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STUDY ON YIELD PERFORMANCE ANALYSIS WITHIN A PRODUCTION LINE

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Abstract: This scientific paper aims to present a study on how to calculate and analyze the efficiency achieved by operators in a production line of a manufacturing company, on their workstations. This analysis is considered necessary by the company's management, as a starting point in a more complex approach, which aims to change its production flow, in order to adapt existing production to the growing demand for products on the market. This paper will refer to a single product from the company's product range, more precisely it will be analyzed to obtain a subassembly that is in turn part of the finished product.

Keywords: efficiency, workstation, production flow, demand, technological process, assembly.

1 INTRODUCTION

The present scientific paper is part of a larger study, which has as its main objective the adaptation of the production capacity of a company producing finished goods, to the increase registered by the market demand of consumers, compared to the company's products.

From the product range of the manufacturing company, only one product was chosen, and for that product, the study will focus on the production line of a single subassembly.

Therefore, the study was structured on the following stages:

- in a first stage, it is necessary the initial analysis of the efficiency in the workstations, in the current production conditions;
- based on the conclusions of the first stage, in the second stage, the solutions for adapting the production flow to the new market demand will be identified;
- later, in the third stage, the found solutions will be implemented and the obtained results will be analyzed [3].

Therefore, the present paper is part of the first stage of the study, respectively it will focus on the initial analysis of the performance in the workstations, in the current production conditions of the company.

Subsequently, the research will continue, by finding solutions to change production, in the sense of increasing it, due to the increased demand for the company's finished products on the market and the need to adapt production parameters to the new demand.

2 INITIAL DATA

When producing production lines for the production of a range of finished products, the assembly of certain parts that are part of the studied subassembly, hereinafter referred to as subassembly S, is performed on the final assembly line, in this process involving many operators, in a small space [2], [3].

This was the main reason why a project for the reorganization and grouping of component assembly operations for subassembly S had to be developed. These assembly operations are distributed over eight workstations, grouped on an assembly line, hereinafter assembly subassembly S, which is attached to the final assembly line.

The productivity of the assembly line of the subassembly S is conditioned by the number of finished products to be assembled on the final assembly line.

The assembly line of the subassembly S is not yet automated, the movement of the storage boxes (kittare) between the stations is performed by the line operators, they perform movements of the hands, arms, back, in a word with the whole body, movements characterized by a high degree of accuracy.

Flow production processes are carried out on the assembly line of the S subassembly, having as main characteristic the fact that the parts (work objects) are processed and transmitted individually (piece by piece), as continuously as possible (without interruptions).

Given the productivity, on the assembly line of the subassembly S, the product range is diversified, the number of manufacturing batches is small and the batch size is large, specific to the production organized in flow and large series.

Each preparation device is obtained by presenting a task plan and an overall drawing. In order to carry out the task plan, the shape, size and positioning of the component elements of the S subassembly were taken into account, as well as the technological assembly process [2]. The preparation device - figure 1 - has in its composition: a metal frame, frame fixing mechanisms (1) and a roller support (2).

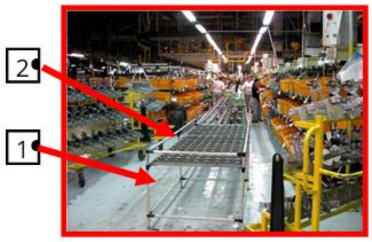

Figure 1. Preparation device

The movement of the kittare boxes between the stations, during the production cycle, is done by the operators, by pushing.

The supply of parts for the workstation is handled by the logistics staff from the Logistics Department, who carry out their activity according to a well-established schedule. Thus, the logistical operator has in evidence the situation of the necessary parts with which the positions of the assembly line of the subassembly S must be supplied. Within the Logistics Department, the parts are stored in containers. The containers are placed on the trolleys by means of forklifts, and the trolleys are towed by electric cars, driven by the logistics operators, to the assembly line, at the work station, according to the program.

In the workstation, the parts are stored as follows:

- on dynamic furniture - shelves provided with rollers, to allow the sliding of the packaging with parts, where small parts are stored: nuts, screws, clips, quick nuts, etc.

- in containers - on a mobile basis (figure 2);
- in containers - transported on trolleys-cranes (figure 3).

