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METHOD FOR EVALUATING THE EFFICIENCY OF UPGRADING SPECIALIZED INFORMATION SYSTEMS

The **subject** of the study in the article is the process of modernization of automated workingplaces of specialized information systems of the organization. The **purpose** of the work is to develop a method for evaluating the efficiency of modernization of automated workingplaces specialized information systems, which allows, on the basis of analysis of the degree of automation of workingplaces and its impact on the performance of an organization, to determine a rational variant of the project solution in the context of budget constraints. The following **tasks** are solved in the article: analysis of the peculiarities of evaluating the effectiveness of specialized information systems; substantiation of influence of completeness and reliability of data of receiving information from automated workingplaces on the performance indicators of the organization; development of forming stages of the method of estimating the efficiency of modernization of automated workingplaces; practical testing of the method. The following **methods** are used: system analysis, functional-cost analysis, modeling of decision making. The following **results** were obtained: a method of evaluating the effectiveness of modernization of automated workingplaces of specialized information systems, which can be applied to organizations whose performance indicators are directly dependent on the completeness and reliability of the primary data of business processes, is proposed;; the calculation of the rational version of the modernization of the automated workingplaces of the specialized information system of the regional blood service center with limited financing of the system modernization using the method was performed. **Conclusions**: application of the method of efficiency estimation of modernization at the stage of planning of expenses for improvement of the automated workingplaces of the specialized information system of the organization will allow to identify the automated workingplaces on which the increase of degree of automation will lead to the most significant potential values of activity indicators of the organization. The practical implementation of the method makes it possible to conclude on its performance both at the stage of modernization of the information system of the organization and at the stage of development of the new system.

Keywords: specialized information systems; efficiency of modernization; automated workingplaces; completeness and reliability of data; degree of automation; cost resources.

Introduction

The activity of any organization can be evaluated in terms of the completeness of its mission at certain resource costs [1]. The completeness of the mission is determined by a set of performance indicators that objectively characterize the quality of the organization.

The actual values of every activity indicator depend to a large extent on the necessary and possible completeness and reliability of the data entered and processed in the course of performing business processes in the workingplace by staff. The reliability and completeness of the data, in turn, is determined by the technical characteristics of the measuring equipment, computer hardware and software, depending on which differentiate the degree of automation of jobs. Partial or complete lack of proper hardware and software results in staff errors during manual data entry and processing operations at the workingplace [2]. The corresponding increase in the degree of automation of workingplaces allows to reduce the probability of mistakes when entering information by personnel, which significantly increases the performance targets of the organization. Each organization has a desire to continuously improve performance, which is determined by the requirements of competitiveness in the market [3]. Usually a specialized information system (SIS) is implemented and operates in the organization with the corresponding current degree of automation of data entry and processing in the workingplace [4]. In practice, operating SIS typically do not provide one hundred percent completeness and reliability of business process information support data, which may determine the need for upgrading hardware and software in their respective workingplaces [5]. Such modernization, especially for budget organizations, is usually carried out under pre-limited funding. The purpose of modernization is to ensure the maximum completeness and reliability of information support data, taking into account their impact on the performance of the organization.

Considering the existing impact of certain data from the set of all data of business process information support on different performance indicators, as well as the ambiguous influence of individual performance indicators from the whole population on the fulfillment of an organization's mission, it can be concluded that the task of preliminary assessment of SIS efficiency before modernization of workingplaces is relevant.

This task requires the development of a method for assessing the effectiveness of the modernization of automated SIS jobs, which will allow, given the limited funding, the current degree of automation of the jobs at which the input and data of information support is carried out, to determine in advance possible options for design solutions of staffing with technical equipment and software necessary for their operation, which in turn will provide the highest possible completeness and reliable Th data information support and therefore improve the targets of the organization.

Analysis of recent research and publications

The issue of SIS efficiency arises on the basis of the quality requirements of the organization's performance because only the proper functioning of the SIS provides

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appropriate collection of input data to improve the organization's business processes. For example, the activities of blood establishments are evaluated by a number of indicators that are directly determined by the strict adherence to international requirements for the quality of blood components [6–7].

