Journal of Theoretical and Applied Information Technology
31st May 2023. Vol.101. No 10

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

ECONOMIC AND MATHEMATICAL MODELING OF INTEGRATION INFLUENCE OF INFORMATION AND COMMUNICATION TECHNOLOGIES ON THE DEVELOPMENT OF E-COMMERCE OF INDUSTRIAL ENTERPRISES

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ABSTRACT

This research aims at establishing the impact of information and communication technologies (ICT) on e-commerce development of industrial enterprises by means of economic and mathematical modelling. The goal was achieved using the following methods: theoretical generalization, analysis and synthesis (to critically analyse the scientific approaches of scientists regarding the expediency of using mathematical models in the context of enterprises' e-commerce development), target, comparison and grouping (to reveal innovative methodological approach to assessing ICT impact on e-commerce development of industrial enterprises), tabular, analytical and integral method (for summarizing the analysis results of enterprises readiness to implement ICT, ICT use in the activities of industrial enterprises of Ukraine and the analysis of e-commerce development), mathematical modelling (to build a regression model determining impact of changes in ICT use on the market share occupied by industrial enterprises), generalization (to determine promising directions of e-commerce developing of industrial enterprises). The implementation of a comprehensive approach to understanding the importance of ICT influence on e-commerce development of industrial enterprises will ensure acceleration of the digitalization of business processes, will contribute to the speed increase of enterprises response to customer requests, and increase the market share occupied by enterprises. A new vision of directions for developing e-commerce of industrial enterprises is suggested, which are determined by the need for enterprise rebranding, the development of e-commerce tools and technologies, the importance of outsourcing service automation and promotion of subscription trade. ICT is considered as integration factor that determines prospects for e-commerce development of industrial enterprises and contributes to increasing efficiency of online business management. Research results demonstrate that the use of economic and mathematical modelling is an important tool for assessing ICT impact, and its absence can negatively affect the accuracy and validity of online business management.

Keywords: *ICT, Online Business Management, E-Commerce, Economic And Mathematical Modelling, Decision-Making, Industrial Enterprises.*

1. INTRODUCTION

The prospects for developing modern industry largely depend on conducting business online, ensuring the improvement of interaction between entities with the help of Internet technologies [1]. The development of ICT accelerated the process of transition from traditional trade to e-commerce [2], which led to the formation of trends different from those previously identified. The issue of the use of ICT in the development of e-commerce in the context of Industry 4.0, and determining its advantages for industrial enterprises, has also gained special importance. The

interest of industrial enterprises in e-commerce is growing significantly and is ensured by increased use of the Internet, cloud technologies, big data analytics, the Internet of Things, etc. Thanks to e-commerce, companies reach more consumers, improve customer service, reduce costs and increase profits [3]. At the same time, the impact of ICT on the change in the share of sales of products obtained from e-commerce has not been researched. This omission will be corrected in the work, because it forms the basis for improving the final performance indicators of industrial enterprises. For modern industrial companies, the use of ICT at all levels of activity management contributes to the improvement of partnership relations, integration of business sectors, compatibility of management goals, external relevance and the possibility of obtaining a synergistic effect [4], as well as increasing the effectiveness of risk management [5]. The market of IT products significantly affects business activity and large-scale changes in business models [6], and for the economy of countries the introduction of ICT has a positive effect on indicators of economic growth [7; 8]. Effective use of ICT, equipped with high-speed Internet and secure servers, allows better reveal the potential of e-commerce [9]. The value of using ICT also emphasizes the disclosure of the relationship between the growth of costs for their implementation and e-commerce development, one of the indicators of which is the dynamics of its share in the world sales of goods. In particular, the amount of expenditure on ICT grew from 3.39 trillion US dollars in 2015 to about 4.26 trillion US dollars in 2021 [10], which contributed to e-commerce development and an increase in its share in the total volume of world trade from 7.4% in 2015 to about 19% in 2021 [11]. Also, it is necessary to take into account the existing issues and limitations of an organizational, financial and managerial nature that may occur during their implementation [12]. After all, as research results show, the efficiency of using ICT even in advanced European countries remains at a relatively mediocre level [13]. While insufficient use of ICT tools is considered as one of the factors that complicates e-commerce development [14]. This actualizes the further study of the impact of ICT on the e-commerce development of industrial enterprises in order to determine the causes of such a situation and promising directions of its development.