Figure 2. Containers on a mobile basis

Figure 3. Containers transported on trolleys-cranes

The technical characteristic of the analyzed production process is given by the sequence of technological operations for assembling parts, through which the S subassembly is made. The sequence of technological assembly operations are described in the document called "Process Operation Sheet" (FOP). Within the FOP, the following are presented:

- the identification sketch of the elements specified in the description of the respective operation;
- note - describing the risks and problems that may arise if the technological process of assembly is not observed;
- date of preparation;
- name and surname of the issuing person;
- name and surname of the approving person;
- operation name;
- FOP number.

Based on the FOP, a "Standard Operating Sheet – Operator Commitment" (FOS) is prepared for each workstation. The FOS presents:

- FOS number;
- version of the operation;
- main stage;
- the key point;
- execution time of each main stage, depending on the product variant;
- required working time;
- FOS learning term;
- date of application;
- implantation scheme;
- job indicators;
- a graph with the representation of time on the job;
- a graph with the representation of the cycle time per variant;
- a graph with the representation of the volume by variant;
- the significance of the variants;
- a table in which the part reference, the part name and the range for which the part is used are written.

The FOS is unique for each workstation and comprises several FOPs, depending on the sequence of operations and related to the required cycle time of the line.

The jobs within the analyzed line can be considered production systems, because they are characterized by a set of elements (resources) of human type, means of production and activities grouped in a specific way [1]. They interact with each other, according to certain rules, to make the product, respecting both the quantity and the specified deadlines, in conditions of efficiency. The jobs are arranged on a production line in the order of the operations mentioned in the FOP and correspond to each job. Thus, the assembly line of the subassembly S consists of 8 workstations, from P01 to P08.

The organizational characteristic of the analyzed production process is given by the work process, consisting of the procedures by which the operators act on the objects of work, with the help of the means of work, in order to obtain the finished product.

Dynamic furniture for workstation parts consists of four shelves: three shelves are occupied by the packaging with matching parts, with the labels on both sides displayed, and the fourth row of shelves is used for storing empty packaging, to be recycled.

The transport of the parts to the work station is done mechanized, in rolling parts of parts, towed by electric cars and forklifts.

The small parts (screws, nuts, clips) are packed in boxes and stored on the dynamic furniture of the parts, from the workstations that have in their composition operations of assembly of these parts.

At each workstation, stripes are drawn on the ground to delimit the positioning areas of the container, or the mobile base in which the parts are stored - figure 4.

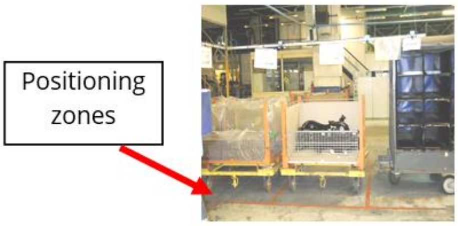

Figure 4. Tracing the positioning areas of mobile bases and containers

Above each positioning area, labels are displayed inscribed on both sides, with the name and number of the part to be assembled on the mobile preparation device according to FOS - figure 5.

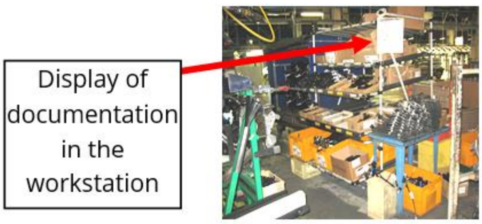

Figure 5. Positioning the documentation in the workstation

In each workstation, the required documentation displayed will include the following forms:

- FOS;
- description of the protective equipment used in the respective position;
- the plan of the assembly line of which the post is part;
- Tightening machine check grid (where applicable), where the tightening indices to be located within a certain range are specified.

3 YIELD PERFORMANCE ANALYSIS. METHODOLOGY

Next, we will move on to the performance analysis for each of the 8 workstations.

For this purpose, the following are presented:

- main stages,
- key points,
- main stage times (TEP), according to FOS,
- associated operations (OA), organized for the necessary cycle time for each of the 8 workstations.