Various groups of methods are widely used to evaluate SIS efficiency, such as cost (boiler, functional point, total cost of ownership), direct result evaluation (consumer index, cost source, economic value added calculation), process ideality estimation (industry average, value for industry), measurement, qualimetric (cumulative economic effect, balanced indicators), investment analysis (calculation of the payback period of investment, determination of internal profitability, index p fisheries investment, average return on investment), financial analysis (functional-value analysis, calculation of return on investment, rapid economic justification), qualitative (calculation of total value of opportunities, analysis of cost behavior, analysis of life cycle of systems), probable probability economy), etc. [8–9].

The method of evaluating the efficiency of the modernization of automated SIS workingplaces under development can be based on a functional-cost analysis method that seeks to find the maximum ratio of the effect of functioning to the cost of achieving this effect [10, 12]. The effect of the functioning of the SIS is usually understood as the degree of achievement of the goals set before the SIS [13]. In this paper, the effect of functioning means obtaining the maximum possible indicators of the organization's activity due to the maximum completeness and reliability of data of information support of business processes in separate automated workingplaces [14].

The purpose and objectives of the publication

The purpose of the article is to substantiate and present the developed method of evaluating the efficiency of modernization of automated workingplaces of the SIS organization in the conditions of existing restrictions on the expendable resources for the acquisition of automated workingplaces.

To achieve this goal, the following tasks were solved:

- a list of initial data on information support has been formed, which should be used in the development of the method;
- the influence of completeness and reliability of data from automated workingplaces on the performance indicators of the organization is substantiated;
- method stages were developed;
- a practical test of the method was performed.

Materials and methods

To build a method for assessing the effectiveness of SIS as output data are:

- a set of all data of information support of business processes, $DS = \{ds_{ijkh}\}$. Indexes i, j, k, h determine indexes of process, element, action, and data respectively, and vary within ranges $i = \overline{1, I}$, $j = \overline{1, J}$, $k = \overline{1, K}$, $h = \overline{1, H}$;
- the degree of automation of data entry $\gamma = \overline{1, 6}$ [15];
- an integrated workload factor ξ_{wp_ω} that reflects the importance of the impact of workingplace-generated data on relevant organizational performance;
- restriction on the spending resources of staffing jobs with hardware and software C_{cl}.

Staff positions can be formally represented as a set as follows:

$$WP = \{wp_\omega\}, \quad (1)$$

where WP – a set of all staff jobs; wp_ω – ω -th staff workingplace; ω - index of the workingplace number that varies in range $\omega = \overline{1, \Omega}$.

Information support data that is entered during the execution of actions (operations) of business processes in the ω -th workingplace of personnel are denoted as $\{ds_{ijkh}\}_\omega$ and are a subset of all data of information support of business processes $\{ds_{ijkh}\}$:

$$\{ds_{ijkh}\}_\omega \subseteq \{ds_{ijkh}\}. \quad (2)$$

All data of business process information support can be grouped by the workingplaces of the staff at which the data is entered. Each data set is characterized by the coefficients of importance of the data in relation to the impact on each performance indicator of the organization, so that for each workingplace wp_ω by the integrated workload factor $\xi_{wp\omega}$ can be determined using the model [14].

The sum of the weighting coefficients for all workingplaces is equal 1:

$$\Xi = \{\xi_{wp_\omega}\}, \sum_{\omega=1}^{\Omega} \xi_{wp_\omega} = 1, \quad (3)$$

where Ξ – a set of integrated weighting factors for all workingplaces; ξ_{wp_ω} – integrated weighting factor of the workingplace wp_ω.

Each workingplace of the personnel wp_ω can be completed with technical means necessary for data processing with the software which defines degree of automation of data input γ during performance of actions (operations) of elements of processes on this workingplace, and, accordingly, define degree of automation of the workingplace $wp_{\omega\gamma}$ (fig. 1) [14].

