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METHODOLOGY OF RAPID VERIFICATION OF WORK STANDARDS

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Abstract: The paper presents the use of properly selected research methods allowing for quick verification of the operator's labour standards for workstations. It concerns the evaluation and improvement of work method on the examined assembly station. The method used the principles of TQM, Lean Thinking, TOC, Kaizen, standardisation of time and ergonomics. The result of this approach was the rapid evaluation of the operator's labour standards and identification of the personalised standard that allows to work specific operators within acceptable deviations from the assumed normative.
Keywords: efficiency, lean, standardization of work, rapid evaluation, statistical tests

INTRODUCTION

Any company, both manufacturing type and service type, want to improve their processes. They always reach for the work optimization tools. But before the company will develop practical solutions it has to often go through the tedious process of collecting and processing data. Therefore, it becomes essential to reduce test time and data analysing time. Hence important is the adoption of appropriate research methods for a rapid, but simultaneously complex operation.

In this study, the authors tried to show how to deal with the problem in the standardization of working time in the development of labour standards in the assembly station with a high degree of employee fluctuation, where the collection of multiple measures is often very limited due to the limited time that can be allocated for the measurement process. Attention was also drawn to the tools of statistical inference, so that the analysis of these data is appropriate and allows for the proper conduct of inference.

PREMISES OF LITERATURE

Looking through the eye of the management concept and the production control concepts [12; 14-20; 23; 25-29] it should be noted that each of them points to the need for optimal process management. Each of the concepts indicates the direction of the appropriate action, as many authors write [12; 14-20; 23; 25-29], the managers may freely choose the appropriate set of tools to evaluate appearing enterprise specific problems. There are a number of different publications, in which there are shown different methodologies used in processes [1-3;5-11;13;15-17;19-21;23-29] and application in case studies [2; 7; 9-10; 13; 19; 22; 27; 29], on the basis of which the persons managing and improving the different processes can freely implement various methods in their processes on the basis of benchmarking.

Considering the number of different approaches to process improvement [12; 14-20; 23; 25-29] and a variety of case studies [1-3;5-21; 23-29], it should be noted that each of the organizations using known management principles must develop its own model of process improvement. This applies both to process management and organization of work stations [12; 14-20; 23; 25-29]. Selection of the appropriate methodology for the procedure is closely connected with the knowledge of managers and their knowledge of the methods, and management techniques.

Following the literature [1-29], one can assume that there is no universal solution for any given problem, therefore, in this paper, based on the presented references a new approach to the problem is presented, taking into account the needs of the enterprise concerned.

RESEARCH METHODOLOGY

For the investigation, the authors adopted the appropriate research methodology, which uses the principles of production management concept, as the philosophy of TQM, Lean Thinking, TOC and Kaizen [1-29].

The main objective of the study was to optimize of the work on the assembly station of the examined production process. In connection with the adoption of this objective thought was given to the two key problems.

1. How can you quickly evaluate initial research sample for the possibility of limiting the number of future measurements?
2. What factors influence the standards of work performed on the surveyed assembly station?

In accordance with a first research question, the following hypotheses were developed:

H_0: it is possible to quickly verify of the existing standards on the tested production line based on a small number of measurements;

H_1: lack of the quick verification of the existing standards on the tested production line based on the small number of measurements.

Accordingly, for the designated assembly station the test methodology consist of 7 stages:

1. observation of the operators using tools of time standardization and statistical data verification,
2. study the movements of hands on assembly station based on the techniques of Work Measurement to assess the standards of the operators,
3. identification of the losses the operators work,

4. assessment of takt time,
5. quick assessment of the accuracy of current standard of work on the assembly station,
6. brainstorming in order to identify the most important changes,
7. develop a new standard.

Because of the complexity of the methodology assumed in this study it will be short presentation of all the points from the above list and the following chapter tries to answer the first research question.

