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Assessment the Cost-effectiveness of Information Support for the Business Processes of a Virtual Machine-building Enterprise in the Framework of Industry 4.0

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ABSTRACT

The features of the organization information support for business processes on the typical virtual machine-building enterprise (VME) with a multi-nomenclature nature of production in the framework of Industrial 4.0 were considered. It has been established that in accordance with the concept of Industry 4.0, namely with the individualization of production and consumption, a modern virtual machine-building enterprise must adapt to the production of goods in small batches, moreover in a large assortment and with frequent change of nomenclature in a wide range. It is shown that under these conditions, the effectiveness of the implementation of production processes directly depends on the effectiveness of information support at all stages of the product life cycle (PLC). A methodology is proposed for evaluating the effectiveness of information support for PLC processes in the conditions of multi-nomenclature production of a virtual engineering enterprise. The methodological basic concepts are web-mining and multi-agent technology. A comparative analysis of the activities of a typical VME was carried out, which showed that the introduction of information support tools increased the efficiency of VME business processes.

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NOMENCLATURE

PLC	Product Life Cycle	TVME	Typical VME
VME	Virtual Machine-building Enterprises		

1. INTRODUCTION

The development of the internet, information and communication technologies, sustainable communication channels, cloud technologies and digital platforms has led to the emergence of open information systems and global industrial networks that go beyond the boundaries of an individual enterprise and interact with each other. Such systems and networks have a transformative effect on all sectors of the modern economy and business and transfer industrial automation to a new, fourth stage of industrialization. Industry 4.0-transition to a fully automated digital production, controlled by intelligent systems in real time in constant interaction with the external environment, going beyond the boundaries of one enterprise, with the prospect of combining things and services into a global industrial network [1, 2]. Many developed countries and business giants are active participants in the fourth industrial revolution: state programs, commercial associations and nonprofit organizations are created with the goal of removing barriers to the creation of Industry 4.0.

The basis of Industry 4.0: interoperability, virtualization, decentralization and real-time operation. Cyberphysical systems, cloud computing and big data

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technologies, the internet of things are becoming increasingly popular in business, along with vertical and horizontal integration, virtualization and digitalization of the entire process of creating a value added chain [3].

Industry 4.0, thanks to the flexibility and adaptability provided by cyberphysical systems, will help to implement mass production on individual orders, which will reduce the price of products. The classical methods of organizing production suggested that only large batches of goods could be produced by the flow method. Thanks to the new principles of organizing production processes, it becomes possible to produce single products in an industrial way. Today, there is a steady trend towards a transition from tight centralized management of production processes to a decentralized model for collecting, processing information and making decisions. Moreover, the level of autonomy is constantly growing. Ultimately, such a system becomes an active component capable of independently managing its production process [4].

Industry 4.0 has led to the emergence of a new type of production, such as virtual, which does not have a fixed organizational and territorial structure, and in which the process of creating information for software-controlled technological equipment and the manufacture of the product itself can be distributed in time and space between many enterprises [5]. The most intensively indicated type of production is developing in the field of mechanical engineering, by acquiring the form of virtual machine-building enterprises (VME) [6, 7]. The key element determining the effectiveness of the VME functioning is a special information environment, implemented on the basis of a special applied information technology.

At the moment, in the publications of foreign and domestic authors, issues related to the justification of the economic efficiency of the creation and operation of VME have not been considered. The main reasons for this research gap is that the technology for creating, deploying and supporting the operation of VME in other countries lies in the field of private business and constitutes elements of know-how. In Ukraine, however, there is practically no experience in organizing such enterprises and, therefore, publications devoted to the problems associated with justifying the economic efficiency of creating and functioning of VME.

The main advantage of VME, which is the almost complete absence of fixed assets, also creates vulnerability for enterprises of this type, since a failure in information communications between subcontractors disrupts the coordination of the entire production process, which entails significant financial losses, up to the financial collapse of VME. Thus, the problem of ensuring the financial efficiency of VME basically boils down to the problem of ensuring the efficiency of information support for business processes in such enterprises.

The aim of the article is to set out the concept of organizing information support for business processes at the VME as typical production facilities within the framework of Industry 4.0, as well as to assess the cost-effectiveness of its implementation at the VME.

2. MATERIALS AND METHODS

VME lifecycle management methodology includes conceptual and methodological parts.

The VME concept is based on the following principles: a virtual enterprise searches for new partners with resources, knowledge and abilities corresponding to market needs for joint organization and implementation of this activity [8, 9].