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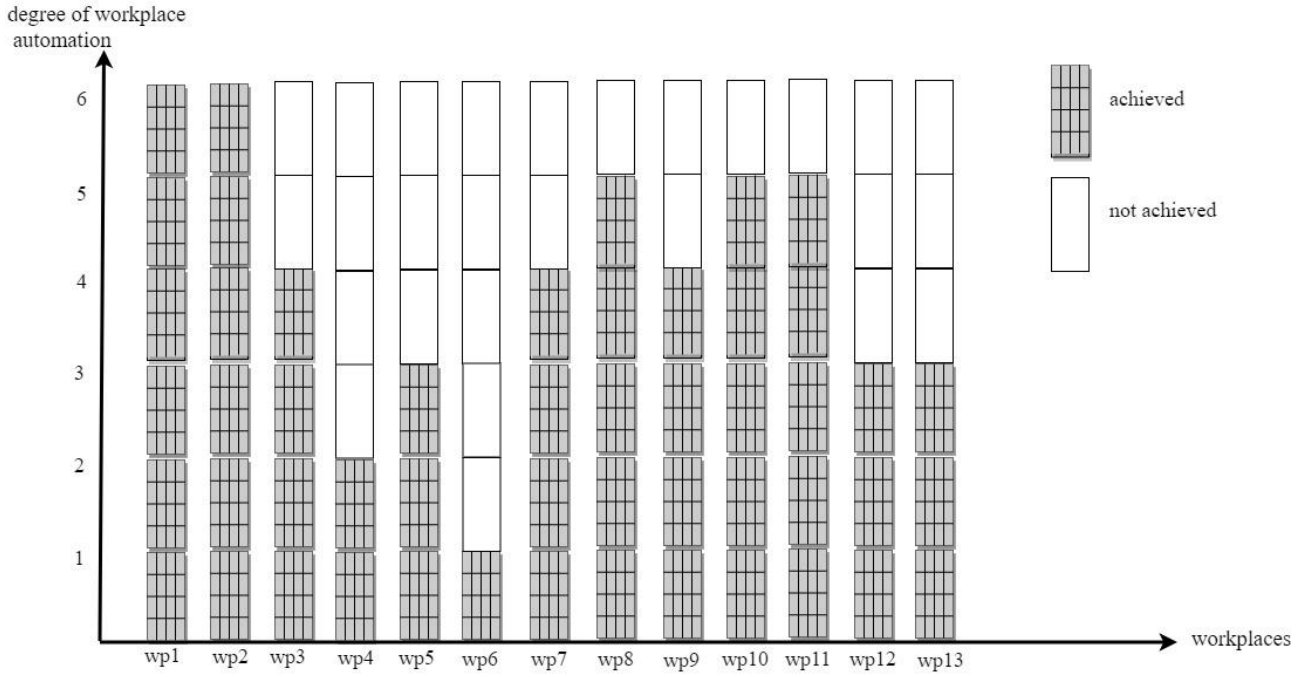

Fig. 1. Acquisition of workingplaces by technical means and the software for functioning of SIS according to degree of their automation

For each automated workingplace in the SIS, the degree of automation γ of the workingplace $wp_{\omega\gamma}$ can be determined, according to which an integrated indicator of the level of reliability of the received data $\theta_{\omega\gamma}$ at the workingplace $wp_{\omega\gamma}$ can be set according to [2].

Modernization of SIS automated workingplaces will effectively affect the functioning of SIS as a whole in terms of improving the performance of the organization. Thus for each workingplace the partial indicator of effect of functioning of each workingplace, which is a multiplication of the integrated coefficient ξ_{wp_ω} of workingplace weight $wp_{\omega\gamma}$ by the integrated indicator of the level of reliability of the received data at the workingplace at the corresponding degree of its automation (table 1). The effect of the functioning of the SIS as a whole is the effect of the functioning of each workingplace with the appropriate degrees of automation of these workingplaces and aims to maximize the value:

$$Fl = \sum_{\omega=1}^{\Omega} \theta_{\omega\gamma}\xi_{wp_\omega} \to \max, \qquad (4)$$

where Fl – the effect obtained from the functioning of the SIS, taking into account the integrated weighting coefficient ξ_{wp_ω} for each workingplace $wp_{\omega\gamma}$ and the integrated indicator of the level of reliability $\theta_{\omega\gamma}$ of the data obtained at that workingplace $wp_{\omega\gamma}$ with the appropriate degree of automation γ.