At the same time, the research of ICT impact on e-commerce development of industrial enterprises requires the search for such scientific and methodological tools in the research of management processes that would improve the understanding of the obtained results. Among them, the use of economic-mathematical modelling tools is highly suggested. After all, their use is intended to improve the efficiency of the management organization, the validity of decision-making, and reduce the number of errors in management tasks performance [15]. Mathematical modelling also provides benefit from frameworks and standards based on statistical principles, including systematic uncertainty assessment [16]. The advantages of modelling in economics, in contrast to other scientific approaches, include universality and availability of goals implementation, low costs and a short time for the modelling process, multiple applications using a wide range of model parameters, the possibility of making changes and improvements, avoiding negative results due to real experiments [17]. Despite certain limitations regarding the use of economic-mathematical modelling in the economy (difficulty of use in interrupted sustainability of development and the need to develop anti-crisis measures) [18], its value and practical application are indisputable in solving various management goals.

The research is aimed at determining ICT impact on e-commerce development of industrial enterprises of Ukraine. The use of integration and regression modelling methods helps to determine the level of ICT use by industrial enterprises, to determine their influence on the dynamics of the share of sales of products remotely, and helps to identify the reasons for the change in e-commerce state. The novelty of the research materials of this article lies in the analysis conducted at the Ukrainian level using methods and mathematical models that ensure proper justification and accuracy of the research results.

The following are defined as the main assumptions in this work:

Hypothesis 1. The use of economic and mathematical modelling helps to better understand ICT and e-commerce impact on the performance of enterprises and the obtained research results.

Hypothesis 2. ICT should be considered as an integrating factor influencing enterprises e-commerce development.

Hypothesis 3. ICT use can significantly affect the dynamics of the volume of sales of products obtained from e-commerce.

2. LITERATURE REVIEW

Traditional business practices have been left behind due to the increased use of data

analytics and information technology in enterprises. To solve the problem of effective business management, the use of applied mathematical models is practiced today, which greatly facilitate the work of enterprises [19]. Their use is extremely important for studying ICT impact on e-commerce development.

In the works of the researchers, in particular, it is noted that ensuring e-commerce development of industrial enterprises cannot be separated from the impact of ICT [2; 4; 9]. The level of impact of ICT largely depends on the degree of technological readiness of industrial enterprises for their use. Assessment of technological readiness plays an important role in determining the degree of integration of enterprises in the processes of digitization of design and production. After all, untimely detection of a decrease in the level of technological readiness of enterprises [20] will worsen the efficiency of their ICT use, and may negatively affect the indicators of e-commerce development of enterprises.

The currently recorded high growth rates of e-commerce [10] determine not only the rapid development of information technologies, but also timely and sufficient developments in this area [21], and ICT implementation should be consistent with the existing and prospective strategic capabilities of enterprises, ensuring the achievement of established goals and tasks of managerial activity [22].

E-commerce covers the processes of selling and purchasing products using computer networks interconnected in the Internet environment using modern ICT [23]. Therefore, when analysing ICT use at industrial enterprises, primary attention should be paid to indicators that characterize the accessibility of the Internet, as well as the degree of its use. This allows you to define the role of the Internet in commercial activities during the implementation of mathematical modelling to show their consequences in commercial activities and that there is a direct and positive relationship between the Internet and commercial activity [24]. Separate works defined the need to take into account a wider list of constituent elements of the ICT structure, in particular such as computing resources, the Internet, mobile telephony, GPS and Wi-Fi, which contribute to entrepreneurial activity development and e-commerce in particular [25; 26]. The attention of scientists is also drawn to the importance of taking into account such indicators as the degree of use of the services of their providers' servers [27], the degree of use of technologies for the analysis of a significant amount of data [28], the degree of use of additive technologies [29].

To solve the problems of high modelling complexity and low degree of overlap of traditional research methods, as well as a better understanding of ICT and e-commerce impact on the performance of enterprises and the obtained research results, the use of different approaches is proposed. One of such is a model of partial adjustment valuation approach, as a comparison to stochastic production frontier approach, to evaluate the business values of information technology and E-commerce [30]. The value of such a model is due to the possibilities to empirically investigate and compare the business values of information technology and e-commerce not only with constant, but also with time-varying dynamic settings. Assessment of ICT and e-commerce impact based on the use of a system of methods, in particular statistical, factor and correlation analysis, as well as linear regression models [31] ensures obtaining reasonable and accurate research results.

