Digital enterprise comprehensive evaluation

Yu V Polyanskov, M N Yardaeva*, S V Lipatova and I V Lutoshkin

Ulyanovsk State University, ‘Digital production of high-tech products in mechanical engineering’ Competence Center

*yardaeva@mail.ru

Abstract. The article presents a method for a comprehensive evaluation of the activities of an aircraft building enterprise. Based on an integral presentation of management principles ‘just in time, risks management’ and ‘design to cost, risks management’, an assessment of the required quality and volume of production is proposed, considering the aggregated nature of indicators and the heterogeneous structure of the enterprise. An automation algorithm for the developed method is described. The methodology for implementation and use of the tool for comprehensive assessment of the aircraft building enterprise is presented.

1. Introduction

The speed of currently occurring technological changes associated with the concepts of Industry 4.0 and Smart Factory has created a significant gap between current capabilities of personnel and the rapidly developing requirements for them [1], as well as the existing level of automation in real Russian production. From this point of view, the issues of changing organizational culture [2, 3] and requirements for the education and qualifications of employees [4], the need for the emergence of new professions [5] and adaptation to the conditions of digital production of existing ones are discussed. In this regard, the development of methods and tools is required to help employees function effectively in new conditions [6].

One of the basic tasks of the transition to the 4th industrial order is to obtain in real time huge amounts of information about the activities of the enterprise. These data are used to build a digital production model (see Figure 1). For production management in such models, an operational complex (integrated and aggregated) assessment is required with the ability to drill down to the selected management level (viewing the values of the assessment elements before the source of their appearance in the management system).

2. Research into the activities of an aircraft building enterprise

Let us highlight the main elements of a digital production model: a model of production processes (in the form of business processes), a structural model of production (performers in business processes), a mathematical model for assessing production (key performance indicators (KPI) and performance (KRI)). The activity of an aircraft building enterprise, from the point of view of the object of modeling, is a complex system with a large number of interacting and influencing processes (see Fig. 2).
2.1. Enterprise processes
The main process at the enterprise is manufacture of products, then the auxiliary processes, without which the main one will not be completed are production preparation (design and technological), production planning, provision of production with material resources (raw materials, blanks, purchased components, tools, etc.) and labor resources, etc.
2.2. Definition of KRI

To manage the processes considered in Figure 2, it is required to determine performance indicators (see Table 1), which will allow to further evaluate management actions and provide feedback in management models taking into account various criteria, such as ‘just in time’, ‘design to cost’, ‘risks management’.

Creating and configuring performance indicators in the system along with modeling business processes (detailing the process: process tasks, responsible for tasks, task indicators, input and output paper or electronic documents) requires searching and defining the storage of input indicators for calculating KRI. The mechanism for assessing the influence of factors based on the accumulation of statistical information is presented in [1,6].

To support organizational and production processes, the enterprise uses automated systems for production management and production resources (ERP), personnel management (HRM), design and standardization of electronic technological operations (CAD TP), etc., which are constantly being improved through the development of additional software modules for new requirements. In the absence of more powerful and ‘smart’ systems (MES/APS, SMART, BPM, BI), a lot of resources are spent on searching, clarifying the values of input indicators, and calculating integral performance indicators. In any case, for introduction of new systems or their own developed software modules, it is necessary to integrate them with already existing and functioning systems [7,8].

Table 1. Performance indicators of enterprise processes

| Process ‘Automated organization and reorganization of production plans’ | • Assessment of production plans quality (plan (period under review-1) / fact (period under consideration)) (%);
| | • Number of reorganizations of plans (for example, for the period under consideration + 1 in the context of months) in view of changes (units);
| | • Evaluation of the linkage of resource plans with the production plan after their elaboration by experts, that is, considering possible risks (%);
| | • Costs for process execution (rubles).
| Process ‘Design and technological preparation of production’ | • Assessment of the quality of drawing up design documents and technical documents in the form of the amount of design and technological errors that led to product rejection (defect) (that is, planned indicators formed in (period under review-1) / actual indicators (period under consideration)) (%);
| | • Coefficient of accuracy of preliminary standardization of production operations during development of a new product in comparison with the resulting fact (that is, a preliminary estimate for accounting in the planning system (standard hour) / actual indicator (standard hour)) (%);
| | • Number of prepared design documents and technical documents ‘on time’;
| | • Costs for the process execution (rubles).
| Process ‘Manufacture’ | • Assessment of the quality of production plans implementation (actual indicators / planned indicators (for the same time period)) (%);
| | • Assessment of accounting for production internal factors acting as plan failure risk (coefficient);
| | • Evaluation of the taken measures, leveling production in view of various changes (%);
| | • Costs for process execution (rubles).
| Process ‘Provision of production with material resources’ | • Assessment of the quality of the provision plan implementation (actual indicators/targets (for the same time period)) (%);
| | • Assessment of external factors acting as the risk of plan failure for providing material resources (coeff.);
| | • Evaluation of the measures taken to level the collateral due to the arrival of various changes (%);
| | • Costs for process execution (rubles).
| Process ‘Provision of production with labor resources’ | • Assessment of the quality of provision plan implementation (actual indicators / targets (for the same time period)) (%);
| | • Assessment of accounting for external and internal factors acting as risk of the plan failure (coefficient);
| | • Evaluation of the taken measures, leveling security in view of any changes (%);
| | • Costs for process execution (rubles).

