Production planning process effectiveness improvement through the automated system introduction

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Abstract. The necessity of special automated systems creation for the effective organization of industrial enterprise processes is substantiated. The effectiveness indicators of the production planning process are defined and the criteria for their evaluation are determined. The results of an automated planning system introduction at several instrument-making enterprises are presented, according to which an improvement in all effectiveness indicators was obtained, namely: the number of mistakes in the data collection subprocess was reduced by 85%, the time of production plan creation was reduced to 1 minute, the mistakes of plan creation process were completely eliminated, the time of plan and it versions assessment was reduced by 60%, and the timing of the studied planning subprocesses was completely observed.

1. Introduction
Modern instrument-making enterprises face a number of problems related with the ever-increasing complexity of manufacturing products and technical requirements for production. Methods for solving such problems are introduction of new information technologies and modernization of production equipment, as well as introduction of new methods of production organizing [1]. In this conditions need of automated systems (AS) that allow reduction of the processes time and improvement of processes effectiveness performance sharply increases.

The effectiveness of the production planning process directly affects quality of manufactured products and profit received by the enterprise [2], therefore, the main direction of production processes effectiveness increasing is development and implementation of automated systems.

The aim of present research is production planning effectiveness increase by introduction of an automated system based on the models and methods proposed by the authors [3, 4].

In accordance with generally accepted terminology, effectiveness - extent to which planned activities are realized and planned results are achieved [5]. Process effectiveness is defined as the ratio of the sum of actual values to the sum of planned values of the criteria. Therefore, effectiveness indicator is a numerical expression of effectiveness for a given process in accordance with an established goal [6].

2. Formulation of studied process effectiveness indicators
In order to assess the effectiveness of production planning process, qualitative and quantitative indicators and criteria for their evaluation were formulated (table 1) for each subprocesses.
As the main result of production planning process is the plan, in table 1 primarily included indicators that affect the speed of initial data gathering, creation and evaluation of the plan (time indicators), as well as indicators that characterize quality of the plan - degree of plan inherent characteristics conformity to requirements. Time indicators are defined based on planning schedule restrictions of the studied enterprises.

**Table 1. Effectiveness indicators of the production planning process.**

| Subprocess                              | №   | Effectiveness indicators                                      | Criteria                                      |
|-----------------------------------------|-----|----------------------------------------------------------------|----------------------------------------------|
| Initial data gathering and handling     | 1.1 | Time of initial calendar creation                             | No improvements, corrective / preventive actions are required |
|                                         | 1.2 | Quantity of mistakes in initial calendar                      | Preventive actions are required               |
|                                         | 1.3 | Time of days statuses and shifts schedule input               | Corrective actions are required               |
|                                         | 1.4 | Quantity of mistakes in days statuses / shifts schedule input |                                            |
|                                         | 1.5 | Time of planned production stoppages input                    |                                            |
|                                         | 1.6 | Quantity of mistakes in planned production stoppages input   |                                            |
|                                         | 1.7 | Time of production restrictions input                          |                                            |
|                                         | 1.8 | Quantity of mistakes in production restrictions               |                                            |
|                                         | 1.9 | Time of common calendar creation                               |                                            |
|                                         | 1.10| Quantity of mistakes in common calendar                       |                                            |
| Plan creation                           | 2.1 | Common calendar used for plan creation                        | No improvements, corrective / preventive actions are required |
|                                         | 2.2 | Takt time (TT) in line with production restrictions            | Preventive actions are required               |
|                                         | 2.3 | TT restrictions reflected correctly in plan                   | Corrective actions are required               |
|                                         | 2.4 | Daily volume calculated correctly                              |                                            |
|                                         | 2.5 | Daily volume of each product in line with production restrictions |                                            |
|                                         | 2.6 | OPR in line with production requirements                      |                                            |
|                                         | 2.7 | Monthly/ period difference between plan and sales order is minimal |                                            |
|                                         | 2.8 | Cumulative difference between plan and sales order is minimal |                                            |
|                                         | 2.9 | Created plan is in line with the conditions set by the planning specialist |                                            |
|                                         | 2.10| Quantity of mistakes in plan                                  |                                            |
|                                         | 2.11| Time of plan creation                                         |                                            |
| Plan assessment                         | 3.1 | Time of plan assessment                                       |                                            |

Also, for clarity of effectiveness indicators presentation, all listed indicators are grouped by criteria values (table 2).