Table 1. *Formalized presentation of partial performance indicators of each workingplace to determine the total effect of the functioning of the SIS, depending on the degree of automation of jobs*

The degree of automation $\gamma=[1-6]$	$\theta_{\omega\gamma}$	wp_1	…	wp_ω	…	wp_Ω
$\gamma=6$	0,997	$\theta_{16}\xi_{wp_1}$	…	$\theta_{\omega6}\xi_{wp_\omega}$	…	$\theta_{\Omega6}\xi_{wp_\Omega}$
$\gamma=5$	0,990	$\theta_{15}\xi_{wp_1}$	…	$\theta_{\omega5}\xi_{wp_\omega}$	…	$\theta_{\Omega5}\xi_{wp_\Omega}$
$\gamma=4$	0,988	$\theta_{14}\xi_{wp_1}$	…	$\theta_{\omega4}\xi_{wp_\omega}$	…	$\theta_{\Omega4}\xi_{wp_\Omega}$
$\gamma=3$	0,985	$\theta_{13}\xi_{wp_1}$	…	$\theta_{\omega3}\xi_{wp_\omega}$	…	$\theta_{\Omega3}\xi_{wp_\Omega}$
$\gamma=2$	0,980	$\theta_{12}\xi_{wp_1}$	…	$\theta_{\omega2}\xi_{wp_\omega}$	…	$\theta_{\Omega2}\xi_{wp_\Omega}$
$\gamma=1$	0,978	$\theta_{11}\xi_{wp_1}$	…	$\theta_{\omega1}\xi_{wp_\omega}$	…	$\theta_{\Omega1}\xi_{wp_\Omega}$

The effect obtained from the operation of the SIS will be maximized while providing the highest degree of automation $\gamma=6$ at each workingplace $wp_{\omega\gamma}$. But increasing the degree of automation of each workingplace requires the appropriate spending resources to buy the hardware and software for those jobs.

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Consideration should be given to analyzing the cost of workingplace resources:

- the organization implements the SIS. For each workingplace, which generates data that affects the performance of the organization, and the corresponding degree of workingplace automation (starting from the first), it is possible to determine the total cost for each degree of automation;

- the organization is upgrading the SIS. The composition of the hardware and software (if any) is analyzed for each workingplace, the current level of automation is determined, the additional costs are determined at the transition to the possible higher levels due to the modernization of existing hardware or software, or the purchase of new ones.

Thus, the expenditures $C_{wp_{\omega\gamma}}$ required for manning the workingplace wp_ω with hardware and software to achieve the appropriate degree of automation γ can be summarized as follows in table 2:

Table 2. *Formalized representation of the costs of modernization (creation) of automated workingplaces for the formation of costs for the modernization of SIS*

The degree of automation $\gamma=[1-6]$	wp_1	…	wp_ω	…	wp_Ω
$\gamma=6$	$C_{wp_{16}}$	…	$C_{wp_{\omega 6}}$	…	$C_{wp_{\Omega 6}}$
$\gamma=5$	$C_{wp_{15}}$	…	$C_{wp_{\omega 5}}$	…	$C_{wp_{\Omega 5}}$
$\gamma=4$	$C_{wp_{14}}$	…	$C_{wp_{\omega 4}}$	…	$C_{wp_{\Omega 4}}$
$\gamma=3$	$C_{wp_{13}}$	…	$C_{wp_{\omega 3}}$	…	$C_{wp_{\Omega 3}}$
$\gamma=2$	$C_{wp_{12}}$	…	$C_{wp_{\omega 2}}$	…	$C_{wp_{\Omega 2}}$
$\gamma=1$	$C_{wp_{11}}$	…	$C_{wp_{\omega 1}}$	…	$C_{wp_{\Omega 1}}$