To assess ICT impact on the change in sales volume of products obtained from e-commerce, the use of the multiple linear regression method, which studies the cause-and-effect relationships of research objects and tests complex hypotheses, has an applied nature. The expediency of its application has been proven to determine the impact of advanced ICT on sales, which are implemented with the help of e-commerce by enterprises [32; 33]. It should be noted that the use of this method is universal when solving various management tasks [34]. The existing advantages of mathematical modelling implemented with the help of multiple linear regression, in particular, adaptability to various research objects, the ability to process a large number of variables, a wide range of procedures for data evaluation, convenience and practicality in use, make it attractive enough to study the integrative impact of ICT on e-commerce development of industrial enterprises. The authors found that using e-commerce, enterprises achieve better results, as well as better interaction with customers based on personalization and customization, including for customers and society as a whole. The driving force for this is the incentives for the introduction and use of information technologies of electronic business and e-commerce by enterprises [35] and the cause-and-effect nature of the identified problems of e-commerce development. It is they who determine the promising directions of the development of e-

commerce, which industrial enterprises will focus on.

To make decisions in e-commerce using along with the listed methods, it is proposed to use intelligent decision support systems [36], which contribute to the improvement of information support for online business management.

Given the fact that the listed methods and models greatly facilitate the analysis of ICT use and the adequate assessment of their impact on e-commerce, the use of integration and regression modelling in this research will provide significant advantages in the implementation of the methodological approach that will be developed.

3. METHODOLOGY

The purpose of the research in this work is to reveal the impact of ICT on the development of e-commerce of industrial enterprises using integration and regression modelling. This is achieved by general scientific and special research methods applied to obtain results. Firstly, it is useful for understanding the economic benefits of applying economic-mathematical modelling. Secondly, it will allow confirming the expediency of using ICT to improve the effectiveness of business online by industrial enterprises based on the received evidence.

The practical orientation of the presented idea requires the following tasks to be performed:

- ✓ Development of methodological approach to determine the integration impact of ICT on e-commerce development of industrial enterprises.
- ✓ Studying the readiness of enterprises to implement ICT.
- ✓ Analysis of ICT use at industrial enterprises.
- ✓ Analysis of e-commerce development at industrial enterprises.
- ✓ Assessment of ICT impact on the change in sales volume of products received from e-commerce by industrial enterprises.
- ✓ Determining reasons that caused changes in e-commerce development of industrial enterprises.
- ✓ Determining perspective directions of e-commerce development of industrial enterprises.

For further analysis in order to select research objects, a ranking of the world's countries by income level was compiled (refer to table 1).

Table 1: Top 3 Countries By Income Group.

High-income	Upper middle-income	Lower middle-income	Low-income
1.Netherlands	1.China	1.Ukraine	1.Rwanda
2.Sweden	2.Malaysia	2.Vietnam	2.Tajikistan
3.Denmark	3.Russia	3.India	3.Gambia

Source: compiled by the authors based on [37]

The top performers in each income group are characterized by a strong correlation between income level and technological readiness for change. Low-middle-income countries are of potential interest because they have significant potential for growth, unlike high and middle-income countries. Therefore, industrial enterprises of Ukraine were selected for further research.

The introduction of management innovations into the business of modern industrial enterprises contributes to the solution of many problems [38], but requires proper economic and mathematical support, which acts as an important tool for collecting relevant information databases for making effective management decisions and is accompanied by scientific methods that add better validity to analytical conclusions

In order to solve the tasks set in the work, the following research methods were used: target, comparison and grouping (to reveal the innovative methodological approach of evaluating ICT impact on e-commerce development of industrial enterprises), tabular, analytical and integral method (to generalize the results of the analysis of industrial enterprises readiness to ICT implementation, ICT use in the activities of industrial enterprises of Ukraine, analysis of e-commerce development at enterprises), mathematical modelling (to build a regression model that determines the impact of changes in ICT use on the share of sales of products obtained from e-commerce), logical generalization (to determine perspective directions for e-commerce development of industrial enterprises of Ukraine, which will take into account the impact of ICT).

It is suggested to implement methodological approach in several stages.

At the organizational stage, the information and analytical base is prepared for further research, analysis and assessment of the state of business and ICT used for e-commerce development. To ensure the reliability of the results, the author's approach to data collection and determining the structure of the research was applied. In particular, to obtain information databases, a targeted sampling method was used based on the compilation and processing of

statistical information obtained according to UNSTAD [39], State Statistics Service of Ukraine [40-43]. The statistical sample consists of 13,352 enterprises operating in the industrial sector of Ukraine. Research period: 2016-2020.

At the stage of further analytical evaluation of research results, the readiness of industrial enterprises to implement ICT and their use at industrial enterprises is analysed. Business analytics [44; 45] is an important tool that unites an expert system of data analysis (statistical analysis, mathematical modelling) as a process of processing data into new knowledge that can be used to improve the efficiency of managing commercial activity. To determine the degree of readiness for ICT introduction, it is advisable to use UNSTAD's analytical data on technologies and innovations [46].

