The use KPI’s to determine the waste in production process

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Abstract. In theory and practice of management is well-known Lean approach about forms of waste from production processes (Muda) and the method VSM (Value Stream Map), one of the most effective methods for determining the activities generating value within industrial companies. It is also obvious concern of the specialists for performance measurement regardless of purview of the organizations. The literature review has shown that the link between performance indicators and the objectives of the companies is researched in detail. However, the correlation between indicators and the forms of waste that generate deviations from the setpoints is rather nature practical and it depends on the talent and managerial skills of those directing production processes. The paper presents the results of a applied study, performed by the authors, through which it was has sought to will create a system of performance indicators specific to manufacturing activity that to be a useful tool to quantify the losses and to determining ways to improve default losses.

1. Introduction
The current economic environment obliges the managers of the industrial company to seek permanent optimization of activity of the organizations that they lead.

In addition, an ever more difficult access to resources whether financial or material, requires special attention with regard to minimize wastage (in all its forms - as defined in the Lean philosophy).

The correlation between organizational performance and reducing waste is unequivocal and there are many books and papers by renowned theorists and practitioners of management, which support this claim [1, 2, 3].

Concepts such as Lean Manufacturing, Value Stream Map (VSM), Kaizen, well known by specialists, emerged in response to the issue of eliminating waste from production processes and became, in time, the essential management tools for obtaining performance by industrial companies and not only.

The industrial performance is another very important topic in production management. In this case, literature abounds with works on the subject of the performance of organizations and systems to measure them.

Some researchers have studied the link between performance management and performance measurement system (SMP), showing that SMP contribute to increasing managerial performance through relevant information that it gives managers in decision-making [4].

A standard SMP is represented by the system of performance indicators (Key Performance Indicators - KPIs). KPI provides information on what to do to increase performance substantially [5].
The researches made by the authors of this article have revealed that PMSs have only the role to highlight how the results meet initial expectations of the organization, yet without to determine the link between indicators and forms of waste.

Starting from these premises, we sought to develop a performance measurement system of the production process that highlights not only deviations of measured values of indicators from the permissible limits but also the amount of the main forms of waste that causes these deviations.

2. Theoretical considerations about wasting and performance in industrial processes

2.1. The waste in industrial processes

Wasting (loss) in industrial processes is represented by those activities that consume resources but do not add value to the final product [6, 7, 8]. In addition, the corrections, reprocessing pending are classified as forms of waste [8].

According to the Lean philosophy, within an enterprise are three types of activities [8]: activities that add value, activities that do not add value and can be eliminated and activities that add no value but are necessary.

The most non-value activities are the losses generators in one or more forms.

Lean defines seven forms of waste (Muda) [6, 7, 8, 9]: overproduction, waiting, movement, transport, reprocessing, areas, stocks.

To the seven forms can be added: personal inefficiency and overloading.

2.2. Performance processes within the enterprise

Performance is the main concern of managers being an element of enterprise competitiveness.

Peter Drucker [10] shows the connection between objectives and performance and states that the objectives of organizations should established in certain areas of performance such as productivity, profitability, innovation, attitude and work, performance, management performance, resources, market position.

Other researchers [4] states that characteristics such as the specific objectives, the difficulty, comprehensibility, tangibility affects the organizations performance.

Increase process performance and hence the company is the main task of managers. For this there is a whole panoply of tools and methods: Lean, Kaizen, TQM (Total Quality Management), Lean Six Sigma, etc. [11].

The performance measurement is essential in the management process. Numerous studies have shown that, to adopt the best decisions regarding development of the organization, managers must have accurate and actual data about the performance of processes taking place within the company. Thus, Rylková and Bernatik [12] shows that for maximum efficiency, performance measurement must made in five areas: finance, marketing, human resources, processes, standards for the future.

It is recognized that a production process not only aims to produce quantities of goods but also the production of these goods at a quality level as high as possible, with the least cost and in the shortest time (high productivity). In conclusion, we can say that the output performance is a multivariables function:

\[ Pp = f \{ N, Q, C, T \} \]  \hspace{1cm} (1)

Where:
- \( Pp \) – the performance of the process;
- \( N \) – The quality of the products;
- \( Q \) – Amount produced;
- \( C \) – Cost of production;
- \( T \) – Duration of production (productivity).

