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MATHEMATICAL AND STATISTICAL EVALUATION OF PROCESSES OF USING INFORMATION TECHNOLOGIES

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The article covers the methodological issues of mathematical and statistical evaluation of the information technology use. The necessity of using information technologies to ensure control system flexibility has been substantiated. The impact of the level of integration of implemented information technologies on the increase of production management efficiency through data processing models and use of a single information space has been determined. To achieve the appropriate characteristics of stochastic processes of information technology, it is proposed to use methodological approaches to modeling on the basis of mathematical and statistical evaluation with elements of correlation and regression analysis.

We have established the features of regression model development on the basis of which the estimation of the modeled process is carried out in the forecasting period. The paper investigates the issue of modeling methodology based on correlation and regression models and special cases in their evaluation. The main stages of model development and the sequence of their implementation are given.

The impact on the number of enterprises that use computer technology in their activities, such factors as: Internet connection, the use of social media and the availability of websites has been assessed. Particular attention is paid to the use of social media as one of the key resources in defining the ideology of using information resources. The model parameters were estimated by the least square method. The analysis of the influence of the studied factors has been carried out based on the obtained regression model parameters taking into account their significance on the influence of the process of information technology use. The necessity of theoretical substantiation of interdependent factor effect with the application of variance analysis and mathematical theory of hypotheses has been proved.

***Key words**: mathematical and statistical analysis, mathematical model, factor effect, information technologies, model parameters.*

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1. Definition of problem

The use of information technology stipulates to the introduction of new data processing methods, information systems projects, modeling and reengineering of complex systems management processes. One of the popular areas of information technology is the development of websites (their number is growing rapidly and they are popularized among enterprises in various fields). Information is the main element of the management process, which acts as the most popular and surplus resource. It is the link in the formation of relationships between the subject and the object of control, or between the control and the controlled parts in the control system. The increase in information traffic is affecting the information infrastructure, in particular the expansion of Internet communication due to the growth of broadband connections. The use of information and automated systems in production results in the information scale increase and the need to develop information support systems, effective information and analytical systems, the key function of which is the control and protection of information traffic and their formation sources.

Today, the management system flexibility is determined by the integration level of implemented information technologies and systems, the action of which is aimed at improving the efficiency of production management through data processing models and the use of a single information space. The evolution of information technology is characterized by such features as increasing the volume and forms of information (necessary for decision making) on the one hand, and mathematization and complexity of data processing techniques on the other hand (from the standpoint of new developments in computer technology and

telecommunications) [1]. Therefore, data evaluation and substantiation of methods of sequential calculation of parameters of mathematical and statistical factor models with reference to the information technology use is an urgent task.

2. Analysis of the latest research and publications

Issues of conducting and developing mathematical and statistical models are widely represented in modern scientific publications. In the works of Gunko IV [5], Bolshakova LV [6], Ivanova TO [8], Samarets NM [9] and others, methodological approaches and elements of substantiation of use of mathematical modeling in scientific and applied researches have been revealed. However, the use of mathematical and statistical evaluation methods in the field of information technology have significant research potential, in particular, taking into account the latest digital approaches in management.

3. Aim of research

The basis of systems management is a systems approach, which is built on the causative factor identification, their impact assessing and the relationship study that cover the structure of the system.

4. Results of the research

The basis of systems management is a systems approach, which is built on the causative factor identification, their impact assessing and the relationship study that cover the structure of the system.

The task of developing a system model and evaluating its parameters prevails in the context of the problem of constructing the optimal structure of control systems. It is in the strategy of information technology development that the main emphasis is placed on working out an effective information traffic management system that reproduces the basis of the project solution. The delimitation of the functions performed between the components of the control system lays in the problem design solution, the addressing of which is aimed at attaining the efficiency of joint use of many types of information technology. [1]

In the process of developing and operating information systems, the matter of focusing on a specific type of information technology and the way they are used determines the number of jobs and cost indicators of projects. Therefore, the issue of demand for the involvement of certain types of information resources is one of the key issues in technology markets and in the development of systems for the use of information resources.

