RECENT J. (2023), 71:228-233
https://doi.org/10.31926/RECENT.2023.71.228

The Performance of Production Systems: Indicators, Influencing Factors, Improvement Solutions

Ileana Georgiana LIMBĂȘAN
Transilvania University Brașov, Romania, limbasan.g@unitbv.ro

Abstract
Nowadays, the demanding requirements of the market and the accelerated pace of change are the main threats to the production systems. The survival and success of a production system depends on its ability to produce goods adapted to the requirements, the speed with which it responds to requests, the prices of products, etc. These requirements must be considered permanently, throughout the life of the productive system, materializing in specific performance indicators. Performance indicators are defined for all relevant departments and functions of the company, starting from its strategic objectives. The Key Performance Indicators are the relevant indicators regarding the performance of the system to which they refer. The purpose of this article is to evaluate the efficiency of the use of human resources and equipment for a component assembly line in the automotive industry. The considered performance indicators were labour productivity and OEE. In the presented case study, it was shown how and to what extent the adopted work method and work organization influence the considered KPIs values. Also, the causes of deviations from the planned levels and possible solutions for improvement were highlighted.

Keywords
performance management, productivity, OEE, RULA analysis

1. Introduction

We live in a world concerned with performance, so in all areas of social and economic life this concept is used. Currently, in production systems, achieving a planned level of performance has become a sine qua non condition for survival and organizational success.

According to DEX online [8], performance means a special achievement in a field, the best result obtained by a technical system, a machine, etc. For economic organizations, performance means the yield/results of the activities carried out in relation to the goals pursued [1]. Performance evaluation has an important place in organization management. Performance assessment is usually done by reference to a reference system, either in relation to clearly defined objectives, or by comparison with the achievements of others.

Nowadays, performance evaluation in economic organizations is done in an integrated approach that includes models, techniques, measurement methods, specialized software, subsumed under the name of performance management. [1, 5]. The purpose of performance management is to ensure long-term success by improving the performance of the organization, teams and employee. This objective is achieved through planning, control and continuous improvement of performance.

Performance planning (Plan) refers to setting goals and the level of indicators for the organization as a whole, at the level of operational and functional compartments, but also at the level of processes and workplaces.

Achievement of performance (DO) implies the operationalization of work tasks in correlation with the established objectives.

Performance control (Check) refers to performance measurement and evaluation. The control is carried out continuously, both during the work processes, but also at their end. The achieved levels of the performance indicators are compared with the planned levels. If deviations are occurred (from objectives, norms, standards, etc.) from the planned level, the causes of these deviations are sought and analyzed in order to establish remedial measures and/or improve the values obtained.

Performance improvement (ACT) refers to actions to solve the problems and deep changes to enable the transition to higher performance levels.

Performance management is a continuous process through which the organization systematically realizes the cycle PDCA. In this context, appropriate tools are developed to allow planning, control and continuous improvement of performance.

In this general context, the purpose of this article is to evaluate the efficiency of the use of human resources and equipment for a component assembly line in the automotive industry, unsatisfactory results and possible solutions for improvement.

2. Case Study on the Efficiency of the Use of Human Resources and Equipment in the Assembly Process of Components in the Automotive Industry

2.1. Methods and tools for performance evaluation and improvement

Key performance indicators are measurable quantities established prior to the performance of the evaluated activity. The establishment of these indicators (KPYs) is done in correlation with the specifics of the organization/ system/ process/ workplace and the adopted strategy [1, 2, 6].

Given that KPYs belong to several categories [1] and taking into account the peculiarities of the work system considered, the main activity characterization indicators at the level of the studied assembly process are presented in Table 1.

Table 1. KPYs considered for the assembly process

Elements of differentiation		Indicators
Human resource	Efficiency	Work productivity Workplace risk
Equipment/workstations	The available time	Overall Equipment Effectiveness
	Manufacturing cycle (length of time)	
	Non-technological interruptions (length of time)	

The operation and performance of the organization is undoubtedly related to the way its employees work. At the level of the organization, the use of human resources can be expressed extensively and intensively [2]. The main extensive synthetic evaluation indicator is labor productivity – the efficiency with which labor is used.

Usually, labor productivity is calculated as the ratio between output, Q (pieces) and the amount of labor used to obtain that output, L (number of operators, man-hours, man-days worked):

$$W = \frac{Q}{L} \tag{1}$$

Within the manufacturing processes, labor productivity is influenced by technical, organizational and social factors: work method, type of work (manual, mechanized, semi-automated, or automated), work content, operator's work posture, microclimate conditions, organization and servicing of the workplace, etc. [3]. Some of them, for a certain particular situation, can become risk factors.