**Table 2. Grouped effectiveness indicators.**

| Effectiveness indicators                              | Criteria                                      |
|------------------------------------------------------|----------------------------------------------|
|                                                      | No improvements, corrective / preventive actions are required |
|                                                      | Preventive actions are required               |
|                                                      | Corrective actions are required               |

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| Time of initial calendar creation/ of common calendar creation/ plan creation | <1 minute | 1-30 minutes | >30 minutes |
|---|---|---|---|
| Quantity of mistakes in initial calendar/ in days statuses or shifts schedule/ in planned production stoppages/ in common calendar/ in plan | 0 | >0 |
| Time of days statuses and shifts schedule input/ of planned production stoppages input | <10 minutes | 10-30 minutes | >30 minutes |
| Time of production restrictions input/ of plan assessment | <4 hours | 4-8 hours | >8 hours |
| Common calendar used for plan creation | Yes | No |
| Takt time (TT) in line with production restrictions | Yes | No |
| Daily volume calculated correctly/ daily volume of each product in line with production restrictions | Yes | No |
| OPR in line with production requirements | Yes | No |
| Monthly or period difference/ cumulative difference between plan and sales order is minimal | Yes | No |
| Created plan is in line with the conditions set by the planning specialist | Yes | No |

Identification of the most significant for considered process effectiveness indicators leads to the vector optimization task, which consists in finding the maximum of the vector function (F) [7]. The formula of this method is as follows:

\[
F(x) = (f_1(x), f_2(x), \ldots, f_n(x)) \rightarrow \max, x \in D,
\]

where \(f_1(x), f_2(x), \ldots, f_n(x)\) – particular subprocess criteria, \(D\) – acceptable region.

The main stages of convolution:

- justification for the convolution;
- normalization of criteria;
- consideration of criteria priorities;
- building a convolution function.

A prerequisite is classifying of convolution criteria to one type of indicators [7] - responsiveness, effectiveness and etc. Convolution of particular criteria must be done separately for each group of indicators. The indicators presented in table 1 relate to different groups and different subprocesses, which indicates the non-expediency of the convolution. Also, since intervals are chosen as the criteria, their normalization is not possible.

In order to evaluate the effectiveness indicators of production processes, various models are developed and applied [8, 9]. It is proposed to use for planning process the model shown in figure 1.

![Figure 1. A model for effectiveness evaluation of the production planning process.](image)
The actual values of the effectiveness indicators were recorded and evaluated based on the results of the planning process in the developed automated system. Elements of an automated system [6, 7], models and methods laid in its foundation are presented in other works of the authors [1-3], and therefore are not given in this article.

3. Effectiveness evaluation after developed automated system introduction

Evaluation of the effectiveness of the production planning process after using the developed AS at several instrument-making enterprises was carried out according to the formulated indicators, and revealed that an improvement was achieved in all indicators of the planning process in the complex.

Due to the automation of manual processes, it was possible to significantly reduce the time of planning processes, in particular, the time of one plan creation in the system does not exceed 1 minute [2, 8], which was chosen as an indicator of the effectiveness of plan creation (figure 2). Since the process of production plan creation was completely transferred to an automated environment, mistakes in the process of plan creation were completely eliminated.

![Figure 2. Time of plan creation.](image)

By standardizing the formats for entering data and evaluating plans, sending notifications using the system, as well as creating the system as a website, it was possible to significantly reduce the time of production planning subprocesses. The deadlines for these subprocesses are fully respected, and the time for plan versions evaluation, including the time for evaluation by all departments/shops and the time for evaluations summary, in particular, was reduced by 60% (figure 3). Summary of evaluations has become a fully automated process.

![Figure 3. Time of plan evaluation and evaluations summarizing.](image)
It should be noted that the number of mistakes in data collection subprocess for plan creation was reduced by 85% due to the means proposed by the authors (figure 4) [7], which is confirmed by the act of introducing instrument-making enterprises like Laser Systems LLC, but since the data input into the system remains mainly manual process, it is necessary to continue the development and application of corrective and warning tools in order to minimize quantity of mistakes.

![Figure 4. Quantity of mistakes in the data collection subprocess.](image)

### 4. Conclusion

Implementation of the production planning process using an automated system and evaluation of this process effectiveness showed that the use of the developed software product can improve all effectiveness indicators, namely: reduce number of mistakes of data collection subprocess by 85%, reduce time of plan creation to 1 minute and completely eliminate mistakes in process of plan creation, reduce the time of plan versions evaluation by 60%, and also made it possible to fully comply with schedule of production planning process.

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