Evaluation of the use of information technology is based on mathematical methods that can adequately reflect the real situation and provide results for further conclusions. These are mathematical and statistical methods of multidimensional analysis. In most cases, all real characteristics that are caused by changes in many factors cannot sometimes be distinctly subject to formalized description. [6]

The initial set of data for research is defined by many objects and factors, each of which has its own characteristics and specific features. In this way, the common characteristics of the objects are identified and the key evaluation parameters are systematized. Enterprises, territories, business entities, technical components of systems, technical products, etc. can be taken as objects; the factors that to some extent determine the specificity of these objects in accordance with the use of information technology and resource component are chosen as characteristic features. Thus, the analysis of the information technology use is based on a clear idea of the problem addressing on the basis of connection multidimensionality of bonds, object types and factors that cause changes in this process in the digital space.

The methodological basis of multidimensional analysis is the use of many methods and techniques, in particular they include: correlation and regression analysis, factor, variance, cluster ones and others. One of the most effective methods is the method of estimation by multiple (multifactor) regression models, which allow to determine the weight and degree of tightness of the interdependent influence of factors based on the measurement stochastic nature. The conceptual framework includes the analysis of stochastic relationships between factors, in particular, the dependent variable and the set of independent variables, which are defined as an argument for explaining the effects on this independent variable. This approach provides an opportunity to explore the relationship between phenomena and processes caused by the emergence of causative relationships between them. Correlation and regression analysis are widely used in the forecast assessment, planning decision development, factor identification that determine the key characteristics of processes. It should be noted that in cases where the analysis is performed in the frames of inhomogeneous objects, the models obtained by correlation and regression analysis may have inadequate estimates. In such cases, the similarity study within the sample has one of the primary characteristics of the process. Therefore, it is advisable to use clustering as a method of grouping objects.

Regression models are able to convert a certain amount of information (data) into a model of cause-effect relationships. The substantiation and definition of such characteristics establishes the degree of influence between the factors and the degree of deviation from the average expected values in the experimental data sample. The data sample is formed taking into account the scatter of values within individual groups, or depending on time changes. The model development process takes into account a number of specific features that are based on the use of different evaluation approaches. Such features may be parameter significance criteria, multicollinearity, adequacy determination, heteroskedasticity, etc. [1]

The use of mathematical and statistical methods is one of the promising ways to create an evidence base for research in the field of information technology. This is due to the specific features of this methodology use in modern research:

- firstly, theoretical law reproduction on the basis of experimental data in a set of factor features selected as ones explaining the characteristics of the studied processes;
- secondly, the presence of a quantitative assessment of stochastic relationships of causative properties based on mathematical and statistical calculations;
- thirdly, substantiation of the decision-making process on the basis of the developed regression models of simple and complex type.

The study of the basic process elements is based not only on the comparison of the elements of analysis of set of objects but also due to the mathematical proof of the rules describing the system behavior [5]. Here two directions are dedicated: set of sample data substantiation and regression model development. Sample data substantiation includes a representative sample evaluation, proof of the contrast of mean values hypothesis, assessment of the neighboring relationship level, distribution law establishment, etc. The development and testing of regression models cover elements of theoretical justification of the influence of factors based on cause-effect changes, which is one of the complex issues of the applied research [6]. This is due to the choice and inclusion of different categories in the factor pattern, their measurement comparability, the total impact rate, limitations, etc.

The linchpin in mathematical and statistical research is the evaluation of hypotheses, which involves the justification of any assumption made on the basis of quantitative calculations and estimates. The form of communication, groups of objects homogeneity by equality of average signs, the model confidence estimation are substantiated.

The main stages of model development are the following:

1. Justification of cause-effect relationships between factors.
2. Establishing the nature of endogenous and exogenous variables with a distinction between input and output data streams and established efficiency criteria.
3. The choice of the studied model type: assessment of changes or factor influence on the selected explanatory characteristics over time.
4. Determining the sample scope.
5. Estimation and type of factorial dependence function.
6. Assessment of factorial influence level.
7. Autocorrelation processes evaluation.
8. Determination of model parameters based on the least square method.
9. Determination of confidence intervals for parameter value dispersion.
10. Checking the adequacy and reliability of the model parameter values.
11. Research of factor changes on the basis of the model developed.

