu na broj mašina kojima upravlja jedan operater i potreban broj operatera u odnosu na ritam toka, što je opet povezano sa obimom proizvodnje. Konačno, biće izvršeno poređenje ovih podataka kako bi se odredilo buduće stanje proizvodnog procesa.*

***Ključne reči:*** *Lean metodologija, proizvodni proces, ritam toka.*

## 1. INTRODUCTION

The growing domestic and global competition, the incessant development of new technologies, the constant changes in the consumer demands, the short product life cycle, and the increased costs are the reasons why organizations are focused on product development, response times, demands, budget and performance. For a company to be one step ahead of its competitors, the most important thing to focus on is reducing the time that does not add value, continuously improving all of its processes from within and finding a way to produce products with lower price, better quality and faster delivery [1,2]. In order for companies to survive on the market and be competitive, they need to apply methodologies that achieve positive results across the entire process of production.

## 2. LEAN METHODOLOGY AND LEAN TOOLS

The lean principles are not created as a result of theoretical consideration; they were originally developed in practice and later adopted by scientists [1]. Lean means less of everything: less energy, less investment, effort and capital. Lean is a production philosophy that by its implementation affects the shortening of time of delivery of the finished product to the client; and it eliminates all sources of waste, that is, the losses in the production process. The basic principle of Lean's management, production is to produce exactly what the client wants, in other words, the quality and quantity of the products are directly dictated by the market i.e. the client. Lean management is a way of thinking and working of the entire system. Such a system uses different models and tools in order to continuously improve the functioning of the system.

It is worth pointing out that Lean is thinking about the best performance in all technological processes. The ultimate goal is human development and the use of the mind of all employees. Therefore, such thinking should be shared by all employees and must also be involved in the implementation. Lean principles as means of testing the business process [2]:

- The first principle defines the values. The product or service must be delivered to the client when the client wants it and at the place where the client wants it. It is necessary to listen to and recognize the needs of the client and to identify well the value that the product has for the customer, how customers see the product.
- The second principle is the mapping of the flow of values
- The third principle of the Lean methodology is to create a flow. In order to achieve the best flow in the production process, we need to distance ourselves from traditional thinking and rebuild resources so that the process can take place with continuous flow.
- The fourth principle of Lean's methodology is the pull principle,

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- The ultimate principle of Lean's methodology perfection, pursuing perfection or aspiration for continuous improvements.

When it comes to Lean in manufacturing companies, several things must be provided to ensure that Lean will function successfully, and these are:

- Well-established and balanced production,
- Flexible people and machines,
- Top-notch quality,
- Reliable equipment and machinery,
- Reliable suppliers,
- Very short tool replacement time
- A great deal of discipline.

The principles discussed above provide the framework of the Lean philosophy and their application supports the transformation of the organization into Lean enterprise [3]. Next is the presentation of some of the most popular Lean management methods and tools and their use in the production environment.

1) Value Stream Mapping (VSM) corresponds directly to the first Lean principle, that is, to the Value Determination Principle. It includes the process of graphically drafting all the activities needed to move the product through the value stream and to identify and remove the waste thereafter. In doing so, it is necessary to illustrate both the material flow and the flow of information. As an initial step for one Lean business is creating the current state of the value flow. Afterwards, improvements are made according to the Lean philosophy and the desired state (future) is recorded in a new map of the value stream.

2) Standardized work process

The standardization of the work process establishes the best methods and sequences for optimizing performance and minimizing waste (activities that do not add value). This ensures that the activities will be carried out the same way at any time. With the standards in the performance of its activities, Lean company gets consistency in its production processes.

3) 5S Methodology

The 5S methodology provides a standardized working environment and allows the employees see the flow of the process. The 5S can be seen as a good starting point for implementing the Lean Initiative.

4) Visual Management

Visual management allows workers to be fully informed about the production procedures, the current state and other important things so that the process would take place more efficiently. Large displays in the halls are a far better way of communication than written reports, so more should be used. When it comes to improving the processes, visual management helps the team of workers to better understand the work, facilitates understanding of the order of the complicated activities and their internal and external tasks interactions with the surrounding work units

5) Kanban

Kanban is a method based on the extraction system, which uses visual signals (for example, cards in different colors) to signal production contrary to the course of production. In fact it represents a certain complement system: complementing the required parts in the right amount at the right time and at the right time. It is means of communication in the extraction system. Kanban can be: a card, an empty pallet, a visual display, that is, any element that gives a signal to start producing a particular part.

## 3. CASE STUDY OF LEAN APPLICATION IN A PRODUCTION COMPANY

Lean production presents optimization of the process, using empirical methods to figure out what adds value to the client, as opposed to the uncritical welcome to all ideas [4,5]. The benefits of implementing Lean manufacturing principles to real productive environment are presented in this case study implemented in Aptiv, Macedonia.

