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IMPROVEMENT OF THE ENTERPRISE INFRASTRUCTURE EVALUATION METHOD

Об'єктом дослідження є інфр структур підприємств . Основним з вд нням інфр структури підприємств є з безпечення доступності IT-сервісів і прогр много з безпечення для користув чів і підтримк зрост ння бізнесу. Основним недоліком існуючого процесу оцінюв ння інфр структури підприємств є визн чення основних її компонентів. Одним з н йбільш проблемних місць є оцінюв ння інфр структури підприємств для визн чення впливу від впров дження нового IT-сервісу в умов х постійної зміни функціон льних вимог кінцевих користув чів.

Н основі результ тів проведеного н лізу проблем оцінюв ння інфр структури т існуючих в рі нтів терміну «інфр структур підприємств » визн чено основні елементи інфр структури підприємств . З пропонов но визн чити інфр структуру підприємств як н бір вз ємопов'яз них IT-сервісів, інформ - ційних т комунік ційних технологій, об'єдн них комп'ютерною мережею підприємств .

В ході дослідження проведено н ліз основних методів оцінюв ння інфр структури підприємств , визн чено їх перев ги т недоліки. В результ ті н лізу процесу оцінюв ння інфр структури підприємств з пропонов но удоскон лений метод оцінюв ння інфр структури підприємств .

З пропонов ний метод, н відміну від існуючих, поєднує кількісну оцінку витр т і якісну оцінку компонентів оновленої інфр структури підприємств , що дозволяє комплексно оцінити його інфр структуру і сформув ти рекоменд ції щодо з стосув ння обр ного IT-сервісу.

Перев г з пропонов ного методу поляг є в тому, що він д є можливість сформув ти попередню оцінку пл нов них змін в інфр структурі підприємств і тим с мим відмовитися від проведення змін в р зі їх низької ефективності. Відзн чено, що будь-як модифік ція інфр структури підприємств призводить до зміни пок зник оцінки його якості. Отже, виявлення дин міки пок зник оцінки якості дозволить контролюв ти рівень якості інфр структури підприємств . Н копичен ст тистик д є можливість виявити тренди і н основі їх н лізу своєч сно прийняти рішення про необхідність змін в інфр структурі підприємств з метою його д пт ції до нових умов.

Результ ти оцінки інфр структури підприємств т кож можуть бути використ ні для розробки упр влінських рішень щодо розвитку і вдоскон лення підприємств .

Ключові слова: *інфр структур підприємств , комплексн оцінк , якісн оцінк , витр ти н упр вління інфр структурою підприємств , впров дження нового IT-сервісу.*

1. Introduction

Effective and sustainable development of a modern enterprise requires an appropriate infrastructure, and managing its operation is impossible without a comprehensive evaluation of its effectiveness. It is possible to determine the quality of the enterprise infrastructure (EI) when solving two interrelated tasks [1]:

– definition of baseline indicators reflecting the processes and results of the infrastructure of the enterprise;

– selection and justification of a set of indicators for evaluating the performance of infrastructure support of an enterprise.

The results of the EI evaluation can be used to develop management decisions on the development and improvement of the enterprise, as well as the formation of strategic plans for the development of its infrastructure [2, 3]. The result of the EI evaluation is affected by changes from the implementation of new requests for changes in the functional requirements of end users that require EI re-evaluation, a comparison of the obtained results and the formation of management influences on the received deviations.

Therefore, it is relevant to study and improve the existing methods for evaluating infrastructure enterprises, since the effective development of an enterprise requires the availability of an appropriate infrastructure, as well as the management of its functioning processes.

2. The object of research and its technological audit

The object of research is the enterprise infrastructure.

Solving the problems of analyzing the EI operation efficiency can be carried out using both general methodologies for evaluating the quality of systems, as well as using special techniques adapted for evaluating EI. Among the common universal methods of quality evaluation are the following [4, 5]:

– cost-benefit analysis method, which provides a comparison of the benefits (economic and social effects) derived from the operation of the system, and the costs of supporting its performance over a certain period of time;

– cost-effectiveness analysis method, associated with the evaluation of the obtained effects, not in monetary

terms, but in physical units. The method is used in cases where it is difficult or impossible to measure the effect in terms of value;

– cost-utility analysis method, which implies a comparison of monetary costs and utility values obtained from the operation of systems, measured in utility units.