When analysing ICT use at industrial enterprises, important attention should be paid to indicators that allow analysing the trends of changes in the number of enterprises that carried out e-commerce and the volumes of their e-commerce. It is also important to analyse the attitude of enterprises to the Internet and web resources, the use of robotics, computer technology, cloud computing and 3D printing, etc.

To calculate the integral indicator of ICT use by industrial enterprises, it is advisable to form a system of the following partial indicators: accessibility to the Internet, the degree of use of the Internet network, the degree of use of the services of their providers' servers, the degree of use of technologies for the analysis of a significant amount of data, the degree of use of additive technologies. The calculated values of the indicators are subject to standardization, the weighting factors are determined according to the rule of symmetrical distribution.

To calculate the final result of ICT use by industrial enterprises, it is suggested using an integral indicator:

$$I_{ict} = \sum_{i=1}^{n}(R_i k_i), \quad (1)$$

where I_{ict} – integral indicator of ICT use;

R_i – resulting value of partial indicators of ICT use;

k_i – i-th weight coefficient of partial indicators of ICT use.

Evaluation of integral indicators is made by grouping of obtained results. This makes it possible to divide the obtained values of ICT usage indicators of industrial enterprises into the following evaluation groups:

[0; 0.2) – critical level;
[0.2; 0.4) – low level;
[0.4; 0.6) – satisfactory level;
[0.6; 0.8) – sufficient level;
[0.8; 1.0] – high level.

Assessment of ICT impact on e-commerce development, in particular on the volume of products sales of industrial enterprises, will also have a targeted direction. To do this, methods of statistical analysis are used that allow establishing influence of one or another factor on the analysed indicator, in particular, the one-dimensional linear regression method. With the help of a package of application programs, the function of the dependence of the partial indicator "Part of the volume of sales of products obtained from e-commerce" on the factor "ICT usage" is built:

$$\Delta Q_p^{et} = b_o + b_1 U_{ICT}, \quad (2)$$

where ΔQ_p^{et} – dependent variable "Part of the volume of sales of products obtained from e-commerce";

b_0 – free variable;

b_1 – coefficient of significance of the influence factor;

U_{ICT} – independent variable "ICT usage".

A systematic approach to the analysis and evaluation of ICT use at enterprises based on analytical, comparative, tabular, integral methods and the one-dimensional linear regression method will provide a comprehensive view of the level of ICT use and assess their impact on e-commerce development of industrial enterprises.

At the final stage of the research, their results should be summarized for a clear formulation of the conclusions, and based on them, a justification of the perspective directions of e-commerce development in the conditions of the growing ICT influence on commercial activity of industrial enterprises should be carried out.

The proposed methodological approach is designed to ensure the consistency of tasks performance, as well as the integrity and systematicity of the research. Its existing advantages, and in particular the variety of research methods, the versatility of analysis, the ability to follow the trends of changes in indicators and their mutual influence, the availability of information form the necessary analytical basis for making effective decisions in the field of online business management.

4. RESULTS

4.1. Analysis of the technological readiness of industrial enterprises for ICT introduction

Digital transformation has gradually changed its role from priority to global for everyone without exception. Businesses, governments, educational institutions, and individuals have increasingly moved their activities online, especially since the spread of the Covid-19 pandemic. The transition to virtual life has increased dependence on digital technologies, increased demand for network infrastructure, reliable connection, and digital literacy [39]. These processes significantly influenced the inclination of enterprises to create and use ICT to achieve their own business goals.

In this study, the index of technological readiness is compiled from the following indicators, which correspond to the greatest extent to the information and communication development of industrial enterprises: the availability of the latest technologies, investments of companies in innovative technologies, state purchases of advanced technologies, patent applications for ICT, total costs for computer software, robotization degree, ICT application skills, regulatory and legal regulation of the ICT sphere (refer to table 2).

Table 2: Technological readiness of industrial enterprises of Ukraine for changes

Indicators	2016		2019		2020	
	Ranking	Point	Ranking	Point	Ranking	Point
Technological readiness	*67*	*4.3*	*71*	*43.0*	*62*	*41.5*
Availability of the latest technologies	96	4.3	99	35.2	49	53.0
Investments of companies in innovative technologies	102	2.4	62	35.5	63	40.6
State procurement of advanced technologies	98	3.0	83	31.9	-	-
ICT patent applications	50	3.7	47	10.6	45	11.3
Total costs for computer software	-	-	19	45.5	19	46.9
Robotization degree	-	-	56	0.74	56	0.74
ICT application skills	89	4.4	n/a	n/a	53	59.3
Regulatory and legal regulation of the ICT sphere	74	3.8	73	81.7	75	81.7

Source: compiled by the authors based on [37; 39; 46]

An established technology readiness assessment method ensures that new products will be gradually integrated into the design and manufacturing processes and will perform as expected in the user environment.