EVALUATION OF OPERATORS WORK USING TOOLS OF TIME STANDARDIZATION AND STATISTICAL DATA VERIFICATION

— Characteristics of the research sample

Due to the lack of permission of the Management Board of the company to disclose its name, in this study it will be determined by description "manufacturing company with foreign capital." Examined company is a Polish subsidiary of German company which employs nearly 39,000 workers in 43 factories around the world, including Belgium, China, the United States, Canada, Turkey, Holland, Italy, Portugal, Germany, Poland, Russia, Slovakia or France. The company is the largest manufacturer in Europe in its sector and one of the leaders in the sector. The company sells its products under many brand names, fifty-four brand-names in total.

The company started its activity in 1993 in the central part of the Poland, in city of Lodz in 1999. They created a modern production plant, which now has two factories, due to the fact that six years later they expanded as the investment in the Lodz Special Economic Zone. Currently both plants are producing more than 3 million units per year.

Divisions of company in central Poland are certified according to ISO 9001, ISO 14001, OHSAS 18001. The company works mainly with local suppliers of raw materials and semi-finished products, putting the supply within the Just-in-Time system. Among the suppliers there are also the company divisions from three other counties. Analysed company is also a supplier within the Group. The Customers of products manufactured by the company are primarily large retail chains, as well as individual consumers, both in Poland and around the world. Analysed company also runs a number of investments at national and global levels.

— The analysed process of working on workstations

In the analysed company the production staff work three shifts. In addition, every two hours, every shift is obligatory rotation of employees at workplaces.

The analysis covers the work of assembly station fitting engines in final products. The engines are subjected to a process of sub-assembly in the area of picking. The employee has the task of completion of the transportation carriage consisting of 30 pieces sub assembled equipment and 30 pieces of pulleys and in addition a proper quantity of seals. Preparation of carriages is driven by a sequential plan delivered from the production area by e-mail.

After preparing a set of two carriages the "milkrun" driver moves them to the appropriate assembly line every 30 minutes. On the production floor take place the actual process of engine assembly and fitting pulley to the manufactured product. The employee gets from the carriage a pulley and mount it on the spindle, fitting tanks and engine. During installation, the employee performs the control of a serial number of the engine.

In the assembly station the flow of the engine ends as a single component. In further processes, it is present as a subcomponent of another level in Bill of Material.

— Observation of operator using tools of time standardization and statistical data verification

Due to the fact that it was found that one of the main problems in the process is the lack of standardized work in the assembly of the engine, researches carried out their own observation on this position using the method of timing. As is known the success of this method depends on the right amount of data, the collection of which often have time limits, and from the other hand operators are reluctant to agree to the filming and often one should perform this type of observation from the hide. In the analysed company is a serious aspect of the high rotation of employees in positions, which further is reflected in the difficulty in collecting a large number of measurements.

Table 1 – Timing the assembly operations

Operations	Results						
	1	2	3	4	5	6	7
Pick screw	1	1,4	1	1,3	1,4	2	1,1
Pick and fitting pulleys	2	2	2,8	2,5	2,6	2,5	2
Placing screw	1,5	1,2	1,8	1,3	1,2	1,8	1,3
Pick screw gun and transfer to right hand	1,5	1,5	1,3	1,3	1,1	1,5	1,3
Screwing the first screw	2	1,4	1,7	2	1,7	2	1,6
Screwing the second screw	2	1,9	1,3	1,7	1,8	2	1,8
Screwing the third screw	2	1,6	2	1,9	1,8	2	1,8
Screwing the fourth screw	2	1,4	2	1,6	2	1,8	2
Pick foil and fit on engine	3,5	2,7	4	3,5	3,5	3,3	4
Engine assembly	3,5	3,9	3	3,2	3	3	3
Picking two screws and assembly	2	2,5	2,3	2	2,3	2,3	2
Total	23	21,5	23,2	22,3	22,4	23,9	21,8

