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# OPTIMIZATION OF E-DOCUMENT WORKFLOW FOR ORDER CALCULATION

Об'єктом дослідження є автоматизовані системи управління на підприємствах машинобудівної галузі. Одним з найбільш проблемних місць є розрахунок вартості замовлення в умовах наявності великої кількості замовлень різного типу, що є характерним для сучасних підприємств. В ході дослідження було проведено аналіз систем розрахунку вартості замовлення та визначено особливості формування замовлення на машинобудівних підприємствах. Запропоновано шляхи оптимізації електронного документообігу шляхом застосування концепції використання автоматизованого розрахунку вартості замовлення на базі формування даних щодо окремих виробничих одиниць або комплектів. Концепція розрахунку вартості використання кожної виробничої одиниці для виготовлення замовлення дає гнучкий інструмент для менеджменту компанії. Це дозволяє формувати в автоматизованій системі управління необмежену кількість і різноманітність моделей технологічних одиниць, доповнювати та удосконалювати параметри для більш точного визначення вартості виробництва. Для цього використовуються довідники операцій, що містять інформацію про необхідне обладнання, інструменти, витратні матеріали, необхідну кваліфікацію робітників для виконання замовлення, вартість їх праці тощо. Наступним кроком є модернізація алгоритму формування замовлення, що потребує внесення змін до автоматизованої системи управління підприємством. Запропонована концепція використання автоматизованого розрахунку вартості замовлення на базі формування даних щодо окремих виробничих одиниць або комплектів дозволяє значно скоротити витрати на утримання планово-економічного відділу. Під час формування документації щодо замовлення проводиться аналіз наявних витратних матеріалів, відправляється необхідна інформація у відділ закупівель, здійснюється вибір необхідного обладнання з урахуванням завантаження окремих приладів у певний проміжок часу. Також зменшується час обробки замовлень та надання комерційних пропозицій. Це відкриває нові можливості участі підприємства у тендерних пропозиціях та виявленні оптимального варіанту пропозиції, миттєво обчисливши декілька якісно-цінових варіантів виготовлення продукції.

**Ключові слова:** електронний документообіг, розрахунок замовлення, підприємство машинобудівної галузі, автоматизація управління підприємствами, оптимізація бізнес-процесів.

## 1. Introduction

The activity of any modern enterprise in the machine-building industry can't be imagined without information technology and automation. The growth of their values is influenced by such trends as:

- increasing competition, especially from developing countries;
- transition to the type of production by orders, customer requirements for product quality and delivery dates;
- reduction of the cycle of development and preparation of production of new products and increasing the level of complexity of products, reducing the cost of products.

Sales, purchasing, warehouse accounting and a number of other logistics processes are managed by ERP-systems (Enterprise Resource Planning System), and the work of design engineers and technologists are automated with the help of computer-aided design and automated control systems (ACS) by technological processes. The use of electronic document management as part of ERP-systems performs communicative, official and managerial functions [1] in all areas of activity of individual departments of the enterprise.

Automation is a necessary condition for the European integration of Ukrainian enterprises, since the main goals

of automation of management are to expand markets by improving the efficiency and economy of manufacturing products [2]. In modern market conditions, flexibility in setting up an automated management system for a production enterprise is clearly an indispensable criterion. In practice, mechanical engineering enterprises need to modernize the technical base. In the conditions of equipment replacement in the automated control system, it is necessary to make appropriate amendments to the document circulation, taking into account changes in production standards, materials costs, changes in wages, etc.

Therefore, it is relevant to study the possibilities of optimizing workflow in the automated control system for machine-building enterprises in order to increase the speed of processing orders and their implementation, taking into account available supplies and equipment.

## 2. The object of research and its technological audit

*The object of research* is automated control systems for enterprises in the machine-building industry.

To date, the order vector for the machine-building company is aimed at reducing the lots of products, increasing the range and shortening the length of the path from the search for potential customers to the actual order. These

conditions require an instrument for the rapid calculation of the cost of production, depending on the quantity, materials involved, components, terms of delivery, payment terms, etc.