For the analyzed situation, specific risk factors for the human operator and the means of production (component assembly stations) were highlighted.

To evaluate these risk factors, the RULA analysis (Rapid Upper Limb Assessment) was used in the article. This is one of the methods of analyzing and evaluating human activities from an ergonomic point of view [4]. The method is part of the specialized Ergonomics Design and Analysis module of the CATIA software intended for computer-aided ergonomic design of products and manufacturing processes. The method allows the evaluation of the occupational risk that can occur in the case of manual or automated work operations carried out under determined organizational conditions.

To evaluate the efficiency of the use of equipment - assembly stations - the OEE - Overall Equipment Effectiveness indicator, relations (2) and (3) is used for this purpose since the 1990s, as an evaluation tool [6, 7].

$$OEE = disponibility * performance * quality \tag{2}$$

$$OEE = K_d * K_t * K_q \quad (3)$$

Equipment availability takes into account the loss of time caused by unplanned breakdowns. The causes of these interruptions can be: lack of raw materials, operators, breakdown of machines, equipment, etc. Availability is measured by the availability coefficient, K_d

The productivity (performance) of the equipment takes into account the reduction of their yield, due to various causes: operator mistakes, blockages, inadequate technological regime, etc. It is measured by the coefficient of performance, K_t.

Quality takes into account quality losses caused by operator mistakes, inappropriate materials, working regime, etc. It is measured by the quality coefficient, K_q.

2.2. Basic information for the case study

The objective of the case study is to demonstrate how and to what extent the adopted work method and work organization on the assembly line of some components in the automotive industry influence the values of the KPYs: labor productivity and OEE.

The studied work area consists of: six assembly stations, verification station, rotary table, local buffer of finished parts (figure 1).

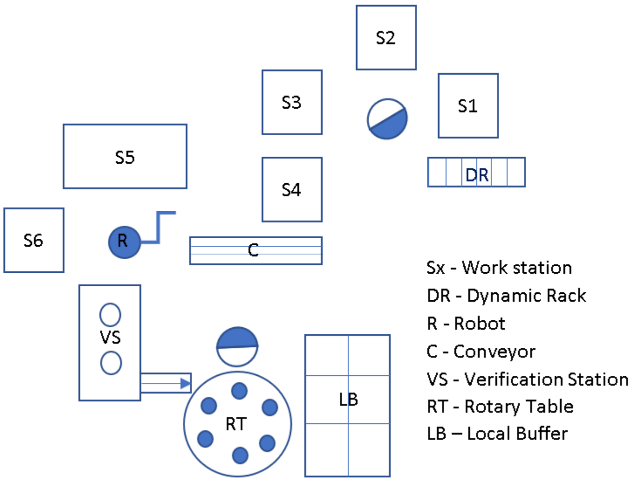

Fig. 1. Components assembly line

The supply of stations S1 – S4 with components (assembly components) is done with the help of a dynamic rack (DR). The previously obtained subassemblies are taken from the dynamic conveyor (C) by the robot (R) and transferred to stations S5 and S6. After the operation at S6, the subassemblies are picked up by the robotic arm (R) and transferred to the verification station (VS). The transfer of the parts to the rotary table (RT) is done by the human operator who takes them from the discharge device of the VS station. The operator packs the finished parts in boxes and stores them in the local buffer (LB).

The location of the workstations is U-shaped - a specific way of placing the machines for series production. The line is partially automated (conveyor, robotic arm, rotary table), the work activities are carried out by the operator at S1 – S4 being handling - positioning of the components in the assembly devices related to the stations.

In order to fulfill the objectives of the study, it was considered appropriate to study the work processes carried out at stations S1 – S4, because they are the ones that set the work rhythm (tact) of the other stations as well.

From the point of view of work organization, poly-service is practiced in the flexible manufacturing cell: one operator serves stations S1 – S4 and another operator serves the VS - RT - LB area. The working time of the operator serving S1 – S4 is 30 min., after which he exchanges with the operator at the final station (RT), the cycle repeating itself during the work shift.

The manipulated components have a weight between 0.5 kg/unassembled component at S1 and 0.7 kg/subassembly at S4.

3. The Obtained Results

From the point of view of the content of the work, it is observed that in the case of the operations performed by the operator at S1 – S4, the work is repetitive, poor in content and tiring.

To assess the risk of the workplace, expressed by the level of fatigue of the human operator at the level of the upper limbs, the RULA analysis was used. The input data refers to the operator's specific way of working:

- manipulation of components, weighing 0.5 kg - 0.7 kg, with both hands, repeated movements with a frequency greater than 4 times/minute;
- the method of grasping the manipulated object: grasping on a closed contour;
- the arms perform work movements in the frontal - sagittal plane and at the middle plane;
- the work is repetitive, monotonous, with physical effort on the upper limbs, forced working position.