Methodological support of VME lifecycle management involves the choice of a paradigm for creating the appropriate software, and within the framework of the chosen paradigm - the development of methods that ensure the creation and support of a VME unified and information space.

Thus, the most important characteristic of a virtual organization is a flexible, adaptive, dynamic network structure. Since such an information space does not exist in the real physical world, but is created through the information integration of the resources of partners (subcontractors). The information of VME activities was carried out within the framework of a concept that covers key aspects of the activity of such an enterprise, namely, planning production volumes, based on an analysis of the market situation, as well as the organization of production, by making an informed choice of subcontractors. Based on the features of VME described above, the methodological part of the methodology should be based on the agent-based programming paradigm [10], as the most appropriate to the specifics of VME. Within this paradigm, two methods have been developed: the method of information support of business processes of VME and the method of forming coordinating decisions by agents when choosing subcontractors for manufacturing products at the VME.

The method of information support of business processes of VME is based on the use of multiple agents in the form of one-page web resources. The generalized description of the method includes five stages, three of which are implemented when creating a multi-agent web-oriented environment, and the fourth and fifth - in the process of its functioning:

1. Development of an online store for the sale of VME products.
2. Development of the main site of the VME with the implementation of the functions of informing users about: the structure of the VME, additional characteristics of the products, the system of discounts, service.

3. Development of a set of reflexive agents in the form of doorway sites, the number of which coincides with the range of products manufactured by VME. In addition to information about a particular type of product, the agent carries information about the VME.
4. Formation of a plan for the production of VME products based on market analysis (this stage is implemented directly in the process of functioning of a multi-agent web-oriented environment).
5. Formation of a community of agents whose mission is to select subcontractors for the implementation of the plan for the production of VME products formed at the previous stage.

The fifth stage of the method of VME business processes informational support is the most critical for ensuring the effective functioning of the VME, since here the greatest number of production risks arise.

Formulate a formal model of the process of selecting subcontractors G when ordering S, taking into account input information about conditions, terms and quality:

$$G_S = \left\langle A_S, D_S, C_D, T_A, E_D, P_E, A^T, A^D, C^D, D^E, E^P \right\rangle, \quad (1)$$

where T_A – many requirements regarding the subcontractor selection process; A_S – the set of all technological operations of filling S; D_S – a set of units (operations), which includes order S; C_D – subcontractors for performing operations from the plurality D_S; P_E – set of parameters of the operation D_S elements E_D; A^T, A^D – mapping, are set by the technological operations of order manufacturing; C^D – mapping is determined by the database; E_D – set of elements that are included in the transaction; D^E, E^P – are in the design documentation for the manufacture of the order (device).

Thus, based on the foregoing, describe the method of forming coordinating decisions by agents when choosing subcontractors for manufacturing products at the VME:

1. For each operation of selecting a subcontractor G_S for manufacturing order S select (using the mapping K_H - the result of the first recognizer in the created system) signs of potential conflicts $H^K : K_H \subseteq H_D$ and form a conflicting set of operations from A_S.
2. Determine the type of each potential collision. Form two subsets - signs of resolvable K_H^+ and insoluble K_H^- collisions in an automated mode. For insoluble collisions, execute a request to the user to form possible coordinating decisions.
3. For each resolvable collision, from K_H^+ determine the participating subcontractors (a subset $D_S = f^{-1}(K_H^+)$ as the full prototype of the signs of resolvable collisions).
4. By analyzing the subcontractors (suitable for performing the necessary operations– C^D) determine the previous subcontractors C_D participating in such an operation involved in the conflict and the corresponding recognizer.
5. Form the necessary restrictions O_T for the requirements of the execution of the order from A_S.
6. To verify the real existence of a collision by completing a request to the appropriate recognizer (determine the truth) $P^O(O_i) = P_j$).
7. In the event of a conflict (if $P^O(O_i) \neq P_j$) determine the method for resolving it using the existing apr`iority knowledge base for resolving typical conflicts.
8. Form a coordinating decision (from O_T) for each conflict identified and fill out a draft output form for the user.

3. RESULTS AND DISCUSSION

To verify the effectiveness of implementing the research results, it is necessary to analyze the financial activities of a typical VME (TVME) to determine the results of implementation supportive information of business processes [11-13] for the last three years of the activity of a typical VME - RSA "Vector" (hereinafter referred to as TVME). Moreover, the analysis is based on comparing the results of the activities of TVME without the introduction (2017, 2018) with the implementation (2019) of the described information support tools.