The analysis of the dynamics of indicators of technological readiness of industrial enterprises for changes in the studied period showed a significant improvement in the availability of the latest technologies, investment by companies in innovative technologies, and ICT application skills. However, it was established that the technological readiness of industrial enterprises of Ukraine for changes in the studied period has an average level (in 2016, the country took 67th place out of 139 countries, in 2017–2018 no research was conducted in this direction, in 2019 – 71st place out of 121 countries, and in 2020 – 62nd place out of 134 countries) based on indicators of technological readiness, on the basis of which the rating was compiled.

The dynamics of the above indicators of technological readiness of Ukrainian enterprises shows a significant lag behind similar indicators of industrialized countries of the world [46]. This is due to insufficient state support of advanced technologies, a weak level of normative and legal regulation of the ICT sphere, and a low level of investment in innovative technologies.

4.2. Analysis of ICT use by industrial enterprises

In today's business context, the implementation of global digital transformation, which has only recently become widespread, requires a flexible method of implementing management policy. As a result, more and more active ICT use is required, which has a direct impact on the decision-making process and the efficiency of commercial activity of enterprises.

The results of the analysis of ICT use by industrial enterprises of Ukraine demonstrate unstable trends in the changes in the values of all the studied indicators.

The analysis showed that the share of industrial enterprises that had access to the Internet decreased during the studied years. In 2016, this indicator was 93.9%, in 2017 – 94.1%, in 2018 – 90.5%, in 2019 – 89.9%, while in 2020 – 90.2%. The same situation is observed in the share of enterprises that had websites. If in 2016 the number of industrial enterprises with websites was 42.8%, then in 2020 this figure decreased to 41.9%. Similarly, the indicator of the share of enterprises that analysed "big data" decreased. In 2016, this indicator was at the level of 27.4%, while in 2020 it

decreased by 14.9% and was 12.5%. The share of enterprises that bought cloud computing in 2020 amounted to 9.7%, which shows the growth of this indicator compared to 2016. The share of industrial enterprises that used 3D printing is quite low and varies between 3.3-3.9%.

Analysis of the dynamics of integral indicators of ICT use by industrial enterprises of Ukraine (refer to table 3) reveals insufficient access to the Internet, a low degree of its use by enterprises, an unsatisfactory degree of their use of the services of their providers' servers, as well as additive technologies, a significant decrease in the level of use of technologies of significant-volume data analysis.

Table 3: Indicators of ICT use by industrial enterprises of Ukraine

Indicators	2016	2017	2018	2019	2020
Accessibility to the Internet	0.939	0.941	0.905	0.899	0.902
Degree of use of the Internet network	0.456	0.469	0.463	0.464	0.465
Degree of the servers services use of their providers'	0.078	0.088	0.091	0.100	0.097
Degree of technologies use for the analysis of a significant-volume of data	0.274	0.233	0.179	0.181	0.125
Degree of additive technologies use	-	-	0.035	0.039	0.033

Source: compiled by the authors based on [40-43]

It was established that industrial enterprises of Ukraine did not use ICT at the required level. In particular, comparing the obtained indicators with the goals of the Second Digital Agenda for Europe, according to which 75% of companies should use cloud computing services, big data and artificial intelligence, and more than 90% of small and medium-sized enterprises should reach a basic level of digital intensity [47], it becomes obvious that the industrial enterprises of Ukraine are significantly behind (among them, only 9.7% use cloud computing services, 12.5% analyse "big data" and 3.3% use artificial intelligence).

Further evaluation of the integral indicators of ICT use by industrial enterprises of Ukraine was carried out on the basis of the values of the indicators given in the previous table. The results of the calculations obtained on the basis of the sum of multipliers of the obtained standardized values of the indicators of ICT use and the weighting factors determined according to the rule of symmetrical distribution (refer to table 4) indicate a satisfactory level of the values of the indicators during the last three years.

Table 4: Dynamics of the integrated indicator of ICT use by industrial enterprises of Ukraine

Year	Meaning	Indicator significance level
2016	0.390	low
2017	0.636	sufficient
2018	0.506	satisfactory
2019	0.598	satisfactory
2020	0.495	satisfactory

Source: built by the authors based on their own calculations

According to research data, it can be concluded that ICT use by industrial enterprises of Ukraine ranges from low (at the beginning of the studied period) to satisfactory level (at the end of the studied period), has extremely unstable trends and demonstrates a relationship both with the level of technological readiness of industrial enterprises for changes, and with the degree of their use of server services of their providers, technologies for analysing a significant amount of data, additive technologies. Such unstable dynamics of complex ICT use by industrial enterprises also affected their e-commerce development.