The results of the RULA analysis are shown in Figure 2.

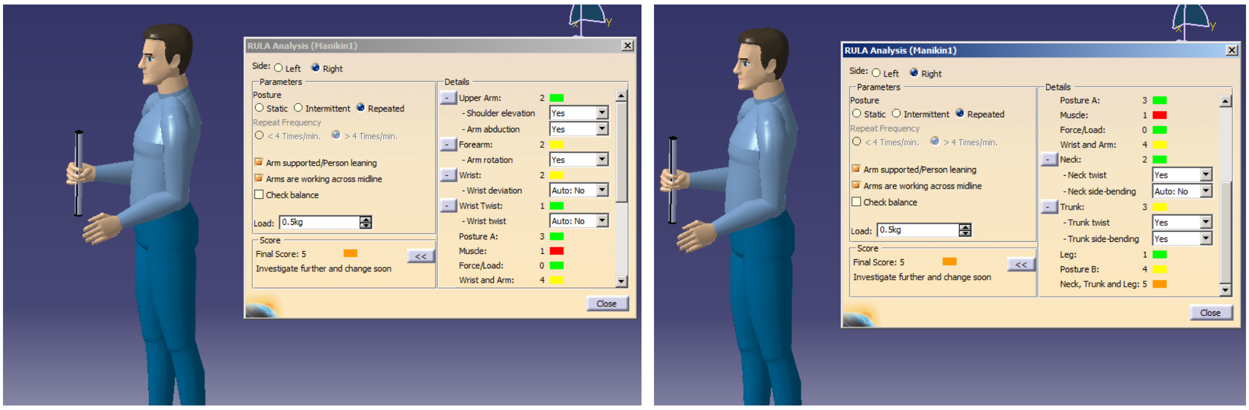

Fig. 2. The results of the RULA analysis

As a result of the combination and examination of the input data (considered risk factors), a final score is generated that varies between 1 and 7. If the score is low (1 - 4), no changes are recommended regarding the work posture. A score with values between 5 - 7 reveals the fact that the working posture is tiring and changes are required, especially if it is maintained in the long term (repeated movements during the work shift) - as in the case of the concrete situation presented.

It was found that the operator from stations S1 – S4 cannot respect the principles of economy of movement due to: the working method and the type and number of movements he performs to carry out the assembly operations. This situation leads to the psychophysiological overload of the human operator and has the effect of physical fatigue that is felt at the level of the muscular system. On the secondary level, due to the repeatability of the work movements, the phenomenon of decreased attention (psychic understrain) appears - specific to automated or semi-automated work systems.

The installation of neuropsychic fatigue determines disinterest and lack of attention to the operations performed, with the effect of decreasing work speed, implicitly in work productivity.

For the determination of OEE and labor productivity, the calculation data presented in Table 2 were considered. These data took into account the planned cycle time of the assembly for each reference number.

Table 2. Calculation data for the planned situation

Calculation data	Values
Work time	480 min (8 hours)
Break time	30 min
Planned time loss	10 min – the start of the work shift 10 min – the end of the work shift
Unplanned breakdowns	30 min
Planned cycle time of work/part	0.33 min/part
Total parts planned/ 8 hours	1350 pcs.
Parts with non-conformities	4 pcs.

Based on the data in Table 2, the coefficients related to the factors of the OEE_p indicator, relations (4)-(7), and labor productivity – W_p, relation (8), were calculated. These values constitute the planned levels of the considered KPYs.

$$K_{dp} = \frac{T_l}{T_d} = \frac{450 - 30}{450} = 0.933 \tag{4}$$

$$K_{tp} = \frac{t_p}{t_{realiz}} = \frac{0.33}{0.36} = 0.91 \tag{5}$$

$$K_{qp} = \frac{good\ parts}{total\ parts} = \frac{1346}{1350} = 0.997 \tag{6}$$

$$OEE_p = K_{dp} * K_{tp} * K_{qp} = 0.8465 \tag{7}$$

$$W_p = \frac{Q}{L} = \frac{1350}{480} = 2.81\ pcs/min \tag{8}$$

According to the classification of production systems according to the OEE score [6] the value obtained (OEE = 84.65%) could be considered a very good score, which demonstrates a good performance of the workstations and a high work productivity.

In reality, however, due to the current way of organizing work, which leads to the premature installation of operator fatigue, a smaller number of pieces are made in the same time interval. The calculation data is presented in Table 3.