In the conditions of limitation of expenditures on manning workingplaces $\{wp_\omega\}$ by hardware and software and gradual increase of the degree of automation of each workingplace, it becomes necessary to determine the list of those workingplaces $\{wp_\omega\}'$ from the whole set $\{wp_\omega\}$, which increase the degree of automation to the appropriate level and give the maximum possible effect of the functioning of the SIS as a whole.

Since the modernization of the SIS involves consideration of options $\{v_n\}$ for completing one or more automated workingplaces with hardware and software, the cost of acquiring hardware and software $C_{wp_{\omega\gamma}}$ to transfer the workingplace $wp_{\omega\gamma}$ to another degree of automation can be calculated for each variant $v_{wp\omega\gamma}$ of the implementation of completing the workingplace.

To evaluate the effectiveness of the SIS modernization, a method is proposed, which consists of the following stages:

Stage 1. Determine the current degree of automation γ for each workingplace $wp_{\omega\gamma}$ during the execution of business processes (related to the current SIS implementation).

Stage 2. Determine partial performance indicators for each workingplace with the appropriate degree of automation and the cost of upgrading, starting from the next to the current one. In the case of SIS implementation, all the degrees of workingplace automation and the corresponding costs of hardware and software are taken into account.

Stage 3. Calculation of the values of the effect of the functioning of the SIS as a whole for each variant of the modernization of the set of workingplaces, taking into account the coefficients of the weight of the workingplaces

$$Fl=\sum_{\omega=1}^{\Omega}\theta_{\omega\gamma}\xi_{wp_\omega}. \quad (5)$$

Stage 4. Ratio of the values of the effect of functioning with the cost of hardware and software for each of the options, checking for compliance with the specified cost limit, the search for a rational option by the criterion of maximum (4).

To perform the calculations, it is advisable to use well-known design decision algorithms, such as the MS EXCEL, which is designed to solve linear optimization problems.

Results of the studies and their discussion

Practical testing of the method of estimating the efficiency of modernization of the automated workingplaces of specialized information systems was performed on several business processes of the organization of the Municipal Institution of Health Protection the Kharkiv Regional Center of Blood Service. Namely, business processes of donation, centrifugation of blood, distribution of blood into components, marking of blood products at the appropriate posts of the operating nurse, technician, nurse of the fractionation station, medical registrar of testing (fig. 2). At these workingplaces, the current degree of automation was determined: the nurse of operating room has the first degree of automation; workingplace of technician - the second one; fractionation nurse's workingplace - the first one; the workingplace of the medical registrar of

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approbation - the third. Expenditure on the purchase of technical equipment and software for the modernization of these workingplaces is 1000000 UAH. To find a rational solution for the modernization project for each of the identified workingplaces, a method for assessing the effectiveness of the modernization of the SIS was applied.

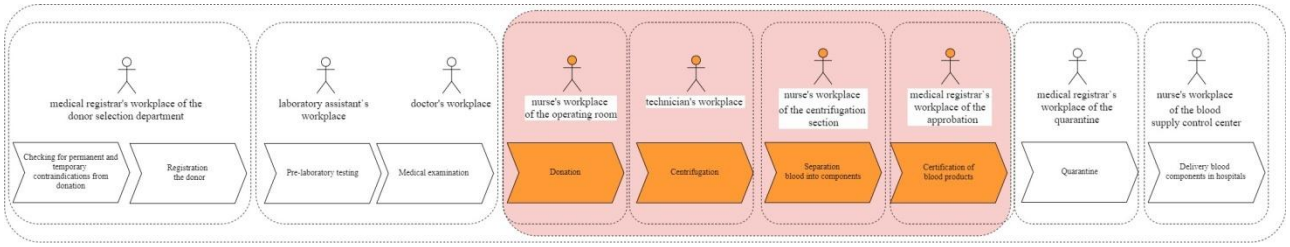

Fig. 2. Staff workingplaces for implementing a fragment of the business processes of the blood service center

The task of finding a rational variant of project solutions for the workingplaces of the operating room nurse, technician, nurse of the fractionation station, medical registrar of approbation is solved with the limitations of the expenditures on modernization. The calculations were made using the MS EXCEL module. Fig. 3 presents the results of the calculations to determine the rational options for designing workingplaces.