To ensure modernization of the digital model of production management, it is necessary to solve a number of problems:
• operational provision of the planning system with data that require the reorganization of plans from the processes of production, supply, staffing;
• prompt informing of production workers about changes in plans or issuing current shift-daily tasks;
• prompt informing of suppliers about changes in plans for providing material resources;
• comprehensive assessment of the quality of process execution by organizational elements (responsible) that affect KPI.

To solve such problems, it is required to integrate data and processes within one information system, ‘add-in’ over the automated systems of an enterprise that simulates business processes, evaluates their implementation in the form of calculated integral performance indicators, evaluates alternative scenarios of pre-modeled production plans, and calculates KPIs. The information system in the paradigm of digital production should be based on fully automated enterprise management processes, contain management models [9, 10] and be guided by these requirements of a particular enterprise, while intellectually supporting each of the stages of enterprise activity. The scheme of enterprise functioning when using an integrated system is shown in Figure 3.

![Diagram of enterprise functioning when using an integrated system](image_url)

2.3. Definition of KPI

To meet the needs of a customer, the main attention in monitoring implementation of organizational and production processes is paid to deviations in the delivery time of finished products in the required volume and quality. At the same time, the enterprise is interested in reducing or preventing an increase in the value of the specified (planned) cost of manufactured products. The influence of internal and external factors in the form of fixed data changes in planning and accounting systems can negatively affect implementation of production plans, which will lead to non-fulfillment of orders on time. Therefore, a solution is proposed in the form of a comprehensive assessment of indicators’ performance taking into account risks, which is a tool for calculating the following KPIs:

• KPI_JIT - % of manufacturing products ‘just in time, risks management’,
• KPI_COST - % of manufacturing products ‘design to cost, risks management’.

There are two options for assessing the activities of an enterprise: the current state, when the actual values of the indicators are compared with the planned ones and their deviations from each other are analyzed; and the future state, when the predicted values of indicators are compared with the planned ones and their deviations from each other are analyzed. Both options take into account the risks (changes) that have entered the planning and accounting systems by the time of calculation.

KPI_JIT is influenced by updates of the following data: changes in the dates and volumes of delivery of the necessary material resources for the manufacture of products of the planned item; failure of
equipment; breakage of a tool or fixture and other events due to which the required volume of production is not completed by the specified date.

KPI_COST is affected by updates of the following data: changes in the labor intensity of technological processes; the cost of material resources, their delivery; the purchase of new raw materials, tools, purchased components and other additional costs due to which the required volume of production will exceed the specified cost.

3. Calculation algorithm of KPI_JIT and KPI_COST

KPI_JIT and KPI_COST indicators are calculated using the following formulas:

\[
KPI_{\text{JIT}} = \frac{V_{\text{fact,JIT}}}{V_{\text{plan,JIT}}} \times 100\% \quad \text{and} \quad KPI_{\text{COST}} = \frac{V_{\text{fact,COST}}}{V_{\text{fact,COST}}} \times 100\%,
\]

where:

- \(V_{\text{fact,JIT}}, V_{\text{plan,JIT}}\) – actual and planned volume of production ‘just in time’, respectively;
- \(V_{\text{fact,COST}}, V_{\text{plan,COST}}\) – actual and planned volume of production ‘design to cost’, respectively.

KPI_JIT and KPI_COST values in the system are calculated based on requests on the server:

- for the current date (to assess the current state of production),
- on the due date of the order (due date is greater than the current date) (to assess the future state of production).

The following variables are used in the algorithm (see Figure 4):

- \(V_{\text{plan}}, V_{\text{fact}}, V_{\text{risk}}\) – these are production volumes of parts (det) for the products (product) of the order (order) by the types: planned, actual, in the production risk zone, respectively;
- \(date_{\text{plan}}, date_{\text{fact}}, date_{\text{risk}}\) – these are the dates of manufacture of parts (det) for the products (product) of the order (order) by the types: planned, actual, received more than planned, respectively;
- \(cost_{\text{plan}}, cost_{\text{fact}}, cost_{\text{risk}}\) – these are the costs of manufacturing parts (det) for the products (product) of the order (order) by the types: planned, actual, received more than planned, respectively.

As a result of the calculation, \(KPI_{\text{JIT}}\) values can take on the following values: <100%, which means that the planned volume of production ‘just in time’ has not been completed; = 100%, which means as of the current date = the date of production of the product (s) for the selected order, the planned volume is fully completed; >100%, which means that the planned volume has been completed ahead of schedule.