Aptiv is one of the largest suppliers to the automotive industry delivering advanced electrical and electronic, motor and vehicle safety technologies around the world, enabling the manufactures to make vehicles that are safer and better connected.

Aptiv Macedonia in particular produces printed circuit boards. The production area as shown in Figure 1 is separated in two parts SMT (surface mount technology) and FA (final assembly). This project aims at improving the final assembly and determining the optimal number of operators in this part of the production.

In this case almost all of the Lean tools are used, but the predominant one is the Standardized Work process because with the help of the Standardized work process it is easier to analyze the working pattern and/or improve it.

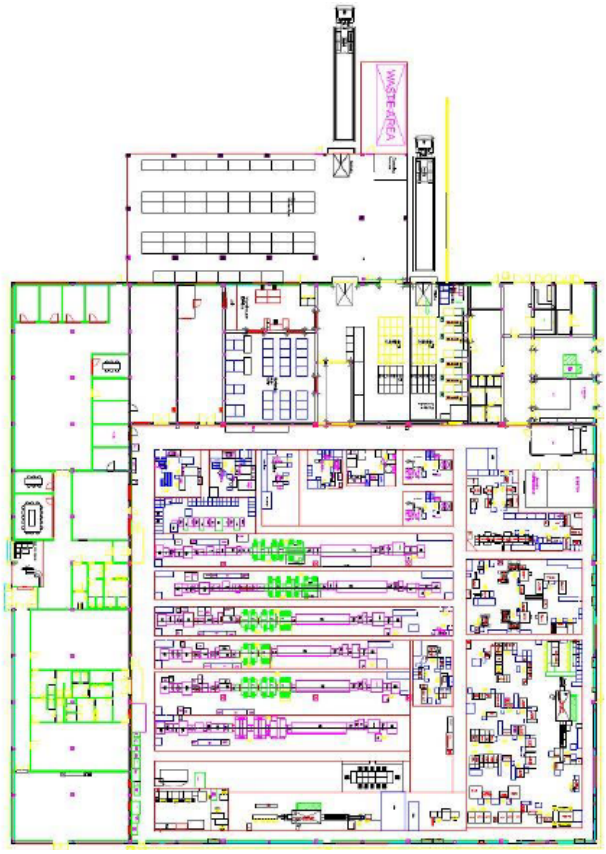


Fig. 1. Company layout

### 3.1. Definition phase

The analysis of the production process and the standardized work process of every post led to a problem with the operator's utilization after which we decided to analyze the process in terms of two parameters, the number of machines and the takt time to see the optimal number of operators.

### 3.2. Measurement phase

In this phase we measured each working activity performed by the operators. In this phase both the cycle times and the non-cycle times that are included (for example activity that happens every 3rd or 6th cycle). The time for one printed board is given in seconds, with 10 measurements done for each cycle (Tab.1& 2).

| Machine | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Singulation | 6.3 | 6.05 | 6.3 | 6.2 | 6 | 6.01 | 6.4 | 6.15 | 6.1 | 6 | 6 |
| Pressfit Single | 17.4 | 16 | 18.7 | 18.6 | 19 | 18.8 | 18.6 | 18.5 | 18.9 | 19 | 18 |
| Pressfit Double | 13.4 | 13.5 | 14 | 13.05 | 13.5 | 13.3 | 13.6 | 13.6 | 13.5 | 14 | 13.5 |
| ICT test | 8.9 | 9 | 9.25 | 8.87 | 9.25 | 9.25 | 9.25 | 9 | 9 | 9 | 9 |
| Coating | 8 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8 |
| Housing | 6.8 | 7 | 6.5 | 6.3 | 6.5 | 6.6 | 6.8 | 6.3 | 6.6 | 6.05 | 7 |
| EOL test | 9 | 9 | 8.9 | 9 | 8.7 | 8.8 | 9 | 9.2 | 9.3 | 9.1 | 9 |
| Bracket assembly & CMI | 9.6 | 9.3 | 9 | 9.15 | 9.7 | 9.9 | 9 | 9.3 | 9.4 | 9.1 | 9 |

Table 1. Measured Cycle time

| Machine | Time |
|---|---|
| Singulation | 0.65 |
| Pressfit Single | 0.3 |
| ICT test | 0.5 |
| Coating | 0.5 |
| Housing | 1 |
| EOL test | 2 |
| Bracket assembly & CMI | 1.5 |

Table 2. Measured Non-Cycle time

### 3.3. Analysis phase

#### 3.3.1 In relation to the number of machines that are operated by one operator

The purpose of this paper is optimization, improving the production process through time parameters. First to calculate is the number of operators required in relation to the number of operated machines, because in some cases there is more than one machine operated by one operator, depending on the times, that is, the manual time and the machine time.