Evaluating the use of information technology can take into account multiplicity of factors, one of which is the number of companies that use computer technology in their activities. The change in this indicator demonstrates the rate of new participant involvement in the information community and the processes of using information technology both at the sectoral level and at the state level. At the same time, it is expected to extent the network infrastructure to promote information traffic. The key elements of the information infrastructure are: social media, websites, ways to connect to the Internet, etc. These factors determine the degree of activity of the information space participants and their ability to carry out information activities, thereby ensuring the appropriate level of the information society development.

The number of enterprises in the main areas of economic activity in Ukraine that used computers in 2017–2019 is shown in Table 1.

The key positions in terms of the use of computer technology is held by the construction industry where the number of such enterprises increased up to 4971 in 2019, which is by 20.6% more than in 2017. The lowest growth rates are shown by enterprises in the area of other types of services (-1.7%).

At the user level, the following stages of implementation of new information technologies can be distinguished:

- Internet, specialized global networks;
- global social networks;
- cloud computing and Internet sensors.

Table 1.

Number of enterprises in Ukraine that used computers, units, 2017–2019 *

No.	Branch of activities	2017	2018	2019	Deviation of 2019 from 2017, %
1	Processing industry	10,090	11,089	11,279	11.8
2	Supply of electricity, gas, steam and air conditioning	647	706	714	10.4
3	Water supply; sewerage, waste management	1,065	1,147	1,152	8.2
4	Construction	4,121	4,871	4,971	20.6
5	Wholesale and retail trade; repair of motor vehicles and motorcycles	10,011	10,912	10,889	8.8
6	Transport, warehousing, postal and courier activities	3,287	3,542	3,626	10.3
7	Temporary accommodation and catering	1,207	1,312	1,286	6.5
8	Information and telecommunications	1,804	1,962	1,961	8.7
9	Real estate transactions	2,615	2,787	2,763	5.7
10	Professional, scientific and technical activities	2,522	2,688	2,729	8.2
11	Activities in the field of administrative and support services	2,898	3,052	3,103	7.1
12	Other types of services	60	65	59	-1.7

* Compiled and calculated by the authors based on sources [2, 3, 4]

The means of social networks are in great demand, which determines the wide availability of different categories of users and the formation of the single behavioral strategy usage to promote their own information resources. The information logistics infrastructure with its web portals, websites, etc. is used to possibly promote a certain type of activity to the information end user. The influence of these factors is due to changes in modern information technologies and types of information resources.

Estimates of the number of enterprises that used social media as a means of sharing knowledge for the period 2017–2019 are shown in Table 2.

Social media includes Internet resources, which are filled and created by users themselves and are intended for mass distribution. According to Table 2, in 2017-2019, the largest changes in the number of enterprises in Ukraine that used social media as a means of sharing knowledge were observed in the following sectors: construction (+ 20.1%); administrative and support services (+ 16.5%); information and telecommunications (+ 17.8%); trade (14.8%) and processing industry (+ 14.3%). The use of social media is based on data exchange and removal technology with the help of content filled with users – experts in a particular field of knowledge.

The formation of the state information policy of Ukraine is entrusted to the Department of Development of Information and Communication Technology, Document Management and Electronic Services within the structure of the Ministry of Economic Development and Trade. The main elements of the development of digitalization of the economy and society are set out in the “Concept of the Digital Economy and Society Development of Ukraine for 2018–2020”. Particular attention is paid to the elements of implementation of the concept of digital jobs, digital transformation of all activities and the use of digital technologies in the field of national security and others.

Internet connection provides access to the resources of the digital world, which ensures the appropriate level of use of information resources and the continuity of the process of using information technology. The most commonly used connection methods are narrowband and broadband. Most countries provide users with high-quality broadband access on the basis of relationships with providers and compliance with the speed of 0.128 Mb/s - 20 Mb/s.

Table 2.

