Economic aspects of measuring technological processes

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Abstract. The theory and practice of efficient organization the technological processes has significant developments. However, the issues of measuring technological processes and monitoring their execution remain poorly studied. On the one hand, there should be a lot of control points to ensure a timely assessment of the current state of the system, to form an effective management impact to adjust its trajectory. On the other hand, continuous monitoring is too costly, burdens the information system with redundant data. This article describes the theoretical aspects of measuring technological processes and monitoring their performance. The proposed approach to determining the frequency and scale of control procedures is based on the critical principles of rationality and efficiency. It allows you to determine the necessary and sufficient number of control points. Another problem is the presence of a large number of benchmarks, the number of which increases with the development of management theory. This problem is solved by applying universal metrics that characterize any technological process of the company: "work", "speed", "time", "acceleration". This approach unifies the economic space of measurement, makes it visible and accessible to any level of management, allows for accurate identification of process parameters at any time at minimal cost.

1. Introduction
The management in the process of financial and economic activity is faced with the problem measuring and monitoring the implementation technological processes, achieving targets. The results of such control are crucial for business decision. Plans, standards, norms set the model of technological processes, allow you to determine the deviation of the process parameters at any time. In this sense, the process is a physical body, and «determine the position the body means to describe, using some mathematical tools, the position all points the body we are interested in relative to the point we selected…» [1]. In the economic space, as in the physical, there are many material points, measured parameters of financial and economic activity, affected by factors of internal and external environment [2]. The problem of measurement and control is that today technological processes are characterized by dozens indicators of efficiency and effectiveness [3] [4]. This problem is solved by applying metrics to measure the state of the process. The term "metric" is a broader concept than the concept of «indicator». The characteristics of the metric are [2]:

- The metric describes the phenomenon on the quantitative and qualitative side (measurement);
- The metric evaluates the results of activities by levels of management (differentiation);
- The metric is chosen in accordance with business objectives (targeting);
- Periodic or constant monitoring is based on metrics (control);
- Using the metric results in a predicted result (effectiveness);
Therefore, we can say that process metrics are qualitative and quantitative parameters that are monitored on a regular basis and at various levels of management, which are used to measure technological processes, analyze, correct current and model subsequent actions. This article describes universal metrics for measuring and managing technological processes [2].

2. Materials and methods

First, we give a few theoretical points. An enterprise is considered as an object moving towards achieving its goals. A planned target or budget indicator (π) represents the amount of work (A) that must be completed in a specified period of time (t). Its duration is limited to $0 \leq t \leq t_{\text{plan}}$. Work (A) can be defined as the volume products, works, services, projects developed, equal to the product of the volume products, works, services per unit of time for the time during which the volume was produced [5]:

$$A = Q \times t,$$

(1)

where A is a work, and t is time of process.

Obviously, the amount of work fully performed is equal to 100%. The planned amount of work is indicated $A_{\text{plan}}$, the actual amount of work is $A_{\text{fact}}$. Some work needs to be done at each point in the planning period. The increase in the volume of products, works, and services for the same unit of time is qualified as acceleration [6]:

$$a_{\text{(ac)}} = \frac{\Delta A}{t},$$

(2)

where $a_{\text{ac}}$ is acceleration, $\Delta A$ is the increase in production volume.

The size of the planned task and the time of its execution is directly dependent on the amount of available material, energy, human, capital resources (R). Obviously, the work is performed at a certain speed (V):

$$V = \frac{A}{t},$$

(3)

Control actions of the manager are aimed at accelerating or slowing down the process speed and are carried out using organizational, technological, psychological, financial tools [7]. The maximum speed ($V_{\text{max}}$) characterizes the situation when the process is fully and without interruptions provided with the necessary resources, carried out without violating the established operating mode, operating rules of the equipment, without reducing the quality of the products. At minimum speed ($V_{\text{min}}$), the process will be completed at the most recent allowable time [5].