In this regard, for a number of leading enterprises of the machine-building industry, a management concept such as planning and dispatching is widely used. This is due to the growth of production directly on the available order, the need to improve the efficiency of production and profitability of the enterprise. This approach reduces the gap between planning for the whole enterprise and a separate subdivision, reducing its duration. This allows to respond more quickly to tasks, needs and changes. However, the effectiveness of this process depends on the state of the automated control system used in the enterprise.

One of the most problematic places is the low level of interaction between individual departments, which leads to an increase in the processing time of the order, calculation of the cost and its implementation. As a result, the competitiveness of the enterprise in the market is decreasing.

### **3. The aim and objectives of research**

*The aim of research* is improvement of e-document management at machine building enterprises.

To achieve this aim, it is necessary to perform the following tasks:

1. To analyze the current state of economic and industrial activities of machine-building enterprises.
2. To determine the features of calculating the cost of the order and developing the necessary documents.
3. To suggest ways of modernization of the document management system in order to reduce the time and level of interaction between production departments and procurement and sales departments.

### **4. Research of existing solutions of the problem**

A number of works are devoted to the optimization of document circulation and determining the cost of order for industrial enterprises. This is connected both with the prospects of the problem, and with different approaches to its solution, taking into account the different types of production and management.

In particular, the papers [3, 4] are devoted to the analysis of two production systems – by order and process system. In this case, the calculation of the cost price has its own characteristics in each case. It should be noted that for the Ukrainian enterprises of the machine-building industry the process system was inherent for a long time, but for today the fulfillment of individual orders in accordance with individual requirements becomes more promising, which requires changes in the management system.

The authors of [5] consider the issue of implicit, additional costs (sticky costs), which should also be taken into account for calculating the cost of the order. However, the authors don't suggest a mechanism for solving this problem.

Complex mathematical systems for dynamic analysis of orders and equipment loading are proposed in [6, 7]. Their use in industrial plants may require the re-equipment of automated control systems with more modern and expensive software.

An alternative solution to the problem is outlined in [8], which presupposes cases of orders by categories in ac-

cordance with the complexity, volumes of the order and expected value of the order. In [9], it is proposed to create a system of orders with access to the Internet. Such solutions can be applied at light industry enterprises, for example, in printing plants of textile factories [10]. However, for the enterprises of the machine-building industry, the calculation of the cost of an order requires considerably more time for processing information from the customer and from the production departments.

A significant number of parameters should be taken into account when calculating the cost of the order, and the complexity of its calculation, indicated in [11, 12].

Thus, the results of the analysis allow to conclude that the issue of automating the calculation of an order taking into account the characteristics of an enterprise is promising. At the same time, the cost of re-equipment of control systems should be minimal.

### **5. Methods of research**

The following scientific methods are used in the study:

- method of analysis in the study of bottlenecks in automated control systems for enterprises in the machine-building industry;
- method of classification in determining the parameters that form the cost of the order;
- calculation method when determining the cost of an order;
- method for forecasting the duration of an order, based on information about the utilization of equipment and production lines, availability of consumables in warehouses, and the like.

### **6. Research results**

In view of the foregoing, let's propose to begin the modernization of any existing automated control system or the creation of a new e-document «Order calculation». This document can be adjusted a large number of times in the above parameters, affecting the value of the products, until an optimal solution and agreement with the potential customer is reached, then the order will be transferred to production.

The structure of the «Calculation» document should include both general data and an individual set of production units necessary for manufacturing. General information includes the name, quantity, type of products, size, terms of delivery, terms of payment, etc. Individual information includes data that includes parameters relating directly to these production units: types of consumed materials, units of necessary processing, etc. (Table 1).

Module concept of the document that allows to flexibly change any components of the order and instantly obtain new calculation results. In practice, the customer wishes to receive several price proposals for products that may differ in quality and, correspondingly, in the price of the used materials, in the number of products in the batch, in the technological processing and manufacturing of parts.

When modernizing or optimizing the operation of technological sections of an industrial enterprise, new data are entered into the database for the given production unit, namely: the norms of material costs, the cost of labor, the norms for the use of resources, and the processing time per unit of output.