Accordingly, statistical tools were used with the highlight on statistical Ryan-Joiner test appropriate for the small samples [4] test that helps determine the sample size for a reliable analysis of the time distribution operations. This test involves checking the strength of the correlation between the data from the sample and the normal distribution for the data. If the correlation coefficient (1) is close to 1, it is presumed that the data are normally distributed. However, if the ratio is below the critical level, then one must reject the null hypothesis H_0. Determination of distribution of test data is necessary for the selection of appropriate statistical methods in further stages of research.

$$R = \frac{\sum_{i=1}^{n} b_i y_i}{\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2 \cdot \sum_{i=1}^{n} {b_i}^2}} \quad (1)$$

where: y_i - sample data, b_i - percentage point from the normal distribution

Therefore, for the investigated process, researchers initiated two hypotheses: the null and alternative which reads as follows:

H_0: Time distribution of operation is a normal distribution

H_1: Time distribution of operation is not a normal distribution

In order to verify the hypotheses were made observation of the variation of the operation for the worker and the results are shown in Table 1. On the basis of the data contained in it started to test for normality Ryan-Joiner time distribution operations. The results obtained are shown in Figure 1.

» Interpretation of results:

The analysis of the parameters shown in Figure 1 shows that if the critical level P. Value is greater than 0.1 then there is no reason to reject the null hypothesis. Therefore, it is assumed that the distribution operation time in the assembly of the engine is normally distributed.

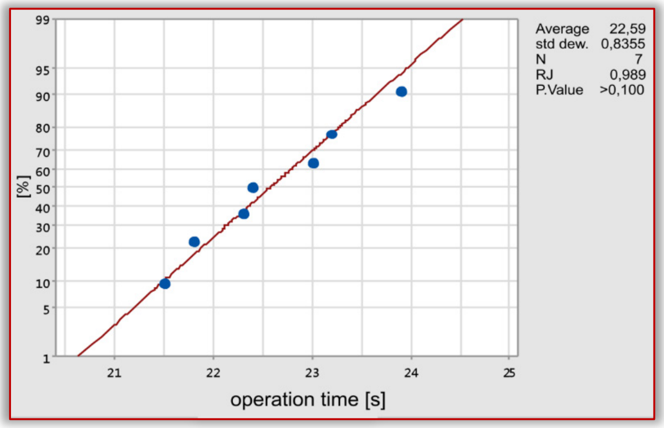

Figure 1 – Test Ryan-Joiner to prove normal distribution of operation time in the assembly line (*Source:* own study based on calculations in Minitab)

Referring to the result obtained in the test Ryan-Joiner, assuming that the operation time in the assembly the engine has a normal distribution, Minitab software application determined the required minimum number of measurements.

If the population has a normal distribution N(μ,σ), where σ2 is unknown, and value $\hat{s}^2$ obtained from initial small trials with a number of n0 elements, the necessary population size was determined in the Formula 2 [4]:

$$n = \frac{t_{\alpha}^2 \cdot \hat{s}^2}{d^2} \quad (2)$$

where: t_{α} - the value of the variable t-Student read from the statistical tables for n-1 degrees of freedom and 1-α (t_{α}= 2,4469); is to P{-t_{α}< t < t_{α}} = 1 – α, $\hat{s}$ - the standard deviation of the initial sample; d – margin of error (0,5*s*).

As a result of the program analysis it was obtained that at the 95% confidence level it is necessary to perform fourteen motion measurements of engine assembly for one workers according to individual movement patterns Figure 2.

Table 2 summarizes the average results and deviations of the cycle time of observed 5 employees. The analysis of the data shows that there is a difference in the meantime operations by employees, as well as their volatility. The histogram of processing time – Figure 3 it can be seen that the operators the third and fifth workers have the shortest average assembly times, and the first worker have the highest average installation time.