4.3. Analysis of e-commerce development at industrial enterprises

As the global practice of e-commerce shows it plays an extremely important role in promoting products to the market, increasing the volume of sales of the main and secondary products, forming a positive image of industrial enterprises from the point of view of their use of modern digital technologies to improve the final results of commercial activity.

In the conditions of modern economic development, e-commerce is one of the most important factors that allow enterprises increasing sales and rapid consumer demand to the greatest extent. In particular, during the spread of Covid-19, it was especially important for industrial enterprises to increase the volume of e-commerce to ensure their survival in difficult economic conditions.

The e-commerce market is one of the most dynamic in Ukraine in terms of growth rates, so more and more industrial enterprises are switching

from traditional trade to online trade, which opens up significant prospects for the development of their activities. IBM experts point out that the Covid-19 pandemic prompted businesses to actively engage in e-commerce and accelerated the transition from offline to online by about five years.

Conduction of analysis of e-commerce development of industrial enterprises of Ukraine is suggested to be made by comparing the number of enterprises that carried out e-commerce and the supply of products online in the studied period (refer to figure 1).

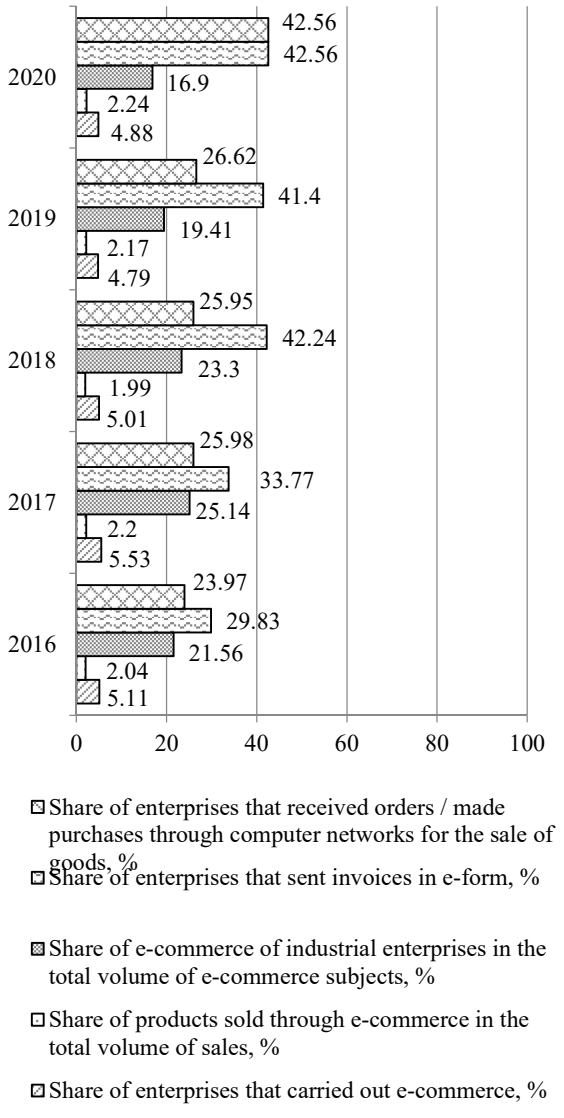

Figure 1: Dynamics of e-commerce indicators of industrial enterprises of Ukraine
Source: compiled by the authors based on [40]

The volumes of e-commerce of industrial enterprises in the studied period grew steadily: 2016 – 39,210 million UAH, 2017 – 50,611 million UAH, 2018 – 53,133 million UAH, 2019 – 56,808 million UAH, and in 2020 – 61,612 million UAH. The analysis of e-commerce development industrial enterprises of Ukraine revealed an increase in the volume of products sold remotely with the help of ICT. At the same time, the rate of growth of e-commerce volumes during the entire period of the study slowed down significantly. It was established that such dynamics could have been much better. The reduction of the share of enterprises engaged in e-commerce (from 5.11% in 2016 to 4.88% in 2020), as well as the share of e-commerce of industrial enterprises in the total volume of e-commerce by business entities (from 21.56% in 2016 to 16.90% in 2020) is problematic.