In the process transition to the intended goal, the process is subjected to positive and negative parametric disturbances. Failures of equipment, failures in logistics, interruptions in the supply of electricity, the occurrence of unplanned work are negative parametric disturbances leading to a decrease in speed and an increase in the time to reach the goal. When implementing the results scientific research, improving the quality raw materials, increasing labor discipline, they are considered as positive parametric violations associated with an increase in speed and a reduction in time. It is the presence of interference that determines the need to measure and control processes. Measurement and monitoring the planned task can be carried out continuously or discretely. Continuous monitoring, as well as monitoring with high frequency, causes an excessive load on the information system, leading to increased costs. The described approach to monitoring and measuring technological processes is based on critical principles of efficiency and rationality, according to which the cost of the process should always be lower than the results obtained when using it [2]. The figure shows the progress of the process towards achieving the goal.
In this case, \( A_1(t) \), \( A(t) \), \( A_2(t) \) is the amount of work performed during \( t_{\text{min}} \), \( t_{\text{plan}} \), \( t_{\text{max}} \) at a speed of \( V_{\text{min}} \), \( V_{\text{plan}} \), \( V_{\text{max}} \). The process must be within the limits bounded by straight \( A_1(t) \) and \( A_2(t) \) [8].

To find the time measurement and control of the process, we will make additional constructions (figure 2). Through the point B with coordinates \( (A_{\text{plan}}; t_{\text{plan}}) \), draw a straight line BC parallel to the line AO. It reflects the progress of the process at the maximum speed; the indicator will be executed at the scheduled time \( t_{\text{plan}} \). Point C can be interpreted as the first control point: the amount of work performed at point C is different from zero, but if the resources remain unchanged, the probability failure of the process in the prescribed period is high. Through a point with coordinates \( (A_1(t); t_1) \) we draw a perpendicular to the intersection with the line BC: we get the point \( t_2 \). This is the start time of the second control procedure. All subsequent control points are defined in the same way. Thus, the time of each subsequent checkpoint can be found by the formula:

\[
t_{i+1} = t_1 + \frac{A_1(t_i)}{A_{\text{plan}}} \times (t_{\text{plan}} - t_1),
\]

where \( t_{i+1} \) is time of the next control procedure, \( t_1 \) is time the first control procedure, \( A_1(t_i) \) is the actual amount work performed at the time control, \( A_{\text{plan}} \) is the value the process indicator, \( t_{\text{plan}} \) is planned time process execution.

Depending on the speed the system to the planned state, the following areas can be distinguished (figure 2):

1. OABI - the system reaches any point in this area when the speed moves within \( V_{\text{min}} \leq V \leq V_{\text{max}} \) with short-term positive and negative parametric disturbances; management consists in specifying the required speed of the process;

2. OIE - the system falls into this area if the process speed becomes less than \( V_{\text{min}} \), the probability of the process failure is high due to the action negative parametric disturbances; the task the manager for affordable tools to increase the speed of the process, including through additional resources.
3. ODA – in this area, the speed of the system exceeds the maximum due to the action positive parametric disturbances, the probability achieving the planned indicator in the shortest possible time is high; the Manager's decisions are aimed at reducing the speed of the process and / or switching the freed resources to perform another task.

The task of the process measurement and control system is to assess its current state, the risk failure to meet the deadlines, and the approach of the system to a critical area in which the process can no longer be completed within the planned time frame with any additional resources involved. Therefore, the system measurement and control acts simultaneously as a system of replanning.

3. Results and discussion

Next, the above algorithm will be considered by example. The company carries out the production ophthalmic instruments, for a month has a planned task for the production and sale of instruments presented in table 1.

| Table 1. Planned indicators for the production ophthalmic instruments. |
|---------------------------------------------------------------|
| Indicator                  | Value of indicator |
|----------------------------|-------------------|
| 1. Break-even sales, unit | 3 253             |
| 2. Production volume, unit | 5 904             |
| 3. The production time for unit, hours | 10                |
| 4. The planning period, days | 30                |
| 5. Planned completion time, days | 26                |

Manufacturing ophthalmic instruments includes the following technological stages: forming, surface finish first, thermal treatment, surface finish second, joining parts, coating, assembling, labeling and quality control.

The value the break-even volume is found by the formula [7] [9] [10]:

\[ Q = \frac{FC}{P-AVC} \]  

where \( Q \) is break-even sales (unit), \( FC \) is total fixed costs, \( P \) is price, \( AVC \) is average variable cost.