Number of enterprises in Ukraine that used social media as a means of sharing knowledge, units, 2017–2019

No.	Branch of activities	2017	2018	2019	Deviation of 2019 from 2017, %
1	Processing industry	1,113	1,239	1,272	14.3
2	Supply of electricity, gas, steam and air conditioning	79	80	89	12.7
3	Water supply; sewerage, waste management	136	133	146	7.4
4	Construction	532	604	639	20.1
5	Wholesale and retail trade; repair of motor vehicles and motorcycles	1,320	1,471	1,515	14.8
6	Transport, warehousing, postal and courier activities	362	391	399	10.2
7	Temporary accommodation and catering	161	170	163	1.2
8	Information and telecommunications	353	392	416	17.8
9	Real estate transactions	284	303	302	6.3
10	Professional, scientific and technical activities	380	408	440	15.8
11	Activities in the field of administrative and support services	340	380	396	16.5
12	Other types of services	9	13	9	0.0

* Compiled and calculated by the authors based on sources [2, 3, 4]

Changes in the ratio of broadband to narrowband connection to the network of Ukrainian enterprises are shown in Table 3. Broadband connection is the highest priority. However, in some sectors of the economy there was a decrease in this ratio: in wholesale and retail trade; repair of motor vehicles and motorcycles (-0.03%); at enterprises of temporary accommodation and catering (-0.15%) and other types of services (-1.04%).

Table 3.

Broadband to narrowband connection ratio at the enterprises of Ukraine, 2017–2019

No.	Branch of activities	2017	2018	2019	Deviation of 2019 from 2017, %
1	Processing industry	2.04	1.97	1.94	0.10
2	Supply of electricity, gas, steam and air conditioning	2.26	2.26	2.21	0.05
3	Water supply; sewerage, waste management	1.75	1.55	1.75	0.00
4	Construction	1.75	1.70	1.71	0.04
5	Wholesale and retail trade; repair of motor vehicles and motorcycles	2.15	2.14	2.18	-0.03
6	Transport, warehousing, postal and courier activities	1.68	1.65	1.69	-0.01
7	Temporary accommodation and catering	1.70	1.73	1.85	-0.15
8	Information and telecommunications	3.40	3.49	3.33	0.07
9	Real estate transactions	1.82	1.74	1.82	0.00
10	Professional, scientific and technical activities	2.53	2.58	2.66	-0.13
11	Activities in the field of administrative and support services	1.76	1.70	1.65	0.11
12	Other types of services	2.88	4.15	3.92	-1.04

* Compiled and calculated by the authors based on sources [2, 3, 4]

Most users of legal organizations apply to websites to create their own image and get opportunities to effectively communicate with customers on the Internet. The website is a set of software, information and media tools, the interaction of which is aimed at performing the tasks of the subject initialization in virtual space. The main tasks of a website are:

- providing promotional activities and marketing services;
- electronic sale of goods and services;
- provision of information services;
- information support of product promotion;

- organization of processes of interaction with clients.

The outcome of changes in the number of enterprises that had a website that operated on the Internet are shown in Table 4. The growth in the number of enterprises with their own website confirms the desire of enterprises to adapt to the new conditions of the digital economy.

Table 4

Number of Ukrainian enterprises that had a website that operated on the Internet, units, 2017–2019

No.	Branch of activities	2017	2018	2019	Deviation of 2019 from 2017, %
1	Processing industry	4,910	5,500	5,358	9.12
2	Supply of electricity, gas, steam and air conditioning	275	370	330	20.00
3	Water supply; sewerage, waste management	253	538	308	21.74
4	Construction	1,195	2,307	1,397	16.90
5	Wholesale and retail trade; repair of motor vehicles and motorcycles	4,257	6,110	4,692	10.22
6	Transport, warehousing, postal and courier activities	845	1746	893	5.68
7	Temporary accommodation and catering	554	576	601	8.48
8	Information and telecommunications	1,175	1,236	1,245	5.96
9	Real estate transactions	697	1,109	764	9.61
10	Professional, scientific and technical activities	1,251	1,478	1,342	7.27
11	Activities in the field of administrative and support services	792	1,325	886	11.87
12	Other types of services	36	36	40	11.11

* Compiled and calculated by the authors based on sources [2, 3, 4]

The growth of enterprises' websites was observed (Table 4) in such areas of activity as: water supply (+ 21.74%); supply of electricity, gas, steam and air conditioning (+ 20.0%). The operation of user data websites is one of the key elements of personal activities related to the provision of logistics infrastructure aimed at ensuring the level of customer service and the formation of a system of relationships with suppliers.