Despite the existence of objective advantages of each of the considered methods, none of them can be fully considered universal. The presence of deficiencies prevents their effective practical application in relation to the elements of the infrastructure of the enterprise.

Among the main drawbacks of the considered methods are:

– complexity of evaluating the effect of the introduction of a new IT service, both in monetary terms and in utility units;

– need to eliminate the influence of external effects on the result;

– reducing the objectivity of the introduction effect evaluation of IT service due to the use of expert opinion;

– complexity of evaluating the various additional effects of infrastructure services in proportional terms.

The disadvantages of the existing evaluation methods include the comparison of evaluation indicators with the standard object, which significantly reduces their versatility. At the same time, the use of an integrated evaluation of the qualitative and quantitative elements of the EI does not require comparison with the indicators of the enterprise-standard, which significantly increases the universality of the proposed approach.

In the process of EI evaluation, the effectiveness of using available resources is determined and recommendations are made to improve this indicator. The implementation of the recommendations formulated on the basis of the EI evaluation will:

– identify problem areas and develop an effective IT concept;

– reduce the level of hardware and software failures;

– enhance the transparency of the IT infrastructure;

– increase the stability of the IT services.

3. The aim and objectives of research

The aim of research is improving the enterprise infrastructure evaluation to determine the impact of the introduction of a new IT service in the face of constant changes in functional requirements. To achieve this aim it is necessary to perform the following tasks:

1. To analyze the existing approaches and methods for enterprise infrastructure evaluation.

2. To determine the main elements of the enterprise infrastructure.

3. To determine the impact of the introduction of a new IT service on the enterprise infrastructure.

4. Research of existing solutions of the problem

The main objective of the enterprise infrastructure is ensuring the availability of software applications of IT services for users and support business growth. In the course of their activities, enterprises solve various tasks: entering new markets, reducing production costs, and adhering to government regulatory documents from accounting to processing personal data. Employees of the enterprise need to effectively interact with each other, with existing and potential customers, to process a lot of data in a timely manner [6]. For all this, it is necessary to have the appropriate infrastructure of the enterprise.

The description of the infrastructure of an enterprise existing in modern literature [7, 8] is intended, first of all, in order to form an idea of the composition of the infrastructure elements and the connections between them. However, the use of such approaches in the absence of formal models does not allow one to describe the state of an object at a certain point in time. It is also worth noting that due to the heterogeneity of the elements of the enterprise infrastructure, it is extremely difficult to speak of an evaluation of the infrastructure being operated as there is a problem of combining many different evaluations [9, 10]. The lack of an overall EI evaluation significantly complicates the process of evaluating the changes made within the framework of the service management task.

In [11, 12], the enterprise infrastructure is considered from the point of view of the ITIL (IT Infrastructure Library). Infrastructure refers to all hardware and software, network, premises, etc. required for the development, testing, provision, monitoring, control or support of IT services. However, according to the authors, personnel, processes and documentation should not be included in the enterprise infrastructure.

In turn, the term «IT infrastructure» is proposed in [13, 14]. The company's IT infrastructure includes devices with Internet access, databases, software, corporate mail, and an infrastructure management interface. All these elements are combined through the Internet and work in conjunction, which allows to effectively perform various tasks and create a business environment for the coordinated work of the entire company and each of its divisions. However, in this case it is impossible to evaluate the quality of individual IT services to support the functional requirements of the end users, it is a mandatory task in managing the provision of IT services.

According to DSTU ISO 9004:2012 [15], the infrastructure of an enterprise includes various resources, such as: production facilities, work equipment and equipment, support services, information and communication technologies, and vehicles.