**Table 1**

Structure of the «Order calculation» document

Order	Date of formation	Order number	Customer	Other common parameters
Total data	Author	Product category	–	–
	Terms of payment	Terms of delivery	–	–
	Quantity	–	Sizes	–
Applied production units	Production unit 1	Parameters required for the production unit	–	–
	Production unit <i>n</i>	Parameters required for the production unit <i>n</i>	–	–
Additional expenses	Materials	–	–	–
	Services	–	–	–
Order nomenclature	–	–	–	–

The proposed concept of using automated calculation of the order cost based on the formation of data for individual production units or sets allows to significantly reduce the cost of maintaining the planning and economic department. In addition, the processing time of orders and the provision of commercial offers are reduced several times. This, of course, opens up new opportunities for the company to participate in tender proposals and to identify the optimal variant of the offer, instantly calculating several quality-price options for manufacturing products.

As part of the automation of the management system, it is possible to extend the functions of the electronic document «Order calculation» to the automated formation of a commercial offer, invoices and the like. Thus, it is possible to create a sales department that meets world standards in terms of the speed of response to changes in the market situation. Other advantages are the fast service of processing offers for the customers of the enterprise and the ability to find competitive options for manufacturing products. These features are very important in the stringent conditions of a high level of competition in world markets. Undoubtedly, the operational work of the sales department will positively influence the relations with the existing customers of the industrial enterprise and will increase the competitiveness among Ukrainian producers in the domestic market.

The possibility of calculating the cost/product cost in several variants, with a change in the use of the same production units, allows analysis and identification of «weaknesses» in the enterprise. Thus, it is possible to identify which production units are not optimal for use and unreasonably increase the cost [13]. Such production units should be put in the plan for updating the material and technical base of the enterprise.

For the basic unit for calculating the cost of performing each technological operation, it is proposed to take the prime cost of each production unit, such as a machine, production line, brigade (for manual operations), etc. To determine the production costs of each such unit in the ACS, it is necessary to form a directory (list) of such production units, where for each unit a list of the use of the types of work and the costs of trade and material values (TMV), taking into account the utilization factor in accordance and with the order parameters.

Under the order hereinafter referred to as products that are manufactured in accordance with the requirements of the customer. The concept of the formation of such unit is given in Table 2.

**Table 2**

The concept of calculating the cost of work of a production unit

Production unit	Using	Dependence	Utilization rate
Machine 1	Operation 1	Parameter 1	<i>K1</i>
	Operation 2	Parameter 2	<i>K2</i>
	Operation <i>n</i>	Parameter <i>n</i>	<i>Kn</i>
	TMV 1	Parameter 3	<i>K3</i>
	TMV 2	Parameter 4	<i>K4</i>
	TMV <i>n</i>	Parameter <i>n</i>	<i>Kn</i>

$$\begin{aligned}
 & \text{The cost price (Machine1)=} \\
 & = \text{PriceOperation1} \cdot K1 \cdot \text{parameter1} + \\
 & + \dots + \text{PriceOperation } n \cdot Kn \cdot \text{Parameter } n + \\
 & + \text{Price TMV1} \cdot \text{parameter1} \cdot K1 + \dots + \\
 & + \text{Price TMV } n \cdot \text{Parameter } n \cdot Kn.
 \end{aligned}$$

To use the above concept of calculating the cost of using a production unit in the process of manufacturing products, it is necessary to create operations manuals containing information on the name and cost of implementation (wages) of such operation, as well as reference parameters. Such handbooks can be supplemented with data on the estimated market value of performing such an operation. Thus, it is possible to simultaneously receive not only the cost of production, but also the estimated market value of sales. The latter is an integral part of determining the price of products and greatly facilitates the work with the customer for the sales department of the enterprise in providing a commercial offer on the conditions for manufacturing the order.

An example of such representation of information is given in Table 3.