Output data and restrictions:

Manning cost`s workplaces < = 1000000 UAH

The current degree of automation of nurse's workplace of the operating room **-first;**

The current degree of automation of technician's workplace **- second;**

The current degree of automation of nurse's workplace of the centrifugation section **- first;**

The current degree of automation of medical registrar`s workplace of the approbation **- third.**

Effect of functioning of workplaces depending on degree of automation

Workplaces/ degree of automation	first	second	third	fourth	fifth	sixth
nurse's workplace of the operating room	0,3912	0,392	0,394	0,3952	0,396	0,3988
technician's workplace		0,098	0,0985	0,0988	0,099	0,0997
nurse's workplace of the centrifugation section	0,2934	0,294	0,2955	0,2964	0,297	0,2991
medical registrar`s workplace of the approbation			0,197	0,1976	0,198	0,1994

Manning cost`s to provide every degree of automation for each workplace (UAH)

Workplaces/ degree of automation	first	second	third	fourth	fifth	sixth
nurse's workplace of the operating room	100000	110000	130000	150000	200000	250000
technician's workplace		140000	180000	250000	300000	400000
nurse's workplace of the centrifugation section	100000	105000	110000	140000	180000	200000
medical registrar`s workplace of the approbation			300000	400000	500000	600000

The choice of the optimal variant of the design solution for each workplace

Workplaces/ degree of automation	first	second	third	fourth	fifth	sixth
nurse's workplace of the operating room	0	0	0	1	0	0
technician's workplace	0	1	0	0	0	0
nurse's workplace of the centrifugation section	0	0	1	0	0	0
medical registrar`s workplace of the approbation	0	0	0	0	0	1

Fig. 3. The results of the calculations to determine the rational variants of project solutions for workingplaces

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Based on the results of the calculations, within the limits of the expendable resources, a rational variant of workingplace modernization was determined, according to which the degree of automation of the workingplace of the operating room nurse could be increased from the first to the fourth; the degree of the technique's workingplace will not change and will remain the second; the degree of automation of the fractionation nurse's workingplace can be increased from the first to the third; the degree of automation of workingplace of the medical registrar of approbation can be increased from the third to the sixth.

The results of the work were discussed at the scientific-practical conference "Topical issues of clinical and industrial transfusion" (Kharkiv, September 12-13, 2019).

Conclusions and prospects for further development

The use of the developed method for assessing the effectiveness of SIS modernization in determining the implementation of SIS allows to determine the configuration of workingplaces by hardware and software so as to ensure the maximum completeness and reliability of the data entered in these workingplaces within the allocated cost resources, and, accordingly, lead to the most significant potential values of the organization's performance.

The results obtained can be used as a basis for further detailing the selection of hardware and software with different qualitative characteristics (in accordance with different costs for their acquisition), which requires input instead of a fixed value of costs to achieve a certain degree of automation of price zones.