Based on the results of the study of the process of evaluating the costs of EI management [16], as well as the developed model of EI evaluation [17], it is proposed to group the costs associated with EI management, as follows:

– cost of IT services;

– cost of communication technology;

– cost of information technology;

– cost of computer network.

Thus, on the basis of the EI evaluation model presented in [17] and the above expenditure groups, it is proposed to improve the method for EI evaluation by accounting for the costs of acquiring, developing or improving existing IT services.

5. Methods of research

Evaluation of EI elements is carried out by specialists who evaluate the condition of equipment and software of computer networks, data storage systems, security systems and anti-virus protection for compliance with the goals and

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objectives of the client. For EI qualitative evaluation, it is proposed to use expert evaluations that are converted to the appropriate numerical scale. As a result of qualitative and quantitative evaluations, a comprehensive evaluation of the enterprise's infrastructure is formed.

Based on the enterprise infrastructure evaluation model [17], the evaluation of IT service costs $O_{ITs} = Z_{S_i}$ is represented by the expression:

$$Z_{S_i} = \sum_{j=1}^{n} Z_{S_{ij}}, \quad (1)$$

where Z_{S_i} – the total cost of the company for IT services.

Cost evaluation of communication technology $O_{Ct} = Z_{CT_i}$ is represented by the expression:

$$Z_{CT_i} = \sum_{j=1}^{n} Z_{CT_{ij}}. \quad (2)$$

Cost evaluation of information technology $O_{It} = Z_{IT_i}$ is represented by the expression:

$$Z_{IT_i} = \sum_{j=1}^{n} Z_{IT_{ij}}, \quad (3)$$

where Z_{IT_i} – the total costs of the enterprise for information technology.

Cost evaluation for the enterprise computer network $O_E = Z_{E_i}$ is represented by the expression:

$$Z_{E_i} = \sum_{j=1}^{n} Z_{E_{ij}}, \quad (4)$$

where Z_{E_i} – the total cost of the enterprise on a computer network.

6. Research results

Due to the use of such a grouping of costs to solve this problem, the method for EI evaluation is improved. The essence of the method is presented as a sequence of the following stages.

Stage 1. Determination of the cost of the enterprise's infrastructure for making changes (Z_0) for each selected group of costs:

$$Z_0 = Z_{S_0} + Z_{CT_0} + Z_{IT_0} + Z_{E_0}, \quad (5)$$

where Z_{S_0} – the cost of IT services; Z_{CT_0} – the cost of communication technology; Z_{IT_0} – the cost of information technology; Z_{E_0} – the cost of computer network.

Step 1. Determination of the cost of IT services Z_{S_0} is carried out according to the formula:

$$Z_{S_0} = Z_{dev_0} + Z_{buy_0} + Z_{use_0} + Z_{sup_0}, \quad (6)$$

where Z_{dev_0} – the cost of developing IT services; Z_{buy_0} – the cost of the acquisition of IT services; Z_{use_0} – the cost of operating IT services; Z_{sup_0} – the cost of supporting IT services.

Step 2. Determination of the cost of communication technology Z_{CT} is carried out according to the formula:

$$Z_{CT_0} = Z_{int_0} + Z_{mob_0} + Z_{add_0}, \quad (7)$$

where Z_{int_0} – the cost of using Internet resources; Z_{mob_0} – the cost of providing communication services; Z_{add_0} – overhead cost of communication technology.

Step 3. Determination of the cost of information technology Z_{IT_0} is carried out according to the formula:

$$Z_{IT_0} = Z_{spo_0} + Z_{ss_0} + Z_{st_0}, \quad (8)$$

where Z_{spo_0} – the cost of system software; Z_{ss_0} – the cost of service systems; Z_{st_0} – the cost of maintenance systems.

Step 4. Determination of the cost of a computer network Z_{E_0} is determined by the formula:

$$Z_{E_0} = Z_{ea_0} + Z_{er_0} + Z_{ep_0} + Z_{es_0}, \quad (9)$$

where Z_{ea_0} – the cost of depreciation of equipment and networks; Z_{er_0} – the cost of repairing equipment and networks; Z_{ep_0} – the cost of the planned update and improvement of equipment and networks; Z_{es_0} – warehouse costs.