The calculation of the required number of operators also took into account the previously mentioned standardized work process that was created. Also, this calculation takes into consideration the bottlenecks in the production process.

In production, the bottleneck is one process in the process chain that with its limited capacity reduces the capacity of the entire chain. There are short and long-term bottlenecks. Short-term bottlenecks are temporary and are usually not a significant problem. An example of a short-term bottleneck would be a skilled employee who would take several days off work. Long-term bottlenecks occur all the time and can cumulatively slow down production. An example of a long-term bottleneck is when the machine is not efficient enough and as a result there are delays.

The method of calculating the number of operators in relation to the cycle time, the manual time and the machine time will be shown in the following example.
If we have 4 machines, whose machine time is 58 seconds, and the manual operation lasts 22 seconds, in order to get the required number of operators for operating these machines it is necessary to calculate the required number of operators = (manual operation * number of machines) / machine time or in this example

(22 * 4) / 58 = 1.5 operators

Table 3 gives the calculations for the number of operators in relation to the number of machines.
After the calculation and the numbers we can conclude that there is difference of 0.7 and 0.5 operators on the ICT test and EOL test machines.

| Machine | Cycle time | Non-Cycle Time | Manual work | NCT + MW | Volume per day | Calculated operators | Number of machines | Current number of operators | Difference |
|---|---|---|---|---|---|---|---|---|---|
| Singulation | 6 | 0.65 | 4 | 5 | 7800 | 1 | 1 | 1 | 0 |
| Pressfit Single | 18 | 0.3 | 7 | 7 | 7800 | 0.4 | 1 | 1 | -0.6 |
| Pressfit Double | 13.5 | 0 | 13 | 13 | 7800 | 1.0 | 1 | 1 | 0 |
| ICT test | 9 | 0.5 | 7 | 8 | 7800 | 1.7 | 2 | 1 | 0.7 |
| Coating | 8 | 0.5 | 6 | 7 | 7800 | 0.8 | 1 | 1 | -0.2 |
| Housung | 7 | 1 | 4 | 5 | 7800 | 0.7 | 1 | 1 | -0.3 |
| EOL test | 9 | 2.0 | 2.5 | 5 | 7800 | 1.5 | 3 | 1 | 0.5 |
| Bracket assembly & CMI | 9 | 1.5 | 9 | 11 | 7800 | 1.2 | 1 | 1 | 0 |

Table 3. Calculated number of operators in relation of the number of machines

#### 3.3.2 In relation to the takt time

Next is the calculation of the required number of operators in relation to takt time, with the help of the collected data and the performed measurements of all processes.

With the takt time, it is shown how often a part or product should be produced, that is, the amount of time the product should come out in terms of volume, the

quantity of products that is required by the client.

It is obtained as a ratio between the available working hours per day (in seconds / minutes) and the client's daily demand (in pieces), the quantity of products in number of pieces. This calculation of takt is used to synchronize the pace of production with the pace of sales.

In this particular process, the takt time was calculated by taking the time (in hours) that is used by the company as effective time, together with the foreseen breaks are taken in all of the 3 shifts. It is important to note that the production does not stop during the day, also during the breaks the work continues with less effectiveness and output because fewer operators are working. Here, the takt time for the SMT line and FA is calculated separately (Table 4).

In order to calculate the required number of operators using the takt time which was previously calculated, the same data of the previous calculation will be used .

The calculation of the number of operators with takt time is as follows:

Required number of operators = (manual time * number of machines) / time

In this calculation of the required number of operators the volume as a parameter is included in contrast to the previous calculation.

Table 5. shows the calculations for the number of operators in relation to takt time. If we analyze the Table 6, from the results it can be concluded that this calculation gives similar results, there is a difference in the same processes as before, ICT and Pressfit, but the numbers are smaller than in the previous calculation

| **Takt time** | | |
|---|---|---|
| Work shifts per day | 3 | Shifts |
| Hours per Shift | 8 | Hours |
| Break time per shift | 10 | min |
| Lunch time per shift | 20 | min |
| Customer demand per day | 7800 | units |
| Available time per shift | 480 | min |
| Net working time per shift | 460.2 | min |
| Net working time per shift | 27612 | s |
| Net working time per day SMT | 84960 | s |
| Net working time per day FA | 82836 | s |
| **Takt time SMT** | 10.9 | s |
| **Takt time FA** | 10.6 | s |

Table 4. Calculation of takt time.