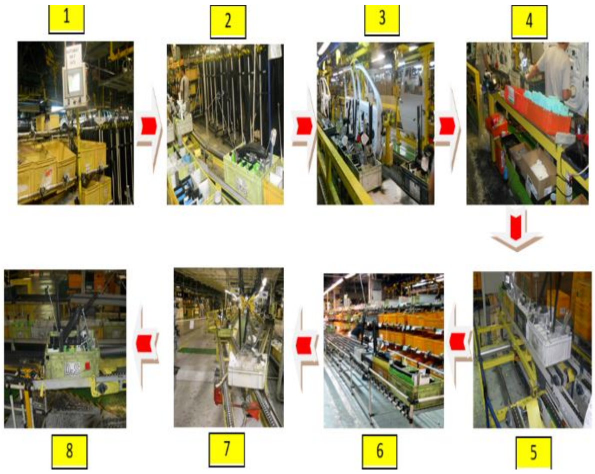

Figure 6. Carrying out operations in the 8 workstations

The starting dates for the performance analysis for 8 workstations are the following:

- the objective to be achieved at company level is to obtain a number of 1200 finished products / day;
- the cadence of the assembly line is 45 finished products / hour, respectively 98 Cmin / finished product, ie the necessary working time (measured in technological cents) for the manufacture of a finished product.

The overall performance of a workstation will demonstrate the total load on that workstation, in percent (%).

Subsequently, the values obtained will be compared, depending on the required cycle time, by means of a graph.

Thus, the overall efficiency of a workstation is a percentage calculation, resulting from the reporting of the total times of the main stages and associated operations, at the required cycle time set for the assembly line cadence of 45 finished products / hour.

R.G. = R.TEP + R.TOA (1)

Where:

PET - during the main stages;
R.TEP - time efficiency with the main stages;
TOA - time of associated operations;
R.OA - time efficiency with associated operations.

For starters, all the operations performed by the operators were timed for the 8 workstations, using the timing method [4], [7].

The values obtained are listed in Table 1.

Table 1. The values for the time allocated to the operations performed in the 8 workstations

	Allocated time (Cmin)							
Operation	P01	P02	P03	P04	P05	P06	P07	P08
O1	0,5	0,4	0,4	0,2	0,6	0,6	0,4	0,6
O2	0,16	0,16	0,6	0,8	0,6	0,6	0,4	0,8
O3	0,16	0,16	0,6	0,1	0,4	0,7	0,4	0,12
O4	0,4	0,4	0,6	0,1	0,4	0,4	0,4	0,4
O5	0,4	0,4	0,6	0,8	0,4	0,4	0,6	0,8
O6	0,2	0,2	0,4	0,8	0,4	0,4	0,4	0,4
O7	0,2	0,2	0,8	0,8	0,4	0,6	0,4	0,4
O8	0,12	0,12	0,4	0,6	0,6	0,6	0,4	0,5
O9	0,4	0,6	0,4	0,7	0,5	0,6	0,4	0,4
O10	0,2	0,2	0,1	0,2	1,5	0,6	0,6	0,2
O11	10	10	10	0,8	10	10	10	10
O12	10	10	10	10	10	10	9	0,6

The yields were further calculated: R.TEP, R.TOA and the overall yield R.G. 01 for workstation number one (P01).

$$\text{R.TEP } = \frac{TEP \bullet 100}{98} = 56{,}12\%$$

$$\text{R.TOA } = \frac{OA \bullet 100}{98} = 32{,}6\%$$

R.G. 01 = 56,12 + 32,6= 88,72%

The yields were further calculated: R.TEP, R.TOA and the overall yield R.G. 02 for workstation number one (P02).

$$\text{R.TEP } = \frac{TEP \bullet 100}{98} = 55{,}1\%$$

$$\text{R.TOA } = \frac{OA \bullet 100}{98} = 32.4\%$$

R.G. 02 = 51,1 + 32,4 = 87,5%

The yields were further calculated: R.TEP, R.TOA and the overall yield R.G. 03 for workstation number one (P03).

$$\text{R.TEP } = \frac{TEP \bullet 100}{98} = 59{,}18\%$$

$$\text{R.TOA } = \frac{OA \bullet 100}{98} = 20{,}4.\%$$

R.G. 03 = 59,18 + 20,4 = 79,58 %

The yields were further calculated: R.TEP, R.TOA and the overall yield R.G. 04 for workstation number one (P04).