Stage 2. Determining the value of the evaluated costs for the EI after the change (Z_1) by summing the costs for each selected group, similar to *Stage 1*, according to the formula:

$$Z_1 = Z_{S_1} + Z_{CT_1} + Z_{IT_1} + Z_{E_1}. \quad (10)$$

Stage 3. Determination of the cost of changes in the EI is performed by comparing the data on the amount of costs on the EI before and after the changes:

$$\Delta Z = Z_1 - Z_0, \quad (11)$$

where ΔZ – shows how much the costs have increased, compared with the initial; Z_1 – the cost of the EI after the change; Z_0 – the cost for making changes in the EI.

Stage 4. The calculation of the overall profitability of the changes in the EI (R) is carried out according to the formula:

$$R = \frac{F}{\Delta Z}, \quad (12)$$

where F – the profit from the sale of goods, products, works or services.

Stage 5. Implementation of the EI expert evaluation based on a scale in which the following levels are provided: «very high quality», «high quality», «medium quality», «low quality», «unsatisfactory quality». These evaluations are proposed to be built on the basis of expert quantitative evaluations, built on a five-point scale. A sample of the scale is presented in Table 1.

Table 1

The scale of quality evaluation of enterprise infrastructure parameters

The quality level of the evaluated parameter	Scores
Very high quality	5
High quality	4
Medium quality	3
Low quality	2
Unsatisfactory quality	1

A sample of summary table of expert evaluations of the considered parameters is presented in Table 2.

Table 2

Summary table of expert evaluations of the considered parameters

No.	Parameter	1 expert	2 expert
1	IT-service No. 1	3	3
2	IT-service No. 2	5	4
n	IT-service No. *n*	Evaluation of the 1 expert	Evaluation of the 2 expert

Stage 6. The formation of a matrix of conformity of the evaluated parameters and evaluations made by experts $M(n\times m)$ is carried out on the basis of the Table 2. In general, the matrix $M(n\times m)$ has the form:

$$M(n\times m)=\begin{pmatrix} O_{11} & \dots & O_{1m} \\ \dots & \dots & \dots \\ O_{n1} & \dots & O_{nm} \end{pmatrix}, \quad (13)$$

where n – the number of involved experts; m – the number of evaluated parameters.

Stage 7. The calculation of the average value of each evaluated parameter, based on the data of the matrix (13), is carried out according to the formula:

$$O_j=\frac{\sum_{i=1}^{n} O_{ij}}{n}, \quad (14)$$

where O_{ij} – evaluation of the j-th parameter by the i-th expert; n – the number of experts.

Stage 8. The formation of the matrix of weights of the evaluated parameters is carried out in the following form:

$$N(n\times m)=\begin{pmatrix} W_{11} & \dots & W_{m1} \\ \dots & W_{ij} & \dots \\ W_{1n} & \dots & W_{mn} \end{pmatrix}, \quad (15)$$

where m – the number of evaluated parameters; n – the number of involved experts.

To determine the value of the weight coefficient of the j-th parameter in the evaluation of the i-th expert W_{ij}, the formula is used:

$$W_{ij}=\frac{O_{ij}}{\sum_{j=1}^{m} O_{ij}}. \quad (16)$$

Stage 9. Determination of average weights for each evaluated parameter and placing them in an ordered sequence:

$$W=\{W_1,W_2,...,W_m\}. \quad (17)$$

The value of the average weighting coefficient (W_j) of each evaluated parameter is determined on the basis of the data of the matrix (15) by the formula:

$$W_j=\frac{1}{n}\cdot\sum_{i=1}^{n} W_{ij}, \quad (18)$$

where W_{ij} – weights of the j-th parameter in the evaluation of the i-th expert.