Sample Size for Estimation	
Data	
Parameter	Mean
Distribution	Normal
Standard deviation	0.84
Confidence level	95%
Confidence interval	Two- sided
Results	
Margin of Error	0.5 s
Sample Size	14
Summary Report for Operation Time	

Figure 2 – Determination of sample size (*Source:* own calculations in Minitab)

Table 2 – Summary installation times for different labour standards

Indicator	Cycle times in the assembly of the engine [s]					
	Small sample	1st person	2nd person	3rd person	4th person	5th person
$\bar{x}$	22,59	22,51	21,04	19,51	20,85	19,72
S (x)	0,84	0,66	0,71	0,63	0,73	0,79

In order to choose the best variant of work appropriate statistical tests were performed to determine whether the differences in times are random or are statistically significant and are based on different standards of work. It was assumed that all tests will be performed at the level of significance α= 0,05.

It was assumed that the assembly times for individual operators are adequate to the pre-test, are normally distributed, therefore, to verify the equality of variances in the population has benefited from the Bartlett test. To perform the test was the following hypotheses:

- H_0: Variances of operation time are the same for each individuals
- H_1: Variances of operation time are the different for each individuals

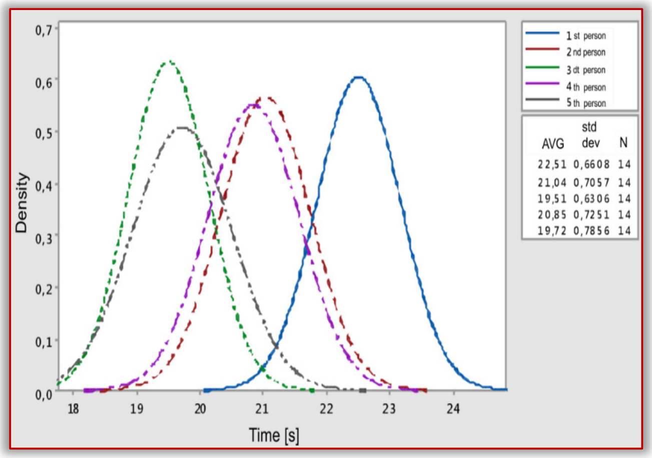

Figure 3 – Histogram of engine assembly time depending on the operator (*Source:* own calculations in Minitab)

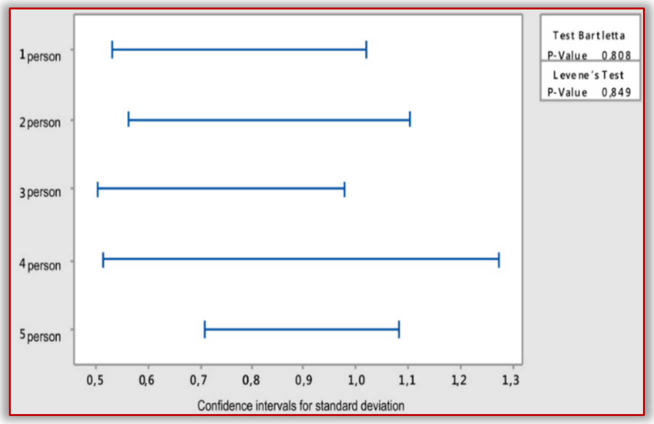

Figure 4 – Bartlett's test for equality of variances for the time of operation the successive operators (*Source:* own calculations in Minitab)

» Interpretation of the result:

Due to the fact that the critical level is 0.808 and is higher than the target level of confidence ($0{,}05 \leq p \leq 0{,}808$) there is no reason to reject the null hypothesis, and therefore it is assumed that the variances of operation time for individuals are the same.

Due to the fact, that it was assumed that the analysed times are normally distributed and have the same variance it is possible to perform the test ANOVA. This test allows to indicate one of the surveyed methods that holds the best average results.

The test ANOVA undertakes two hypotheses regarding the equality of average time of operations for individual employees:

— H_0: All average times of operations for individuals are the same
— H_1: All average times of operations for individuals are not the same

» Interpretation of the result:

Due to the fact that the value of the critical level is lower than the target level of confidence ($p \leq 0{,}05$) the null hypothesis must be rejected. The null hypothesis assumes that the average times of operation are the same.