$$\text{R.TEP} = \frac{TEP \bullet 100}{98} = 68{,}36\%$$

$$\text{R.TOA} = \frac{OA \bullet 100}{98} = 18{,}3\%$$

R.G. 04 = 68,36 + 18,3 = 86,7%

The yields were further calculated: R.TEP, R.TOA and the overall yield R.G. 05 for workstation number one (P05).

$$\text{R.TEP} = \frac{TEP \bullet 100}{98} = 59{,}18\%$$

$$\text{R.TOA} = \frac{OA \bullet 100}{98} = 20{,}4\%$$

R.G. 05 = 59,18 + 20,4 = 79,58 %

The yields were further calculated: R.TEP, R.TOA and the overall yield R.G. 06 for workstation number one (P06).

$$\text{R.TEP} = \frac{TEP \bullet 100}{98} = 56{,}12\%$$

$$\text{R.OA} = \frac{OA \bullet 100}{98} = 20{,}4\%$$

R.G. 06 = 56,12 + 20,4 = 76,52 %

The yields were further calculated: R.TEP, R.TOA and the overall yield R.G. 07 for workstation number one (P07).

$$\text{R.TEP} = \frac{TEP \bullet 100}{98} = 53{,}06\%$$

$$\text{R.OA} = \frac{OA \bullet 100}{98} = 19{,}38\%$$

R.G. 07 = 53,06+ 19,38 = 72,44 %

The yields were further calculated: R.TEP, R.TOA and the overall yield R.G. 08 for workstation number one (P08).

$$\text{R.TEP} = \frac{TEP \bullet 100}{98} = 54{,}08\%$$

$$\text{R.OA} = \frac{OA \bullet 100}{98} = 20{,}4\%$$

R.G. 08 = 54,08 + 20,4 = 74,48 %

4 RESULTS ANALYSIS

Next, in order to be able to analyze the performance of the commitment on the 8 positions, from P01 to P08, all the data obtained in table 2 are centralized.

Table 2. Performance of the engagement of the posts on the analyzed assembly line

Post	TEP	TOA	R.G.
P01	56,12	32.6	88,72
P02	55,1	32,4	87,5
P03	59,18	20,4	79,58
P04	68,36	18,3	86,7
P05	59,18	20,4	79,58
P06	56.12	20.4	76.52
P07	53.6	19.38	72.98
P08	54.88	20.4	74.88

Based on these results, the graph of the loading of the stations is made, related to the required cycle time of 98 Cmin - figure 7.

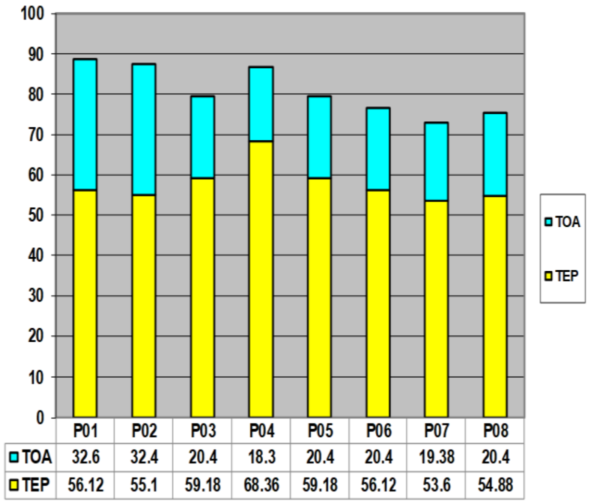

Figure 7. Post loading, relative to the required cycle time

5 CONCLUSIONS AND PERSPECTIVES

In order to be able to adapt the production to the increased demand on the market, the final dates for achieving an improved efficiency for the 8 jobs will be the following:

- the objective to be achieved at company level will be to obtain a number of 1325 finished products / day, compared to the initial value which was 1200;
- the cadence of the assembly line will have to be changed from 45 finished products / hour - as it is at the moment, it will increase to the value of 50 finished products / hour, respectively from the value of 98 Cmin / finished product, it must be reduced to the value of 91 Cmin / finished product.

From the analysis of the results obtained regarding the loading of the posts, related to the necessary cycle time, it is found that a reorganization of the posts is necessary, by redistributing the operations, so that the new objective necessary to be achieved can be achieved at company level [8], [9].

Consequently, from the moment of information on the intention to increase the production until the implantation of the program for the realization of the new production, a significant period of preparation is necessary.