Stage 10. Determining the values of the indicator of EI quality evaluation (K) on the basis of the calculated average weights taking into account the profitability of the changes made in the EI by the formula:

$$K=R\cdot\sum_{j=1}^{m} W_j\cdot O_j, \quad (19)$$

where R – the profitability indicator of the changes made in EI; m – the number of used parameters for EI quality evaluation; W_j – the average weighting factor of each evaluated EI quality parameter; O_j – the average value of the evaluated EI quality parameter.

Stage 11. EI qualitative evaluation according to the results of quantitative evaluation of the indicator K on the scale presented in Table 3. Completion of method application.

Table 3

Compliance with the value of the indicator of quantitative and qualitative evaluation of enterprise infrastructure

The value of the EI quantitative evaluation	Qualitative characteristic of the EI effectiveness	Recommendations for the application of the chosen IT service
$K \geq 4.5$	Highly effective	IT service recommended for use
$3 \leq K < 4.5$	Moderately effective	Application of IT service within operational management
$2 \leq K < 3$	Low effective	Application of IT service within tactical management
$K < 2$	Ineffective	Application of IT service in the framework of strategic management

The following are refined performance of some stages of the proposed method.

To carry out the calculations in Stage 1, it is necessary to collect relevant operational data about the enterprise under study, which is planning to introduce a new IT service. In addition, when changing in any form of information system support, the accumulated statistical information will allow determining the effect of the made changes [18].

The negative value ΔZ obtained at Stage 3 means cost savings and, accordingly, the profit of the enterprise.

The average weights obtained in Stage 8 determine the significance of the evaluated parameters: if the j-th indicator, according to experts, is insignificant, then its weighting factor W_j should be almost zero. The higher the value of the weighting factor W_j, the more significant is the parameter under study.

Any modification of the infrastructure of the enterprise leads to a change in the indicator evaluating its quality K. Therefore, identifying the dynamics of the indicator K will allow monitoring the EI quality level. Accumulated statistics makes it possible to identify trends and, based on their analysis, make timely decisions about the need for changes in the EI in order to adapt it to the new conditions [19].

7. SWOT analysis of research results

Strengths. The main strength of the proposed method is that it provides an opportunity to form a preliminary evaluation of the planned changes in the EI and thus to refuse to make changes in case of their low efficiency.

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Weaknesses. The weak side of this method can be attributed to the complexity of determining the actual information on the EI costs.

Opportunities. In recent years, enterprises have made significant investments in information technology to improve the efficiency of business processes, security, and competitive ability. In modern conditions, the links between information technologies and other elements of business have become much more complicated, since new technologies are of key importance for all sectors of the economy. It is possible to optimize the costs of informatization of an enterprise, subject to analysis of the state, interaction, and effectiveness of information technologies with various business processes. To this end, enterprise infrastructure evaluation is carried out, providing management personnel with the information necessary to restructure the costs of information technology and increase the level of efficiency in their use.

A promising direction for further research in the field of EI evaluation is the evaluation of the made changes, taking into account the accumulated statistical data. Thus, the improvement of the method of EI evaluation and the analysis of the dynamics of the obtained evaluations will improve the accuracy of the EI evaluation, in this regard, additional reserves can be obtained for the development of the enterprise.

Threats. The main threat arising in the process of EI evaluation is significant costs and time for the formation of a comprehensive evaluation. The complexity of the calculations depends on the size of the enterprise. Using the proposed method in large enterprises will require the collection of a large amount of information about the existing infrastructure. There may be cases when, in the absence of information on certain items of expenditure or the provision of false data, the resulting comprehensive evaluation will have a significant error. However, these shortcomings still concern precisely the enterprises with a low level of information and the lack of operational data on the costs of maintaining the existing infrastructure.

8. Conclusions

1. The problem of enterprise infrastructure evaluation is considered to determine the impact of the introduction of a new IT service in the context of the constant change in the functional requirements of end users. To this end, an analysis is made of existing approaches and methods for enterprise infrastructure evaluation. Despite the fact that the enterprise infrastructure has a large number of different objects, the quality of which must be evaluated, the methods of economic analysis and the method of expert evaluation of the components are used.