Table 3. The calculation data for the real situation

The calculation data	Values
Real cycle time of work/part	0.436 min/part
Total parts planned/ 8 hours	1100 pcs.
Parts with non-conformities	4 pcs.

Based on the data in Table 3, the coefficients related to the factors of the OEE_r indicator, relations (9), (10), (11), and W_r, relation (12), were determined for the real situation. The value of the station availability coefficient remains unchanged - K_{dr} = 0.933.

$$K_{tr} = \frac{t_p}{t_{realiz}} = \frac{0.33}{0.436} = 0.756 \tag{9}$$

$$K_{qr} = \frac{good\ parts}{total\ parts} = \frac{1096}{1100} = 0.996 \tag{10}$$

$$OEE_r = K_{dp} * K_{tp} * K_{qp} = 0.702 \tag{11}$$

$$W_p = \frac{Q}{L} = \frac{1100}{480} = 2.28\ pcs/min \tag{12}$$

4. Conclusions

Following the results obtained, we conclude that in the case of the current way of organizing the assembly line, the level of the monitored key performance indicators, labor productivity and OEE is lower than the planned levels (W_p = 1350/480 = 2.81 pcs/min and OEE_p = 84.65 % compared to W_{mr} = 1100/480 = 2.29 pcs/min and OEE_r = 70.2%).

Following the analysis of the work situation, it appears that the main factor that negatively influences the values of the two performance indicators is the physical and mental fatigue of the human operators who serve stations S1 – S4 and the final station. They work at a normal rate (normal productivity) for the first 10-15 minutes of the 30-minute/man sequence, then the rate decreases.

Furthermore, the low working speed has negative influences on the assembly rate at stations S5, S6 and the rotary table. During most of the working time, these stations are waiting, leading to imbalances in terms of capacity and load.

To improve the values of the two key performance indicators, the following solutions are proposed:

- Increasing the number of operators to two for stations S1 – S4. In this way, poly-service is not abandoned, but productivity and, implicitly, the OEE value can be improved considerably;
- Automation of service operations of stations S1-S4. In this way the manufacturing cell will be served by only one operator, at the final station, with the role of controlling all the sequences of the assembly process.

The verification of the technical and economic viability of these solutions could be the subject of future research.

References

1. Popescu M., Limbășan G. (2013): *Sisteme de producție. Fabricația LEAN* (*Production systems. LEAN manufacturing*). Editura Universității Transilvania din Brașov, ISBN 978-606-19-0262-0, pp. 40-46 (in Romanian)
2. März L. (2012): *Key performance indicators for the evaluation of balanced lines.* Proceedings of the 2012 Winter Simulation Conference (WSC), Berlin, Germany, pp. 1-10, doi: 10.1109/WSC.2012.6464993
3. Drăghici A. (2006): *Abordarea ergonomică a sistemului om – mașină* (*The ergonomic approach to the man-machine system*). În: *Ergonomie. Noi abordări teoretice și aplicative* (*Ergonomics. New theoretical and applied approaches*). Vol. I., pp. 99-130, Editura Politehnica Timișoara, ISBN 973-625-168-3 (in Romanian)
4. Drăghici A. (2007): *Concepția ergonomică asistată de calculator. Metodologie și aplicații* (*Computer-aided ergonomic design. Methodology and applications*). In: Drăghici A. (Ed.) *Ergonomie. Aspecte novatoare ale cercetării ergonomice* (*Ergonomics. Innovative aspects of ergonomic research*). Vol. 2, pp. 13-43, Editura Politehnica Timișoara, ISBN 978-973-625-349-2 (in Romanian)
5. Jayanthi M., Majini Jes Bella K. (2020): *Performance management system in private sector*. International Journal of Psychosocial Rehabilitation, ISSN 1475-7192, Vol. 24, is. 06, pp. 8971-8979, https://www.researchgate.net/publication/375325460_performance_management_system_in_private_sector
6. Stefana E., Cocca P., Fantori F., Marciano F., Marini A. (2022): *Resource Overall Equipment Cost Loss indicator to assess equipment performance and product cost.* International Journal of Productivity and Performance Management, eISSN 1741-0401, https://doi.org/10.1108/IJPPM-10-2021-0615
7. Abd W., El Din A., Fathy H., Darwish H.S., Morsy E.M. (2023): *Productivity Improvement Based on Measuring the Overall Equipment Effectiveness in Metal Formation Production Stages.* 2023 InternationalTelecommunications Conference (ITC- Egypt), Alexandria, Egypt, doi: 10.1109/ITC-Egypt58155.2023.10206071
8. https://dexonline.ro/definitie/performanta (in Romanian)