Descriptive statistics of these factors showed the outcome of average changes at enterprises in terms of activities and allowed to determine the largest group fluctuations (Table 5).

Table 5.

Descriptive statistics on indicators of the use of information technology in enterprises of Ukraine, 2017–2019

No.	Performance evaluation	Number of enterprises that used computers, units		Number of enterprises that used such social media as means of sharing knowledge, units		Broadband to narrowband connection ratio		Number of enterprises that had a website that operated on the Internet, units	
		2017	2019	2017	2019	2017	2019	2017	2019
1	Total in Ukraine	40,327	44,532	5,069	5,786	1.96	26.71	16,240	17,856
2	Mean value	3,361	3,711.0	422.4	482.2	2.1	2.2	1,353.3	1,488.0
3	Maximum value	10,090	11,279	1,320	1,515	3.4	3.92	4,910	5,358
4	Minimum value	60	59	9	9	1.68	1.65	36	40
5	Range of variation	10,030	11,220	1,311	1,506	1.72	2.27	4874	5,318
6	Standard deviation	3,191	3,541	384.1	443.6	0.5	0.7	1497.2	1,637.8
7	Coefficient of variation	94.94	95.4	90.9	92.0	24.3	31.2	110.6	110.1

* Compiled and calculated by the authors based on sources [2, 3, 4]

The average number of companies that used computers from 2017 to 2019 increased by 4,205 companies, which amounted to 10.4%. At the same time, the deviation up to the average level in 2017 amounted to 3,191 enterprises (94.9%), in 2019 to 3,541 enterprises (95.4%). This confirms the high level of the sample variation. In terms of the number of enterprises that used social media as a means of sharing knowledge, the average deviation from the average expected value in 2017 amounted to 384 enterprises, which characterizes the sample variation of 90.9% (in 2019 there were 444 enterprises with variation coefficient of 92, 0%). That is, the change in this indicator variation for 2017–2019 was 1.1%.

According to the ratio of broadband to narrowband connection, the average deviation of the indicator from the average expected value in 2017 was 0.5, which characterizes the sample variation of 24.3%; in 2019, it was 0.7 (with variation coefficient of 31.2%). There was an increase in the range of this indicator for 2017 – 2019 by 10.6%.

In 2019, the average expected value of the number of enterprises that had a website operating on the Internet was 17,856, which was 1,616 enterprises more than in 2017. The average deviation from the average expected value in 2017 was 1,497 enterprises, which characterizes the variation in the sample of 110.6%. In 2019, the deviation to the average expected level decreased by 0.5% and amounted up to 1,638 enterprises. Variation analysis of indicators by group of main users (areas of economic activity) determined that the risk of information resources use is in the range from 90% to 110%, which indicates its excessively high value.

Multivariate regression model for estimating the use of information technology at Ukrainian enterprises is represented by the following specification [10]:

$$y = f(x1, x2, x3) \quad (1)$$

where y – is the number of enterprises that used computers, pcs;

$x1$ – is the number of enterprises that used such social media as means of sharing knowledge, units;

$x2$ – is the ratio of broadband to narrowband connection;

$x3$ – is the number of enterprises that had a website operating on the Internet, units.

The regression model has been estimated on the basis of correlation coefficients and the level of model parameters. Individual correlation coefficients of the regression model have been obtained from the calculated correlation matrix, the outcomes of which are shown in Table 6.