As a result of the calculation, KPI_COST values can take on the following values: <100%, which means that the planned volume of production ‘design to cost’ is not fulfilled; = 100%, which means for the current date = the date of production of the product (s) for the selected order, the planned production volume ‘design to cost’ is fully completed; >100%, which means that the planned production volume has been completed with a lower production cost of the product.
Calculation of indicators KPI_JIT and KPI_COST (Client server architecture)

4. Steps in the formation of a comprehensive assessment of activities at the enterprise

To implement the KPI assessment tool (proposed in [11] or developed independently) at the enterprise, it is necessary to perform some preparatory work:

1) define goals -> KPI -> Responsible for KPI;
2) determine storage in databases of input indicators for calculating KPI, external and internal factors that negatively affect them;
3) describe business processes that affect KPI;
4) appoint persons responsible for entering these indicators and modeling business processes;
5) provide integration between databases;

Figure 4. Calculation algorithm of KPI_JIT and KPI_COST
• create an indicator - KPI, determine its place in the structure of a complex model according to [9], set a calculation formula using mathematical operators or aggregation functions of variables (input parameters), set a person responsible for monitoring the indicator, assign a level of refinement of the indicator value according to reference books.
• to simulate a business process using detail elements: task, a person responsible for the task, KRI for tasks, input and output papers or electronic documents.
• assign links in the structure of the complex model [12] between the indicators and tasks of the processes, to make refinements in the modeled business processes.
• set up a dashboard for monitoring the values of indicators at the current moment and at the time of choosing a future date by those responsible for KPI, decision makers.

The main displayed elements for managers can be presented in the form of a diagram and a table (Figure 5).

![Figure 5. Structure of a customized executive dashboard](image)

### 5. Conclusion

The article presents a method for a comprehensive assessment of the activities of an aircraft building enterprise. Based on an integral presentation of management principles ‘just in time, risks management’, ‘design to cost, risks management’, an assessment of the required quality and volume of production is proposed, taking into account the aggregated nature of indicators and the heterogeneous structure of the enterprise.

Modeling the activities of an aircraft building enterprise and creating a layout of a KPI assessment tool are carried out within the framework of the project ГЗ No. 2.1816.2017 / ПЧ.

### References

[1] Martynenko Yu.V. Experience in the development of elements of a decision support system for Aviastar SP // Digital Economy and Industry 4.0: Trends of 2025. Proceedings of a scientific and practical conference with international participation. Edited by A.V. Babkina. 2019. pp. 389-393.

[2] Vasiliev V.I., Gvozdev V.E., Guzairov M.B., Kirillova A.D. Decision support system for ensuring information security of an automated process control system // Information and security. 2017. No 4 (20). pp. 618-623.

[3] Shubenin A.A., Prokina N.V., Mukhin V.N., Pozdnyakov S.Yu. Information technologies of decision support based on data warehouses // Information and mathematical technologies in science and management. 2016. No 3. pp. 80-91.
[4] Novikov D.A. Laws, patterns and principles of management // Innovations in management. 2016. No 7. pp. 44-53.

[5] Scarlat E., Bradea I. Indicators and metrics used in the enterprise risk management (ERM) // Economic computation and economic cybernetics studies and research. Academy of Economic Studies. 2011. No 46(4).

[6] Bolos M., Claudia D. Developing an Adaptive Fuzzy Controller for Risk Management of Company Cash Flow // International Journal of Fuzzy Systems. 2016. 19.10.1007/s40815-016-0159-z.

[7] Mauergauz Yu. Advanced Planning and Scheduling in Manufacturing and Supply Chains / Yu. Mauergauz.— Switzerland: Springer International Publishing, 2016.— 584 p.

[8] Hosseini, Behnaz & Tan, Baris. (2019). Modelling and analysis of a cooperative production network. International Journal of Production Research. 57. 6665-6686. 10.1080/00207543.2019.1571254.

[9] Lutoshkin I., S. Lipatova, Y. Polyanskov, N. Yamaltdinova, and M. Yardaeva. (2019). Mathematical Model for Describing the Principles of Enterprise Management 'just in Time, Design to Cost, Risks Management'. Studies in Systems, Decision and Control. Vol. 199. doi:10.1007/978-3-030-12072-6_55.

[10] Polyanskov Y., Lutoshkin I., Yardaeva M., and Lipatova S. (2019). Model of Production Schedule Modification Assessment for Digital Production Management Systems. doi:10.1088/1757-899X/497/1/012082.

[11] Lutoshkin I.V., Lipatova S.V., Yardaeva M.N. Development of tools for assessing activities of an enterprise in a digital production // Scientific and technical statements of SPbSPU. Economic sciences. 2018.Vol. 11, No 6. pp. 9-22.

[12] Lipatova S.V., Yardaeva M.N., Lutoshkin I.V., Polyanskov Yu.V. (2019). An integrated model as a tool for implementing an enterprise management method. Published under licence by IOP Publishing Ltd. Journal of Physics: Conference Series, Volume 1333, 6 - Operations planning and enterprise information systems. doi:10.1088/1742-6596/1333/7/072015