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Session
Verification of the hipothesis of equality of the many averages of the population - test snalysis of variance (a single classification)

Null hipothesis          All the average of times are equal
Alternative hipothesis   At last one of the average of time is different
Significance level       α=0,05

It was assumed that all variances are equal, according to the Bartlett's test

Analysis of Variance
Source      Degree           SS      MS      F-Value  P-Value
            of freedom
Person         4           81,32   20,3298   41,06    0,000
Error         65           32,18    0,4951
Total         69          113,50

Person    N  Average   std. dev.  95% confidence interval
1 person  14  22,514    0,661       (22,139; 22,890)
2 person  14  21,043    0,706       (20,667; 21,418)
3 person  14  19,507    0,631       (19,132; 19,883)
4 person  14  20,850    0,725       (20,474; 21,226)
5 person  14  19,721    0,786       (19,346; 20,097)
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Figure 5 – The ANOVA test for equality of averages in the population (*Source*: own calculations in Minitab)

Consequently with the obtained result of the ANOVA Figure 5 it is necessary to analyse the confidence interval for average assembly times for operators. Based on Figure 6 it concluded that the best methods are applied by operator 3 and operator 5 because of the shortest duration.

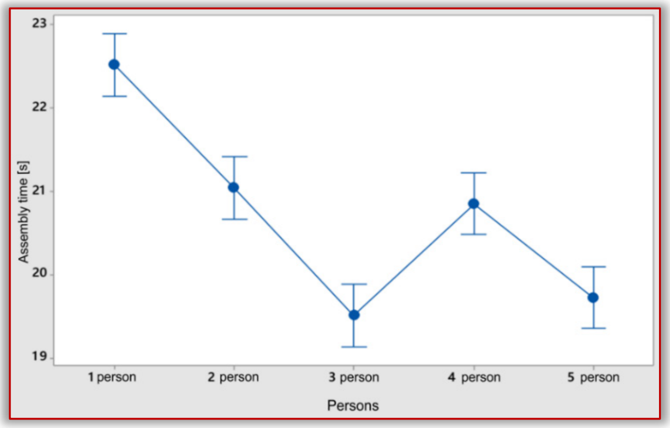

Figure 6 – 95% confidence intervals for the average assembly times

The next step of choosing the best variant from among the designated two is to perform the Student test (3). This test checks whether the average assembly times for these operators are the same or different.

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{n_1 \cdot s_1^2 + n_2 \cdot s_2^2}{n_1 + n_2 - 2} \cdot \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \quad (3)$$

Following hypotheses were posed:

— H_0: Both average times of operations for individuals 3, 5 could be treated as identical
— H_1: the two average times of operations for individuals 3, 5 could not be treated as identical

Result of simulation performed in Minitab software are shown on Figure 7.

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Session
Student t-test for 3rd and 5th person

           N   Average   std. dew.      Standard error
3 Person  14   19,507     0,631            0,17
5 Person  14   19,721     0,786            0,21

Student t-test = 0 (vs ≠): T -Value = -0,80  P -Value = 0,433  DF = 26
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Figure 7 – Student's test for equality of two means in the population (Source: own calculations in Minitab)

» Interpretation of the result:

Due to the fact that the value of the critical level is above a predetermined level of confidence ($0,05 \leq p \leq 0,433$) there are no grounds to reject the null hypothesis.

As a result of conducted statistical tests, it was found that among work standards carried out by operators of engine assembly line two out of five operators deserve attention, because they do not have significant differences in the speed of operations performed, but only in the way they perform. Therefore, it was assumed that the standards of the third operator, and a fifth became the basis for the development of the applicable work standard.

CONCLUSIONS

The adopted research methodology allowed for the rapid assessment of collected data based on a small number of measurements, which allowed to carry out the speedy verification of existing labour standards in workplaces on the assembly line. At the same time research confirmed the validity of tested research hypothesis about the possibility of a rapid verification of the work standards on the designated production line based on a small number of measurements.

Note

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