Table 6

Correlation matrix for evaluating the use of information technology

Factors	2017				2019			
	y	*x1*	*x2*	*x3*	*y*	*x1*	*x2*	*x3*
y (number of enterprises that used computers)	1.00	0.99	-0,18	0,97	1,00	0,98	-0,30	0,97
x1 (number of enterprises that used such social media as a means of sharing knowledge)	0.99	1.00	-0,09	0,97	0,98	1,00	-0,21	0,97
x2 (the ratio of broadband to narrowband connection)	-0.18	-0.09	1,00	-0,02	-0,30	-0,21	1,00	-0,16
x3 (the number of enterprises that had a website that operated on the Internet)	0.97	0.97	-0,02	1,00	0,97	0,97	-0,16	1,00

* Compiled by the authors

Analysis of correlation coefficients *(r(yxi))* showed [9] that changes in the level of neighboring relationship between factors have the following features:

- $r(yx1) = 0.98$, the relationship between the factors is strong, the direction is direct;
- $r(yx2) = -0.30$, the relationship between the factors is weak, the direction is reversed;
- $r(yx3) = 0.97$, the relationship between the factors is strong, the direction is direct;
- $r(x1x2) = -0.21$, the relationship between the factors is weak, the direction is reversed;
- $r(x13) = 0.97$ the relationship between the factors is strong, the direction is direct;
- $r(x2x3) = -0.16$, the relationship between the factors is weak, the direction is reversed.

According to estimates of partial correlation coefficients, the model is dominated by external relationships, i.e. between $y \leftarrow x(i)$ factors. The internal connections between $x(i+1) \leftarrow x(i)$ have a weak correlation, which does not confirm the hypothesis of multicollinearity in the correlation matrix. The exclusion of multicollinearity with a neighboring relationship between *x2* factors (broadband to narrowband ratio) and *x3* factors (number of enterprises that had a website operating on the Internet) is not confirmed based on the

parameter significance of the multifactor regression model. The general type of multifactor dependence is described by the multifactor model equation [10]:

$$y = \hat{y} + e \quad (2)$$

where y – is the actual value of the number of enterprises that use computers;

$\hat{y}$ is the theoretical (regression) value of the number of enterprises that use computers;

e – is the error of outcome between theoretical and actual estimation values.

Regression model for estimating information technology use can be represented as a multifactor linear regression on a set of 3 factors: (multivariate regression model) [10]:

$$\hat{y} = b0 + b1 \cdot x1 + b2 \cdot x2 + b3 \cdot x3 \quad (3)$$

where $\hat{y}$ – is the theoretical (regression) value of the number of enterprises in all sectors of the economy that used computers, units;

x1 – is the number of enterprises that used such social media as means of sharing knowledge, units;

x2 – is the ratio of broadband to narrowband connection;

x3 – is the number of enterprises that had a website that operated on the Internet, units;

bi – is the regression equation parameter calculated according to least square adjustment method.

The estimated multifactor regression model of the use of information resources according to the data of 2017 has the following form:

$$\hat{y} = 1763{,}12 + 4{,}65x1 - 749{,}35x2 + 0{,}92x3 \quad (4)$$

Change characteristics in the number of enterprises factor in all sectors of the economy using computers are as follows:

- the number of enterprises using computers will increase by 4.65 units with an increase by 1 enterprise in the number of enterprises using social media as a means of sharing knowledge (*x1*);
- the number of enterprises using computers will decrease by 749.35 units with an increase of 1 point in the ratio of broadband to narrowband connection (*x2*).
- the number of enterprises using computers will increase by 0.92 units while the number of enterprises that had a website operating on the Internet (*x3*) will increase by 1 enterprise.

The regression model significance is confirmed by the multiple determination coefficient [8] R^2 = *0.99302*. Explanatory factors *x(i)* have 99.3% influence on the resulting "*y*", and the other 0.7% influence belongs to factors not taken into account in the model. The multiple correlation coefficient *r (y, x1, x2, x3)* is 0.99, which confirms the high level of the neighboring relationship between the factors. The model is adequate. Calculations of Fisher statistic in comparison with the critical value confirm the corresponding goodness of fit, $F_{calc} \geq F_{theor}$ (α = 0,05, *df1* = 3, *df2* = 8), i.e. 380.04≥4.07. The model parameter significance is confirmed by Student statistic evaluation at degrees of freedom (n-4, α = 0.05) t_{theor} = 2.31:

- *b0*: t_{calc} (3,86) ≥ t_{theor} (2,31) – significant;
- *b1*: t_{calc} (4,67) ≥ t_{theor} (2,31) – significant;
- *b2*: t_{calc} (-3,98) ≥ t_{theor} (2,31) – significsant;
- *b3*: t_{calc} (3,60) ≥ t_{theor} (2,31) – significant.