Performance measurement systems therefore must include tools and methods capable of assessing evolutionary trend at all four variables from the equation (1).
2.3. Performance indicators

A fundamental tool for measuring performance is the performance indicators system (KPIs) [13].

A classification of KPIs is presented by Fitzgerald et al. [14]. They classify the indicators in the result / driver indicators and lead / lag indicators. Parmenter [5] complements this classification by dividing indicators of lead / lag into three categories: indicators based on the past, present and future.

To be used effectively, performance indicators must submit three main features [5, 13, 15]: responsibility, to be easily assimilated, to be timely.

The required number of KPIs for a more precise measurements of the organization's performance is, according to experts comprised between 10 and 20 [5, 13, 16, 17]. In our opinion, the number of indicators should be determined according to the size of the organization, its peculiarity, the complexity of the processes taking place in the company and of course, depending on the number and characteristics of the goals to be achieved.

3. Use of performance indicators for determining the losses in production processes

Research by Kloviené and Speziale [18] concludes that, although the issue of performance measurement systems is analyzed in detail, performance measurement in companies (especially in SMEs) is not done in a systematic way.

Starting from this, we set the first objective for our research:

O1 - developing a system of performance indicators that reflect as closely developments of the four variables that define the performance of the production process and which to have an emphasized universality.

It is obvious that the existence of waste in production processes generate counter-performance.

The counter-performance is not directly measured by indicators, being considered as the difference between the expected and the realized outcome.

This has a major negative impact on the processes lead by managers with little experience.

To eliminate this drawback, it is necessary both to establish the causality between the measured indicators and forms of waste but also quantification of losses.

This goal is the second objective of the research:

O2 - establishing the correlations between performance indicators and forms of waste.

To achieve the objectives, we conducted a applied study about production process from two industrial companies.

Based on the observation, we creat a system of non-financial performance indicators, that to be able to reflect, as accurately as, the activity of the production's departments from the companies studied.

The study was conducted in several stages:

E1 Analysis of the existing PMS;
E2 Develop a system of indicators that meet the requirements of universality according with the first objective;
E3 Establishing the correlations between KPIs and existing forms of waste in the production process.

In the study, we used the symbols shown in table 1:

| Symbol | Signification | Symbol | Signification | Symbol | Signification |
|--------|---------------|--------|---------------|--------|---------------|
| $I_s$  | stocks index  | $N_{def}$ | Number of defects  | $Sp$  | Overproduction |
| $I_C$  | costs index   | $St$   | Stocks         | $I_T$ | Time utilization index |
| $I_{ls}$ | Overtime index | $R_{Pr}$ | Rework / reprocessing | $T_{oa}$ | Duration of the unplanned stops |
| $P_r$  | Production achieved | $M$ | Movement | $C_r$ | Unit cost achieved |
3.1. E1. Analysis of the existing PMS

The production processes and systems for measuring the performance of the two companies under study, are similar.

Performance indicators used in the production departments of the two companies were classified in terms of the four variables of the organizational performance and are presented in Table 2:

| Category | Symbol | Description | Target value (ideal) | Formula |
|----------|--------|-------------|----------------------|---------|
| N        | FTR    | First time right | 100% | $\frac{P_r - N_{def}}{P_r} \times 100$ |
| Q        | $Q_{nec}$ | Quantity to be produced (planned) | - | $Q_c - (S_e - S_s)$ |
|          | $P_r$  | Production achieved | - | $\frac{P_r}{Q_{nec}}$ |
|          | $G_{rp}$ | Production’s realizing rate | 100% | $\frac{P_r}{Q_{nec}}$ |
| T        | $T_{ef}$ | Time actually worked | 100% | $T_B - T_{oa}$ |
|          | $N_{mr}$ | Achieved work rate | - | $\frac{P_r}{T_{ef}}$ |
| C        | $C_{prr}$ | Manufacturing costs achieved | - | $\frac{C_{prr}}{P_r}$ |
|          | $C_r$  | Unit cost achieved | - | $\frac{C_{prr}}{P_r}$ |

The above indicators are additional to the indicators used at company level (that were not surveyed). Analyze of the PMS from Table 2, it is obviously that it does not provide information about the types of waste present in the production process.