**Table 3**

An example of the calculation of the production unit work cost

Unit	Processes/Used TMV	Dependence	Utilization rate
Surface-grinding machine	Installing/removing of part ( <i>P1</i> )	Number of details	1
	Settings ( <i>P2</i> )	For all orders	1
	Grinding ( <i>P3</i> )	Area, m <sup>2</sup>	1
	TMV 1 – abrasive wheel ( <i>P4</i> )	Area, m <sup>2</sup>	0.005
	TMV 2 – cooling liquid ( <i>P5</i> )	Area, m <sup>2</sup>	0.0001
	TMV <i>n</i> – electric power ( <i>P6</i> )	Area, m <sup>2</sup>	0.003

Based on this example, the cost of using the production unit will be calculated as follows:

$$\begin{aligned}
 P = & P1 \cdot \text{numbparts} \cdot 1 + P2 \cdot 1 \cdot 1 + P3 \cdot Sp \cdot 1 + \\
 & + P4 \cdot Sp \cdot 0.005 + P5 \cdot Sp \cdot 0.0001 + P6 \cdot Sp \cdot 0.003,
 \end{aligned}$$

where *Sp* – the area of processing one part × the number of parts in the order; *Pn* – the average cost of a unit of operation or unit of inventory from the database of the management system database.

Formation of the cost of the operation in the developed control system is carried out by carrying out the normalization and processing of the sample of the received data. The more the sample is processed, the more accurate is the average cost of the operation. In practice, the method of deducing the cost of an operation for calculating the average amount of time necessary to perform an operation is successfully applied. This takes into account the average wage level of the specialist in the region and the number of hours worked per month. To create this database, a separate module of the automated control system is used.

For TMV, the indicator Pn represents the cost of materials with the addition of delivery costs, etc.

It is possible to expand the management system by introducing modules to calculate the depreciation of equipment and other items of expenditure important to the enterprise. However, it should be borne in mind that an increase in the number of used parameters in the calculation of production costs can lead to an uncontrolled result and a price (cost) of products being inconsistent with the market level.

Usually it is possible to use in pricing the currency that is adopted at the enterprise for administrative accounting.

The concept of calculating the cost of using each production unit for manufacturing the order provides a flexible tool for the management of the company. This makes it possible to form an unlimited number and variety of

models of technological units in the automated control system, to supplement and improve parameters for a more accurate determination of the cost of production.

Directories of operations can be supplemented with a convenient tool for determining the cost (wages) of such operation, based on the data of the standardization and the average market level of wages for the involved specialists (workers). An example of the implementation of the proposed concept in the ACS for the enterprise «Dinas» is shown in Fig. 1.

Modernization of the management system of engineering enterprises is a cyclical process in which updating and improving the performance of one site inevitably requires or provides the possibility of upgrading the next.

Since it is impossible to calculate any order without calculation of production components and materials, forming a document «Order calculation», the sales employee actually creates a technological map – a task for the production site, the materials purchasing department, the planning department. Based on the principles of maximum use of available data in all business processes of the enterprise, we propose to use the data from the document «Order calculation» to form the task for production. If the calculation turns into an order, it is necessary to supplement with the necessary data, such as the date of shipment, contract number/account number, etc.

Кол-во	Прайс	Квалификация	Оклад	Часов	Количес...	Минут	Время	Тариф	Ед. изм.	Валюта
1	0.20000	Высекальщик 1 разр	8000	168	2550.000	05:28:11	84.60	0.03900	шт.	гривна
1000	0.18000	Высекальщик 1 разр	8000	168	2550.000	04:12:27		0.03000	шт.	гривна
5000	0.15000	Высекальщик 1 разр	8000	168	2550.000	03:55:37		0.02800	шт.	гривна
50000	0.09000	Высекальщик 1 разр	8000	168	2550.000	03:30:23	84.60	0.02500	шт.	гривна

a

Наименование	Операция/ТМЦ	Зависимость	Кратность	Ед. изм.
настройка	Установка станцфс	На весь заказ	1.00000000	шт.
обрывка	обрывка обля плос	Тираж продукции	1.00000000	шт.
высечка	Высечка ТМЗ	Тираж печатных лис	1.00000000	шт.
растворитель	Растворитель 647	На весь заказ	0.10000000	л.

b

**Fig. 1.** Photo of the operations handbook:

a – information about financial characteristics of the operation; b – information about technological characteristics of the operation

Thus, the enterprise almost instantly receives the document «Order», which contains:

- nomenclature and quantity of necessary materials;
- list of production sites with parameters for each of them;
- nomenclature of finished products for the further formation of shipping documents;
- list of additional services of subcontractors that should be ordered.

The use of the modernized document management system will increase the level of automation of the processes in the work of the materials procurement department.