The nonavailability of multicollinearity is confirmed by the high level of the multiple determination coefficient and the significance of the model coefficients. The range of parameter value change is within the following: $b_{low} < bi < b_{upper}$; 712,099 <b0 <2814.148; 2.352 <b1 <6.942; -1183.378 <b2 <-315.317; 0.330 <b3 <1.503

Based on the obtained characteristics of the change confidence intervals in the model parameters, we can determine that the largest fluctuations occur in the processing industry, wholesale and retail trade and repair of motor vehicles and motorcycles. There is no large variance in other activities, which indicates a relatively stable structure of the computer equipment use in terms of the main users.

When assessing the impact of factors on the linear model according to 2019, the model parameters have the following statistical significance (p_{bi}):

$$\hat{y} = -50{,}7 + 6{,}47x1 - 12{,}9x2 + 0{,}40x3$$
$$(p_{b1} = 0{,}00001)(p_{b2} = 0{,}51)(p_{b1} = 0{,}23) \quad (5)$$

The change characteristics is described by the elasticity coefficient: ϵ_{x1} = 4.65%; ϵ_{x2} = -1.98%; ϵ_{x3} = -3.43%. According to the model developed we have an estimate of changes in the factor "y":

- with an increase in the number of enterprises that used such social media as a means of sharing knowledge (*x1*) by 1%, the number of enterprises that used computers will increase by 4.65%;

- with an increase in the ratio of broadband to narrowband connection (*x2*) by 1%, the number of enterprises that used computers will decrease by 1.98%.

- with an increase in the number of enterprises that had a website operating on the Internet (*x3*) by 1%, the number of enterprises that used computers will decrease by 3.43%.

The model developed is significant, which is confirmed by the value of the multiple determination coefficient *R2* = 0.99. *x(i)* factors have 99.6% of the impact on the resulting "*y*", and the other 0.4% of the impact belongs to factors not taken into account in the model. The multiple correlation coefficient *r* (y, *x1, x2, x3*) is 0.998, which indicates a high neighboring relationship between the factors. The model is adequate, which is confirmed by the calculations of Fisher statistic, $F_{calc} \geq F_{theor}$ (α = 0.05, *df1* = 3, *df2* = 8), i.e. 1826.03≥4.07. The significance of the model parameters is confirmed by Student statistic evaluation at degrees of freedom (n-4, α = 0.05) t*theor* = 2.31:

- *b0*: t_{calc} (-0,31) ≥ t_{theor} (2,31) – not significant at the probability belief of 0.95;
- *b1*: $_{calc}$ (6,22) ≥ t_{theor} (2,31) – significant;
- *b2*: t_{calc} (-0,67) ≥ t_{theor} (2,31) – not significant at the probability belief of 0,95;
- *b3*: t_{calc} (-1,25) ≤tteor (2,31) - not significant at the probability belief of 0.95.

Thus, according to the assessment conducted, it is possible to draw a conclusion about the significance of the influence of only one factor – the number of enterprises that used such social media as a means of sharing knowledge. This outcome characterizes a significant deviation towards the use of social networks and the adjustment of users to behavioral usage strategies.

5. Conclusions

Information uncertainty and new conditions of digital space require the application of mathematical and statistical methods and models for estimating the information technology use. The change assessment in the main areas of information technology use was based on the experimentally estimated data sample of 2017 – 2019. The excessive risk degree of the information technology use is confirmed by the calculated variation coefficient in the range of 94% to 110%. However, the variation in the estimate of the ratio of broadband to narrowband Internet connection is moderate, which determines the maintenance of stable access to the network for different categories of users. Regression models developed for estimation have a high level of significance (99%) and confirm a neighboring level of multiple correlation (98% correlation coefficient). When estimating the individual partial influence of factors, the ratio of broadband to narrowband Internet connection has an inverse effect on the factor of enterprises that use computer technology.