In the structure of industrial products sold remotely, the main share falls on food products, beverages and tobacco products (62.5%), metallurgical products (7.5%), rubber and plastic products (6.6%), motor vehicles (6.5%), wood products and printing (5.2%), chemical products (2.8%), textile products, clothing, leather and leather products (1.70%), which is 92.8% .

Industrial enterprises of Ukraine need to actively use ICT and go on the path of digital transformation, which will have a positive impact on increasing the volume of e-commerce and achieving maximum economic benefit in the future.

4.4. Mathematical model for assessing ICT impact on the volume of product sales

An important point for e-commerce development of industrial enterprises of Ukraine is the activation of their ICT use. It was established that enterprises do not fully use ICT capabilities that directly affects their e-commerce.

In order to build a mathematical model of the dependence of the indicator “Share of products sales obtained from e-commerce” on the factor “ICT Usage” the aggregated initial data was used. (table 5).

Table 5: Initial data for building a mathematical model

Year	U_{ICT}	ΔQ_p^{et}
2016	0.390	2.04
2017	0.636	2.20
2018	0.506	1.99
2019	0.598	2.17
2020	0.495	2.14

Source: built by the authors based on their own calculations

The resulting dependence function is shown in the formula:

$$\Delta Q_p^{et} = 1.752 + 0.679U_{ICT}. \quad (3)$$

As it can be seen, the estimated coefficients have the correct signs: the share of the volume of products sold remotely is higher, the better the use of ICT. The independent variable explains 73.23% of the variation of the ΔQ_p^{et} criterion for the function. The standard error of the regression indicates a slight dispersion of values relative to the regression line and is 0.07019.

The function is interpreted as follows: an improvement in ICT use by industrial enterprises of Ukraine by 0.1 leads to an increase in the share of the volume of remote sales by 1.820.

The analysis of ICT impact on e-commerce development of industrial enterprises showed that with improper use of ICT by industrial enterprises, e-commerce indicators will have unstable dynamics, or a tendency to decrease the values of its indicators.

4.5. Summarizing the reasons for inhibiting e-commerce development of industrial enterprises

Summarizing the results of a step-by-step study of the peculiarities of e-commerce development of Ukrainian enterprises allows establishing the factors and reasons for its inhibition (Table 6).

Table 6: Reasons for inhibiting e-commerce development of industrial enterprises of Ukraine

Factor	Reason
Insufficient use of ICT	Average level of network and technological readiness of enterprises
Insufficient development of e-commerce	Insufficient level of use of the services of providers' servers, additive technologies, a significant decrease in the level of use of technologies for the analysis of large volumes of data
State influence and regulation	Insufficient state support for advanced technologies, weak level of normative and legal regulation of the ICT sphere

Source: compiled by the authors

Other factors of influence include:

- ✓ institutional – insufficiently active and successful state policy in the field of e-commerce of industrial enterprises;
- ✓ information – insufficiently high degree of protection of buyers on the Internet, low level of confidentiality and personal information protection, inconsistency of Ukrainian information protection standards in accordance with EU standards;
- ✓ financial – insufficient development of payment systems;
- ✓ market – insufficient saturation of Ukrainian market of electronic services;
- ✓ logistics – the level of logistics services is not sufficiently developed compared to the countries of the EU and the USA [48].

The deterioration of ICT use by industrial enterprises for e-commerce implementation during the spread of the COVID-19 pandemic indicates the feasibility of its activation for the improvement of ICT use.

In the conditions of conducting insufficiently perfect e-commerce, which is caused both by the pressure of various threats of external nature, and by the unsystematic ICT use in the activity of industrial enterprises of Ukraine, there is a fundamental need to find promising directions for e-commerce development.

4.6. Perspective directions of e-commerce development of industrial enterprises

Among the main trends in e-commerce development are short-term forecasts, automation, permanent accounting and control of communication with customers, advanced customer service, analytical tools for activity and the study of opportunities, the use of social media and Internet networks, business relations of a new level; then among tools of influence are contextual and native advertising, digital and performance marketing, content marketing, direct marketing and SEO, email mailings, etc. [49]. This is convincing for the further growth of ICT influence in the coming years.

In the scientific and methodological aspect, further improvement in the e-commerce system requires such directions as clarification of the basic scientific principles of the formation of e-commerce systems, economic justification of a more expedient application of various e-commerce models; classification of features of e-commerce that differ from traditional forms of trade; justification of the composition of the main elements of the e-commerce system and analysis of their necessary features; analysis of the main

economic and organizational requirements for an e-commerce platform created on the Internet, development of a generalized mathematical model for selecting an effective decision plan in the e-commerce system based on a multi-criteria approach [50].