2. Based on the results of the analysis of infrastructure evaluation problems and the existing variants of the term «enterprise infrastructure», the main elements of the enterprise infrastructure are identified. It is proposed to define the enterprise infrastructure as a set of interrelated IT services, information and communication technologies, united by the enterprise computer network.

3. The impact on the existing infrastructure of the enterprise from the introduction of a new IT service is determined, which makes it possible to improve the method of infrastructure, which, unlike the existing ones, combines a quantitative evaluation of the costs of IT services and a qualitative evaluation of the components of the updated enterprise infrastructure. This makes it possible to comprehensively evaluate the infrastructure of the enterprise and form recommendations on the application of the selected IT service. The advantage of the proposed method is that it allows to form a preliminary evaluation of the planned changes in the infrastructure of the enterprise and thereby refuse to make changes in case of their low efficiency.

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DEVELOPMENT OF INFORMATION TECHNOLOGY FOR THE AUTOMATED CONSTRUCTION AND EXPANSION OF THE TEMPORAL KNOWLEDGE BASE IN THE TASKS OF SUPPORTING MANAGEMENT DECISIONS

Об'єктом дослідження є процес побудови б з зн нь (БЗ), який передб ч є розробку форм льного предст влення зн нь, вилучення зн нь, перевірку їх несуперечливості т включення до скл ду БЗ. Ре ліз ція т кого процесу є необхідною умовою використ ння БЗ в систем х підтримки упр влінських рішень н т ктичному т стр тегічному рівнях орг ніз ційного упр вління. Одн к, н сьогодні існує невідповідність між пр ктичною потребою в ре ліз ції, орієнтов ної н зн ння підтримки упр влінських рішень в умов х невизн ченості з ур хув нням темпор льного спекту упр вляючих дій. А т кож можливостями існуючих методів і технологій інтер ктивної т втом тизов ної побудови БЗ.

Проведений н ліз об'єкту дослідження пок з в можливість втом тизов ної побудови БЗ для підтримки упр влінських рішень з використ нням темпор льних з лежностей. Ост нні можуть бути отрим ні н основі н лізу послідовності ст нів орг ніз ційної системи як об'єкту упр вління. Темпор льні з лежності між ст н ми відобр ж ють зн ння про упр вляючі дії, що були ре лізов ні при викон нні упр влінських рішень.

Удоскон лено логіко-ймовірнісну модель предст влення темпор льних зн нь шляхом вр хув ння ієр рхічного опису контексту упр влінського рішення, що д є можливість спростити побудову цього рішення. З пропонов н модель з безпечує можливість підтримки р ціон льного вибору із множини допустимих упр влінських рішень з пок зником ймовірності переходу до цільового ст ну об'єкту упр вління.

Удоскон лено метод втом тизов ної побудови т підтримки темпор льної БЗ н основі вр хув ння трибутивного опису ст нів об'єкту упр вління т контексту упр влінського рішення. Метод передб ч є опер тивне формув ння т перевірку логіко-ймовірносного предст влення темпор льних зн нь для підтримки упр влінських рішень.

Розроблено інформ ційну технологію втом тизов ної побудови т поповнення темпор льних БЗ. Технологія поєднує можливості формув ння п тернів предст влення т сем нтичної перевірки зн нь, що виконуються спеці лістом у предметній обл сті, т кож втом тичної побудови зв жених темпор льних пр вил н основі виявлення з лежностей у відомих послідовностях ст нів об'єкту упр вління. Це д є можливість опер тивно виявляти х р ктерні для предметної обл сті нові темпор льні з лежності т вносити їх в БЗ після сем нтичної перевірки експертом.

Ключові слова: *упр влінське рішення, підтримк прийняття рішень, темпор льн з лежність, темпор льн б з зн нь.*

1. Introduction

The current state of organizational management is characterized by the wide use of knowledge bases (KB) to support management decisions for solving partially structured and unstructured tasks. The process of making management decisions involves the formation of a set of alternative context-sensitive sets of management actions, choice and implementation of the chosen decision. This choice is made by the decision maker (DM). Knowledge-oriented