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МАТЕМАТИКО-СТАТИСТИЧНЕ ОЦІНЮВАННЯ ПРОЦЕСІВ ВИКОРИСТАННЯ ІНФОРМАЦІЙНИХ ТЕХНОЛОГІЙ

В статті висвітлюються методологічні питання проведення математико-статистичного оцінювання процесів використання інформаційних технологій. Обґрунтовується необхідність використання інформаційних технологій для забезпечення гнучкості систем керування. Визначено вплив рівня інтеграції впроваджуваних інформаційних технологій на підвищення ефективності управління виробництвом через моделі обробки даних та використання єдиного інформаційного простору. Для досягнення відповідних характеристик стохастичних процесів використання інформаційних технологій запропоновано використовувати методологічні підходи моделювання на засадах математико-статистичного оцінювання з елементами кореляційно-регресійного аналізу.

Встановлено особливості розробки регресійних моделей, на основі яких в прогнозованому періоді проводять оцінку процесу, що моделюється. В роботі досліджується питання методики моделювання на основі кореляційно-регресійних моделей та особливих випадків при їх оцінюванні. Наведено основні етапи розробки моделей та послідовність їх виконання.

Оцінено вплив на кількість підприємств, які у своїй діяльності використовують комп'ютерну техніку, таких факторів, як: забезпеченість підключенням до мережі Інтернет, використання соціальних медіа та наявність веб-сайтів. Особлива увага надана використанню соціальних медіа, як одних із ключових ресурсів при формуванні ідеології використання інформаційних ресурсів. Оцінка параметрів моделі проведена за методом найменших квадратів. На основі отриманих параметрів регресійної моделі проведено аналіз впливу досліджуваних факторів з урахуванням їх значимості на вплив процесу використання інформаційних технологій. Доведено необхідність теоретичного обґрунтування взаємозалежного впливу факторів із застосуванням дисперсійного аналізу та математичної теорії гіпотез.

Ключові слова: *математико-статистичний аналіз, математична модель, факторний вплив, інформаційні технології, параметри моделі.*

Ф.5. Табл. 6. Літ. 10.

МАТЕМАТИКО-СТАТИСТИЧЕСКАЯ ОЦЕНКА ПРОЦЕССОВ ИСПОЛЬЗОВАНИЯ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ

В статье освещаются вопросы методологии проведения математико-статистического оценивания процессов использования информационных технологий. Обосновывается необходимость использования информационных технологий для обеспечения гибкости систем управления. Определено влияние уровня интеграции внедряемых информационных технологий на повышение эффективности управления производством путем использования различных моделей обработки данных в едином информационном пространстве. Для достижения соответствующих характеристик стохастических процессов использования информационных технологий предложено использовать методологические подходы моделирования на основе математико-статистического оценивания с элементами корреляционно-регрессионного анализа.

Установлены особенности разработки регрессионных моделей, на основе которых в прогнозируемом периоде проводят оценку моделируемого процесса. В работе исследуется вопрос

методики моделирования на основе корреляционно-регрессионных моделей и особых случаев их оценивания. Приведены основные этапы разработки моделей и последовательность их выполнения.

Оценивается влияние на фактор количества предприятий, которые в своей деятельности используют компьютерную технику, таких факторов, как: обеспеченность подключением к сети Интернет, использование социальных медиа и наличие веб-сайтов. Особое внимание уделено использованию социальных медиа, как одних из ключевых ресурсов при формировании идеологии использования информационных технологий. Оценка параметров модели проведена методом наименьших квадратов. На основе полученных параметров регрессионной модели проведен анализ влияния исследуемых факторов с учетом их значимости на воздействие процесса использования информационных технологий. Доказана необходимость теоретического обоснования взаимосвязи влияния факторов с применением дисперсионного анализа и математической теории гипотез.

Ключевые слова: *математико-статистический анализ, математическая модель, влияние факторов, информационные технологии, параметры модели.*

Ф. 5. Таб. 6. Лит. 10

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