| Machine | Cycle time | Non-Cycle Time | Manual work | MCT + MW | Volume per day | Calculated operators | Number of machines | Current number of operators | Difference | Difference | Calculated operators | Takt time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Singulation | 6 | 0.65 | 4 | 5 | 7800 | 1 | 1 | 1 | 0 | -0.6 | 0.4 | 10.6 |
| Pressfit Single | 18 | 0.3 | 7 | 7 | 7800 | 2.4 | 1 | 1 | -0.6 | -0.3 | 0.7 | |
| Pressfit Double | 13.5 | 0 | 13 | 13 | 7800 | 1.0 | 1 | 1 | 0 | 0.2 | 1.2 | |
| ICT test | 9 | 0.5 | 7 | 8 | 7800 | 1.7 | 2 | 1 | 0.7 | 0.4 | 1.4 | |
| Coating | 8 | 0.5 | 6 | 7 | 7800 | 1.6 | 1 | 1 | -0.2 | -0.4 | 0.6 | |
| Housing | 7 | 1 | 4 | 5 | 7800 | 1.7 | 1 | 1 | -0.3 | -0.5 | 0.5 | |
| EOL test | 9 | 2.0 | 2.5 | 5 | 7800 | 1.5 | 3 | 1 | 0.5 | 0.3 | 1.3 | |
| Bucket assembly & Oil | 9 | 1.5 | 9 | 11 | 7800 | 1.2 | 1 | 1 | 0 | 0.0 | 1.0 | |

Table 5. Calculated number of operators in relation to takt time

| Machine | Cycle time | Non-Cycle Time | Manual work | MCT + MW | Volume per day | Calculated operators | Number of machines | Current number of operators | Difference | Calculated operators | Takt time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Singulation | 6 | 0.65 | 4 | 5 | 7800 | 1 | 1 | 1 | -0.6 | 0.4 | 10.6 |
| Pressfit Single | 18 | 0.3 | 7 | 7 | 7800 | 0.4 | 1 | 1 | -0.3 | 0.7 | |
| Pressfit Double | 13.5 | 0 | 13 | 13 | 7800 | 1.0 | 1 | 1 | 0.2 | 1.2 | |
| ICT test | 9 | 0.5 | 7 | 8 | 7800 | 1.7 | 2 | 1 | 0.4 | 1.4 | |
| Coating | 8 | 0.5 | 6 | 7 | 7800 | 0.8 | 1 | 1 | -0.4 | 0.6 | |
| Housing | 7 | 1 | 4 | 5 | 7800 | 0.7 | 1 | 1 | -0.5 | 0.5 | |
| EOL test | 9 | 2.0 | 2.5 | 5 | 7800 | 1.5 | 3 | 1 | 0.3 | 1.3 | |
| Bucket assembly & Oil | 9 | 1.5 | 9 | 11 | 7800 | 1.2 | 1 | 1 | 0.0 | 1.0 | |

Table 6. Calculated number of operators in relation to the takt time and the number of machines (comparison)

## 4. COMPARATIVE ANALYSIS OF THE IMPROVEMENTS ACHIEVED ON THE ANALYZED PROCESS

If we compare the results of the calculations it can be concluded that in all the processes the optimal number of needed operators obtained with the calculations corresponds to the number of operators currently serving the machines except in the ICT and Pressfit processes, where the operator is missing, both in terms of the number of machines and in relation to time. On these posts more machines are operated by one operator so that the results obtained actually prove that the operator does not manage to operate the machines on time, the operator does not wait for the machines, but the machines wait for the operator and therefore there is a waste of time. Setting up plus one operator on these posts, machines, will result in full capacity and volume and therefore full utilization of the machines.

Additional analysis of the results leads to conclusion that by adding plus one operator on the ICT post, the utilization will reach 70% in comparison to the utilization of the second person of the EOL. By reviewing the remaining results, it can be concluded that the EOL 0.5 operator can be obtained by sharing the operator from the Housing position who is not fully utilized.

## 5. CONCLUSION

Lean is a production philosophy that, when implemented, shortens the time from order to delivery of the finished product to the client, eliminating all sources of waste, i.e. losses in the process of production. The focus of the Lean philosophy is adding value to the client. This way of thinking reduces the unnecessary steps in the activities that add, but also in the activities that don't add value to the clients.

The benefits of Lean are reflected in the reduction of the production time, increased quality, flexibility and customer satisfaction. The effective implementation of

Lean methodology in the organization results in the company strengthening the framework of its organizational and inter-organizational relations. It also achieves better flexibility and ability to quickly respond to the changes in the customer demand, that is, better involvement of the employees and better financial and non-financial results. Although the Lean system has more advantages than flaws, certain caution is required when implementing Lean, so these flaws can have no negative impact on the company. One of its key disadvantages is that the Lean methodology provides little room for errors and does not create inventory. Lean methodology is applicable in all activities and in all organizational structures, both in the manufacturing sector and in the service sector.

In this paper, on the basis of the obtained results from the calculations and analysis it is concluded that the production process in question in the company Aptiv does not work with the optimal number of operators. With the previously obtained results in relation to the number of machines and the takt time which is connected with the quantity of products to be produced, it is concluded that an ICT operator is needed for full utilization of the machines.

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