This leads to difficulties in adopting optimization measures activity, because the production managers are forced to make decisions based solely on intuition and personal experience.

3.2. E2. Development a new system of indicators

Starting from equation (1) and based on direct observations, we have developed a system of indicators that can be used in any company regardless of activity area.

The indicators proposed by us are non-financial and are additional to the performance measuring system of the business.

KPI system developed by us is presented in table 3:
### Table 3. The system of performance indicators developed in the study

| Category | KPI | Formula | Target value (ideal) | The form of waste measured |
|----------|-----|---------|----------------------|---------------------------|
| $N$      | $r$ | $\frac{N_{def}}{P_r} \times 100$ | 0                    | $R_p = |1 - \varepsilon| \times 100$ |
|          | $\varepsilon$ | $\frac{1}{1 - r}$ | 1                    |                           |
| $Q$      | $I_s$ | $\frac{S_e}{S_e + Q_c}$ | 1                    | $S_t = |1 - I_s| \times 100$ |
|          | $Q_{nec}$ | $Q_c - (S_e - S_s)$ | -                    | $S_p = |1 - I_{pr}| \times 100$ |
|          | $P_r$ | $(S_s + Q_c) \times \varepsilon - S_e$ | -                    |                           |
|          | $I_{pr}$ | $\frac{P_r}{Q_{nec}} = \frac{\varepsilon - I_s}{1 - I_s}$ | 1                    |                           |
| $T$      | $T_{ef}$ | $T_D - T_{oa}$ | 1                    | $A = |1 - I_T| \times 100$ |
|          | $I_T$ | $\frac{T_{ef}}{T_D}$ | 1                    |                           |
|          | $N_{mr}$ | $\frac{P_r}{T_{ef}}$ | -                    | $M = |1 - I_{Nm}| \times 100$ |
|          | $I_{Nm}$ | $\frac{N_{mr}}{N_{mt}}$ | 1                    |                           |
| $T_{ot}$ | - | - | - | $T_r = \frac{T_{ot}}{T_D} \times 100$ |
| $I_{ls}$ | $\frac{T_{ls}}{T_D}$ | 0 | $O_v = |0 - I_{ls}| \times 100$ |
| $C$      | $I_C$ | $\frac{C_r}{C_t}$ | 1                    | $Sp + R_{pr} + T_r + M + St + T_r = |1 - I_C| \times 100$ |

3.3. *E3. Establishing the correlation between the indicators and forms of waste*

In the third stage of the study, we associated the indicators with one or more forms of waste possible developments highlighted by the KPI.

Of course, each KPI measures the performance from a certain perspective, but also the proposed system indicates the size of the counter-performance (the difference between the target value and the value obtained).

It is noted that at the level of productivity (time) are manifested most forms of waste.

Starting from the idea that the wasting increases the costs, we considered cost index variation as the result of the sum of all losses in the production process.
In the study we considered as homogeneous production, but if production is heterogeneous, then the indicators proposed by us become partial indicators (for an assortment from the products range), and the total is calculated as sum of partial indicators.

For example, the index of stocks $I_s$, for a product, has the formula shown in table 3, and when there are multiple varieties, the formula is:

$$I_s = \sum_{i=1}^{n} I_{s_i} = \sum_{i=1}^{n} \frac{S_{e_i}}{S_{s_i} + Q_{c_i}}$$

Where:

$S_{e_i}, S_{s_i}, Q_{c_i}$ means existing stock, safety stock and ordered quantity for $i$ product

4. Conclusion

The study presented in the article led us to the conclusion that measuring the performance of production processes within industrial enterprises is a common practice.

However, the PMSs used not marked the counter-performance, which leads to difficulties in optimizing the activity.

Measuring waste improves the management process easier, in the sense that gives managers accurate indications of the direction in which should be acted to achieve operational excellence.

Therefore, we sought to develop a system of indicators that can be used to quantify the losses (in the Lean manufacturing acceptance) of industrial production.

The system developed by us has a high degree of universality and can be adopted, with minor adaptations, by companies in all fields, not just those with industrial specific.

Performance indicators shown cannot be used to characterize the work of the whole organization, so it is necessary for them to complete performance measurement systems business, existing within organizations.

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