In the context the proposed approach, it is necessary to calculate the speed and time of the process. The speed of the process according to plan \( (V_{pl}) \) is 5 904: 30 = 197 unit /day. The problem is the calculation the break-even volume in time indicators. For this purpose, we compose the proportion: in 30 days the enterprise must produce 5 904 unit and the breakeven volume of 3 253 unit the enterprise will produce in 17 days:

\[ \text{Break-even sales (days)} = \frac{3253 \times 30}{5904} \approx 17 \text{ days} \]

Figure 3. Monitoring and measurement the manufacturing process of ophthalmic instruments.
Figure 3 shows the calculation of control points and measurement of the process according to the proposed method. If the production task is performed at the maximum speed, the set volume will be completed in 18 days; according to the plan, the deadline is 26 days; the deadline for the planned task is 30 days. Direct OA, OB, OD are built on the basis of this data. The first control point $t_1$ was obtained by constructing a straight line parallel to the straight line AO. The time of subsequent control points is calculated using formula 4. The results are presented in the table.

**Table 2.** Frequency of control and content of management decisions.

| Control point | Calculation Method | Control time | The value of the controlled indicator, liters | Management decision |
|---------------|--------------------|--------------|-----------------------------------------------|--------------------|
| $t_1$         | Graphic            | 5th day      | Plan 5; Fact 204                              | The maximum increase in speed, the attraction additional resources; high risk non-fulfillment the production program. |
| $t_2$         | Mathematical       | 8th day      | 1206; 204                                    | The maximum increase in speed, the attraction additional resources; high risk non-fulfillment the production program. |
|               | $t_2 = t_1 + \frac{A_1 (t_1)}{A_{in}} \times (t_{in} - t_1)$ |             |                                               |                     |
|               | $= 5 + 204$        |             |                                               |                     |
|               | $+ 1206 \times (26 - 5) = 8$ |             |                                               |                     |
| $t_3$         | Mathematical       | 14th day     | 2 880; 1 300                                 | The risk non-compliance with the production plan is reduced, and the speed the process needs to be increased. |
|               | $t_3 = t_1 + \frac{A_1 (t_1)}{A_{in}} \times (t_{in} - t_1)$ |             |                                               |                     |
|               | $= 5 + 1300$       |             |                                               |                     |
|               | $+ 2880 \times (26 - 5) = 14$ |             |                                               |                     |
| $t_4$         | Monitoring break-even volume | 17th day     | 3253; 3253                                   | Break-even point is reached in a timely manner; the process is carried out with increased speed; part of the resources can be diverted to other processes; the risk non-fulfillment the production plan is minimal; maintaining the speed of the process is necessary. |
| $t_5$         | Graphic            | 18th day     | 3900; 4100                                   | The process is performed at a high speed, some resources may be diverted to other processes; the risk failure to meet the production plan is minimal; the task the manager is to maintain the speed of the process. |
| $t_6$         | Mathematical       | 23rd day     | 5304; 4702                                   | The process has a low speed; the risk failure the production plan is minimal; the task the manager is to increase the speed of the process. |
|               | $t_6 = t_1 + \frac{A_1 (t_1)}{A_{in}} \times (t_{in} - t_1)$ |             |                                               |                     |
|               | $= 5 + 4702$       |             |                                               |                     |
|               | $+ 5302 \times (26 - 5) = 23$ |             |                                               |                     |
| $t_7$         | Graphic            | 26th day     | 5904; 5904                                   | The process was completed on time. |

Discussion questions of this article can be:
• the article describes the basic model of process control, does not disclose the practical aspects of its use in automation programs.
• the presented empirical material is narrow enough to unambiguously prove the effectiveness of the model.

To answer the first type of objection, it is worth noting that there are few conceptual economic and mathematical models of process control. The presented approach can be considered a certain scientific achievement.

In response to the second objection, we say that the volume the article does not allow us to give a sufficient empirical base. The evidence base is more fully presented in the authors’ works [2] [6]. The results obtained indicate that the method works correctly.

4. Conclusions

The presented approach makes it possible to unify the characteristics technological processes, makes them visible and accessible to any level of management; provides the possibility creating a database of statistical data for standardization the processes; creates the possibility accurate identification and analysis the processes at any time. Process management is reduced to tracking the time, speed, acceleration of the process to achieve the planned result. Control is carried out with minimal costs in sufficient volume.

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