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МЕТОД ОЦІНЮВАННЯ ЕФЕКТИВНОСТІ МОДЕРНІЗАЦІЇ СПЕЦІАЛІЗОВАНИХ ІНФОРМАЦІЙНИХ СИСТЕМ

Предметом дослідження в статті є процес модернізації автоматизованих робочих місць спеціалізованих інформаційних систем організації. **Мета** роботи – розробка методу оцінювання ефективності модернізації автоматизованих робочих місць спеціалізованих інформаційних систем, який дозволяє на основі аналізу ступеню автоматизації робочих місць та його впливу на показники діяльності організації визначити раціональний варіант проєктного рішення в умовах обмежень бюджету. В статті вирішуються наступні **завдання**: аналіз особливостей оцінювання ефективності спеціалізованих інформаційних систем; обґрунтування впливу повноти та достовірності даних отримання інформації з автоматизованих робочих місць на показники діяльності організації; розробка формування етапів методу оцінювання ефективності модернізації автоматизованих робочих місць; практична апробація застосування методу. Використовуються такі **методи**: системний аналіз, функціонально-вартісний аналіз, моделювання прийняття управлінських рішень. Отримано наступні **результати**: запропоновано метод оцінювання ефективності модернізації автоматизованих робочих місць спеціалізованих інформаційних систем, який може бути застосовано для організацій, показники діяльності яких безпосередньо мають залежність від повноти та достовірності первинних даних бізнес-процесів; із застосуванням методу виконано розрахунок раціонального варіанту модернізації автоматизованих робочих місць спеціалізованої інформаційної системи обласного центру служби крові при обмеженому фінансуванні модернізації системи. **Висновки**: застосування методу оцінювання ефективності модернізації на етапі планування витрат на вдосконалення автоматизованих робочих місць спеціалізованої інформаційної системи організації дозволить визначити ті автоматизовані робочі місця, на яких підвищення ступеню автоматизації приведе до найбільш вагомих потенційних значень показників діяльності організації. Практична реалізація методу дозволяє зробити висновок щодо його працездатності як на етапі модернізації інформаційної системи організації, так і на етапі розробки нової системи.

Ключові слова: спеціалізовані інформаційні системи; ефективність модернізації; автоматизовані робочі місця; повнота та достовірність даних; ступінь автоматизації; витратні ресурси.

МЕТОД ОЦЕНИВАНИЯ ЭФФЕКТИВНОСТИ МОДЕРНИЗАЦИИ СПЕЦИАЛИЗИРОВАННЫХ ИНФОРМАЦИОННЫХ СИСТЕМ

Предметом исследования в статье является процесс модернизации автоматизированных рабочих мест специализированных информационных систем организации. **Цель** работы – разработка метода оценивания эффективности модернизации автоматизированных рабочих мест специализированных информационных систем, который позволяет на основе анализа степени автоматизации рабочих мест и их влияния на показатели деятельности организации определить рациональный вариант проектного решения в условиях ограничений бюджета. В статье решаются следующие **задачи**: анализ особенностей оценивания эффективности специализированных информационных систем; обоснование влияния полноты и достоверности данных получения информации с автоматизированных рабочих мест на показатели деятельности организации; разработка формирование этапов метода оценивания эффективности модернизации автоматизированных рабочих мест; практическая апробация применения метода. Используются следующие **методы**: системный анализ, функционально-стоимостный анализ, моделирования принятие управленческих решений. Получены следующие **результаты**: предложен метод оценивания эффективности модернизации автоматизированных рабочих мест специализированных информационных систем, который может быть применен для организаций, показатели деятельности которых непосредственно имеют зависимость от полноты и достоверности первичных данных бизнес-процессов; выполнен расчет рационального варианта модернизации автоматизированных рабочих мест специализированной информационной системы областного центра службы крови при ограниченном финансировании модернизации системы с применением предложенного метода. **Выводы**: применение метода оценивания эффективности модернизации на этапе планирования расходов на совершенствование автоматизированных рабочих мест специализированной информационной системы организации позволит определить те автоматизированные рабочие места, на которых повышение степени автоматизации приведет к наиболее весомым потенциальным значениям

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показателей деятельности организации. Практическая реализация метода позволяет сделать вывод о его работоспособности как на этапе модернизации информационной системы организации, так и на этапе разработки новой системы.

Ключевые слова: специализированные информационные системы; эффективность модернизации; автоматизированные рабочие места; полнота и достоверность данных; степень автоматизации; расходные ресурсы.

Бібліографічні описи / Bibliographic descriptions

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