First of all, we will conduct an assessment of business activity [14]. It is aimed to analyze the results and effectiveness of the current main production activities of TVME. The value of the analysis of business activity lies in the formation of an economically sound assessment of the effectiveness and intensity of use of the organization's resources, as well as in identifying reserves for their increase. Reflect the main indicators of the enterprise in Table 1.

Analyzing Table 1, we can conclude that TVME operates at the expense of borrowed funds of customers. In 2019, the cost of production decreased, which should have reflected in revenue from sales and, accordingly, net profit in the negative direction, but with a decrease in the cost of production by 939 thousand c.u. net profit increased by 6.5 thousand c.u. The average headcount of TVME personnel is noticeably allocated - 4 people, which is associated with the virtual form of organization of such an enterprise.

To calculate the total liquidity ratio, it is necessary to summarize all the assets of the enterprise with weighting factors, depending on the speed of their

TABLE 1. Main technical and economic indicators of TVME

No	Indicator, thousand c.u.	2017	2018	2019
1	Income (revenue) from product sales	1605.3	1373.1	1394.1
2	Cost of sales	1104.8	1201.1	1107.2
3	Net profit	1.0	8.8	15.3
4	Equity	11.8	11.8	11.8
5	Current responsibility	694.7	262.9	357.7
6	Fixed assets	148.0	151.9	153.2
7	Current assets	580.9	261.1	353.7
8	Average number of personnel	2	4	4

feasibility, and assess liabilities by the maturity of obligations. Next, we calculated the total liquidity ratio of TVME taking into account the breakdown of assets into groups. At the final stage of applying the methodology, profitability ratios were calculated. Summary calculations are shown in Table 2.

Based on the data in Table 2, construct graphs that display the visibility of the results (Figures 1-4).

Turnover ratios bear a positive trend, as there is an increase in the indicator. This is due to the fact that the periods for which the full production cycle takes place became longer, and consequently, the profit increased.

It is necessary to track the ratio of the turnover of receivables and payables for the analyzed period (Figure 2).

TABLE 2. Summary performance indicators of TVME for 2017-2019 years

Name of indicator	2017	2018	2019	Rate of increase (Δ)
Asset turnover ratio	2.00	2.40	3.03	0.63
Current assets turnover ratio	2.26	3.26	4.53	1.27
Accounts receivable turnover ratio	5.76	7.23	15.78	8.55
Accounts payable turnover ratio	2.66	3.06	4.5	1.44
Inventory turnover ratio	3.04	4.87	3.85	1.02
Equity turnover ratio	38.9	34.93	27.15	-7.78
Accounts payable to total assets ratio	0.82	0.64	0.71	0.07
Total liquidity ratio	0.26	0.28	0.008	-0.272
Production profitability ratio	2.20	3.32	2.75	0.57
Return on sales ratio	0.00062	0.0064	0.01	0.0036
Direct cost margin	0.09	0.73	1.38	0.65

From Figure 2 it is seen that the accounts payable turnover ratio has a higher growth rate than the receivable turnover ratio. Those TVME manages to repay the borrowed funds for the production of the order faster than it receives funds for the purchased goods.

TVME profitability indicators for 2017-2019 in graphical form are shown in Figure 3.

Let us analyze the main indicators that directly affect the profit of the enterprise - the coefficient of profitability of direct costs, the coefficient of profitability of production. Figure 3 shows that the gross cost of TVME significantly decreased, which led to an increase in profit. An increase in the profitability ratio of production indicates an increase in the profitability of production due to the continuous improvement of the means of information support of business processes at TVME.

Figure 4 shows the main performance indicators of TVME. This figure illustrates the change in the coefficient of profitability of sales and the coefficient of total liquidity of the enterprise for 2017 - 2019. The overall liquidity ratio for a virtual manufacturing enterprise is very heterogeneous, because manufacturing enterprises are characterized by a direct relationship between the liquidity ratio and the financial stability of the enterprise. In our case, the liquidity ratio has the opposite value, since TVME exists at the expense of borrowed funds of customers without having fixed assets and stocks in stock.