In this regard, the Board of Directors of the Company organizes meetings to inform all those involved, respectively:

- suppliers,
- Heads of the Methods Department,
- Heads of Maintenance,
- Manufacturing heads.

A first action will consist in choosing capable employees and specialists, who will be involved in the construction of an action plan, regarding the change of cadence, necessary to reach the new production objective of the company.

The process of involving the specialized personnel in the realization of the new action plan - figure 8 - includes:

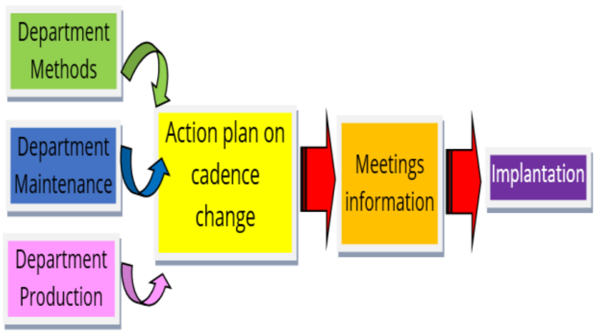

Figure 8. The process of realization and implementation of the new action plan

In the future, in order to be able to continue the study initiated - regarding the adaptation of the production capacity of a company producing finished goods, to the increase registered by the market demand of the consumers, compared to the company's products - it is estimated that the second stage of the study will start [5], [6].

This second stage will start from the results obtained by the initial analysis of the efficiency in the workstations, in the current production conditions, and later will identify and develop the necessary solutions to adapt the production flow to the new market demand.

Another perspective is represented by the third stage of the study, which will propose ways to implement the solutions found and at the same time, will analyze the final results obtained from these changes.

Of course, all the changes will have to allow the production to change, in the sense of increasing it, to the established value, namely 1325 finished products / day, and at the same time, to allow the adaptation of the production parameters to the new assembly line chain to 50 finished products / hour.

BIBLIOGRAPHY

Birgin, E. G., Ferreira, J. E., Ronconi, D. P. (2015). List scheduling and beam search methods for the flexible job shop scheduling problem with sequencing flexibility. *European Journal of Operational Research*, *247*(2), 421-440. [1]

Durana, C., Cetindereb, A., Aksuc. Y. E. (2015). Productivity improvement by work and time study technique for earth energy-glass manufacturing company. *4th World Conference on Business, Economics and Management, WCBEM.* Procedia Economics and Finance 26 (2015) 109 – 113. [2]

Kulkarni, P. P., Kshire, S.S., Chandratre, K.V. (2014). Productivity Improvement through Lean Deployment & Work Study Methods. *International Journal of Research in Engineering and Technology*, 3(2), 429-434. [3]

Kumar, A., Bansal, S. (2020). Creating employment in some indian industries by reducing the working shift timing. *International Conference on Mechanical and Energy Technologies (ICMET 2019). IOP Conf. Series: Materials Science and Engineering 748 (2020) 012005*. https://doi:10.1088/1757-899X/748/1/012005 . [4]

Kumar, N., Mahto, D. (2013). Assembly Line Balancing: A Review of Developments and Trends in Approach to Industrial Application. *Glob. J. Res. Eng. Ind. Eng.* 13, 29–50. [5]

Nourmohammadi, A., Masood, F., Amos, H.C. Ng. (2022). Balancing and scheduling assembly lines with human-robot. *Computers and Operations Research*, 140 (2022) 105674. https://doi:10.1016/j. cor.2021.105674 . [6]

Pisuchpen, R., Chansangar, W. (2014). Modifying Production Line for Productivity Improvement: A Case Study of Vision Lens Factory. *Songklanakarin Journal of Science and Technology*, 36(3), 345-357. [7]

Rianpradub, S., Jantiava, P. (2016). The automobile assembly productivity enhancement by job tasks and sequencing. *Full Paper Proceeding BESSH-2016, Vol. 76- Issue.3, 10-14*. ISBN 978-969-670-180-4. [8]

Tortorelli, A., Imran, M., Delli Priscoli, F., Liberati, F. (2022). A Parallel Deep Reinforcement Learning Framework for Controlling Industrial Assembly Lines. *Electronics 2022, 11, 539*. https://doi.org/10.3390/electronics11040539. [9]