For a modern machine building enterprise, the order flow must be continuous. Consequently, and the corresponding flow of information about the materials necessary for production are continuously changing. New orders form a list of necessary materials to order, which are already produced, partially or fully published materials from the warehouses of the enterprise, some materials are available, some should be purchased. It is impossible to quickly process this information without the use of automated management systems, which links the data of all these factors.

As part of the modernization of the management system at mechanical engineering enterprises, it is proposed to create an electronic online processing of all orders that are currently in work at the enterprise. For this, it is necessary to carry out an analysis for each material on the factor of the required quantity when placing an order, taking into account the quantity, issued from warehouses to production (used) at the present time. The obtained value is important at the time of treatment. Such data should be reduced to tabular forms showing the amount of actual availability and, accordingly, the number of materials and components required for procurement.

Thus, the purchasing department receives the information already in the processed and analyzed mind, which is actually important at the current moment. The information for the purchasing department for new orders falls in a few seconds after the document «Order calculation» is placed in the «Order» document, containing information about the direction of the task in the workflow.

Expansion of the functions of the ACS module «Procurement of materials» is possible in the direction of automatic creation of lists (tables) formed by certain types of materials or by the «supplier» parameter. Thus, it is possible to obtain a ready order for a supplier, a tender site and the like.

Such concept of interaction between departments of a manufacturing enterprise makes it possible to process and transfer information very quickly. Efficiency in order making is an absolute competitive advantage of any enterprise. By receiving the already processed information about them, which are necessary for purchases, the employees of the relevant department significantly reduce the working time necessary to perform their functions.

So, the management of the enterprise will have an opportunity to reduce the expenses for the maintenance of this department, while simultaneously receiving more efficient work, which is extremely promising for today. The use of modernized enterprise management systems means a transition to a higher stage of development, because they allow the company to most effectively realize its capabilities [14].

## 7. SWOT analysis of research results

*Strengths.* Strengths of this research include:

- increase in the information content of the system state data;
- increase in the speed of calculation/volume of processed information;
- reduction of time;
- simplify the workflow by automatically generating a number of documents;
- increase in the speed of processing orders;
- increase in the level of interaction between individual units.

*Weaknesses.* The weaknesses of research include:

- increase in the requirements for technical support to support a modernized automated management system;
- time costs for setting up the control system after optimization (one time);
- financial costs for the modernization of the automated control system (with a short payback time).

*Opportunities.* The implementation of the proposed solution in an industrial enterprise operating in the execution system of individual orders can greatly simplify the processing of data from warehouses and production lines and perform a quick analysis of the utilization of equipment. After this, the optimal method of order execution is selected, the necessary information is assigned to the relevant sections. For example, the purchasing department automatically receives a request for the purchase of certain consumables or components.

The direction of further research is connected with the study of possible ways of optimization of specialized ERP-systems for engineering enterprises.

*Threats.* Today, the market has a number of software products for automated enterprise management: SAP (Germany), Microsoft Dynamics AX (USA), IFS (Sweden), Epicor (USA), Oracle (USA). They have wide functionality and capabilities. However, because of their high cost and complexity, they are often unavailable for small and medium-sized enterprises.

## 8. Conclusions

1. It is established that for today the enterprises for the machine-building industry are increasingly using production for individual orders. Accordingly, in such cases, the system of calculating the cost of the order (Job-on-Order Costing). The Process Costing system is used for long and voluminous orders.

2. It is noted that when performing the calculation of the cost of an order, a number of parameters should be taken into account, such as materials, equipment and instruments for operations, duration of operations, personnel qualification. Obtaining and analyzing complete information about all the necessary indicators can be a challenge because of the low level of interaction between individual production units. This is especially problematic in the presence of a large number of orders of various types.

3. It is proposed to optimize the document management system by introducing changes in the process of calculating the cost of the order. For this purpose, it is proposed to create directories with complete information on operations and the means necessary for their implementation. In addition, the presence in the system of automated enterprise

management information on the loading of each type of technological equipment will make it possible to choose the optimal route for the implementation of a new order. Another advantage is the automatic generation of additional documents (such as a letter-order for the purchasing department, etc.). This will lead to a reduction in time spent on fulfilling orders and, accordingly, will increase the competitiveness of an enterprise in the market.

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