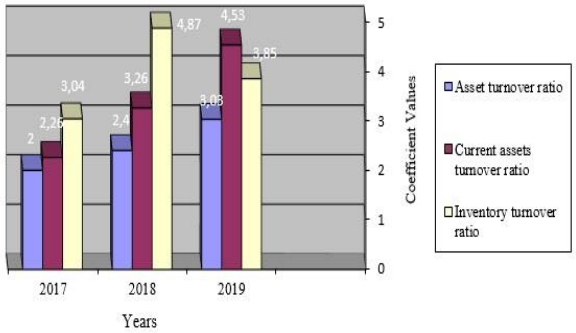

Figure 1. Turnover of TVME assets for 2017-2019 years

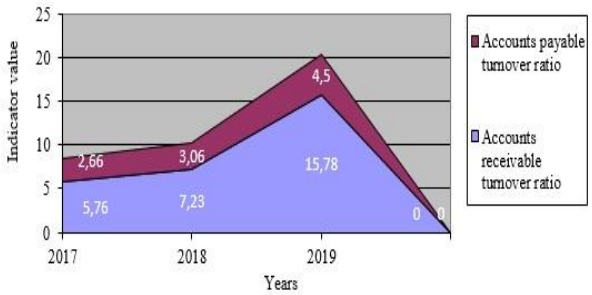

Figure 2. The ratio of the turnover of receivables and payables TVME for 2017-2019 years

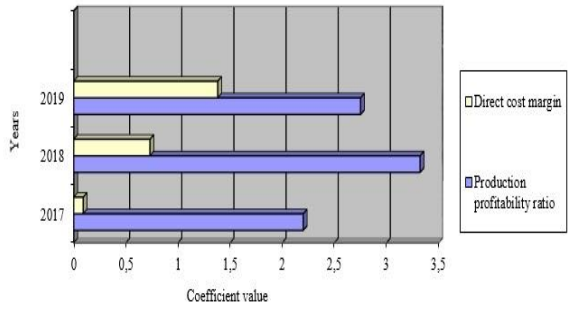

Figure 3. TVME profitability indicators for 2017–2019 years

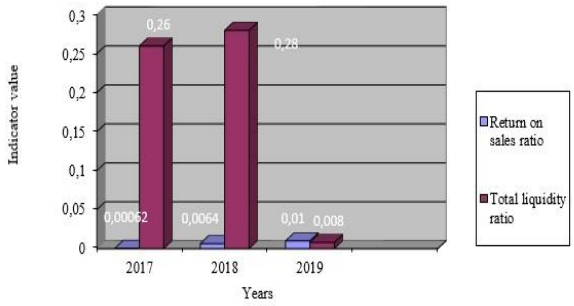

Figure 4. The main performance indicators of TVME for 2017-2019 years

4. CONCLUSION

It is shown that in the conditions of Industry 4.0, VMEs are one of the main types of production facilities. The concept of information of VME activity is presented, which covers two most important stages - technical and economic planning and technical preparation of production. The methodological basic concepts are web-mining and multi-agent technology. A comparative analysis of the activities of a typical VME was carried out, which showed that the introduction of information support tools increased the efficiency of VME business processes.

The main significance of the results obtained is that their application in practice makes it possible, on the one hand, to expand the capabilities of top managers of traditional manufacturing engineering enterprises to diversify order fulfilment by selecting subcontractors, and, on the other hand, to automate the lifecycle management process of existing VMEs.

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Persian Abstract

چکیده

ویژگیهای پشتیبانی اطلاعات سازمان برای فرآیندهای تجاری در شرکت ماشین سازی مجازی معمولی (VME) با ماهیت تولید چند نامی در چارچوب Industrial 4.0 در نظر گرفته شد. مشخص شده است که مطابق با مفهوم صنعت ٤,٠ ، یعنی با خصوصی سازی تولید و مصرف ، یک شرکت ماشین سازی مجازی مدرن باید با تولید کالا در دسته های کوچک ، علاوه بر این در یک مجموعه بزرگ و با تغییرات مکرر ، سازگار شود. از نامگذاری در طیف گسترده ای. نشان داده شده است که تحت این شرایط ، اثربخشی اجرای فرآیندهای تولید مستقیماً به تأثیر پشتیبانی اطلاعات در تمام مراحل چرخه عمر محصول (PLC)بستگی دارد. یک روش برای ارزیابی اثربخشی پشتیبانی اطلاعات برای فرآیندهای PLC در شرایط تولید چند نامی یک شرکت مهندسی مجازی پیشنهاد شده است. مفاهیم اساسی روش شناختی ، وب کاوی و فناوری چند عاملی است. تجزیه و تحلیل مقایسه ای از فعالیت های یک VME معمولی انجام شد ، که نشان داد معرفی ابزارهای پشتیبانی اطلاعات باعث افزایش کارایی فرآیندهای تجاری VME می شود.