Determining the prospects of e-commerce development, one should take as a basis its advantages such as quickly obtaining information about goods and services, reducing production and related costs, accelerating the exchange of information, reducing the duration of production cycles and increasing sales, promoting interaction between e-commerce process participants [51].

In this context and taking into account research results of ICT impact on e-commerce development of industrial enterprises of Ukraine, among promising directions should be highlighted next ones (refer to figure 2):

- ✓ Development of the personal brand of enterprises, including rebranding. The development of a unique brand that stands out in the market has an atypical positioning with the definition of the limits of its existence, in order to minimize efforts to change it in the future. To ensure the integrity of all means of communication, to guarantee the longevity of the brand in time and space, regardless of the region or country of sale. Conduct systematic comparative analysis with competitor's brands.
- ✓ Development of e-commerce tools and technologies. Further development requires the use of cloud computing and kerbside. Improving the use of cloud computing will allow users to reduce current investment costs in ICT. The use of kerbside technology will facilitate the expansion of online ordering, allowing consumers to shop remotely, while retailers will minimize expensive investments in delivery and logistics systems.
- ✓ Automation of the outsourcing service to transfer all processes related to order processing and sending it to the end user will ensure savings on rent for warehouse space and salaries of additional employees, simplification of work and minimal participation of the owner in business processes, constant availability of stock of goods in the warehouse.

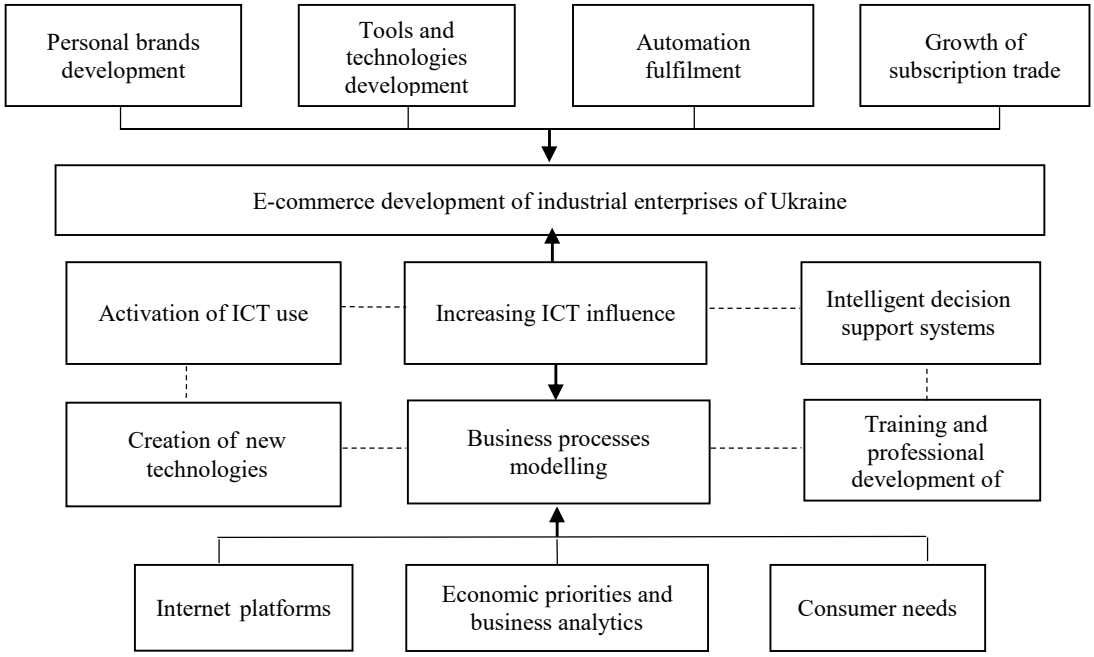

Figure 2: Directions For E-Commerce Development By Industrial Enterprises In The Conditions Of The ICT Influence
Source: Compiled By The Authors

- ✓ Growth of subscription trade. In the context of unforeseen circumstances, subscriptions are becoming an increasingly common business model for e-commerce. Its advantages are the regularity and periodicity of payments for multiple provisions of goods or services. In the context of e-commerce, this includes many new businesses, from streaming services to the purchase of recurring consumer goods.

When implementing these directions, it should be taken into account that the increase in the number of Internet users has significantly expanded the possibilities of attracting consumers of goods and services; consumer awareness is changing day by day, and they seek to implement information technology in all areas of life, including conducting transactions over the Internet; e-commerce entities always have the potential to expand, cover new market segments, different from conventional ones, and involving other groups of people; management of service providers is not limited by time and space [52].

Suggested perspective directions of e-commerce development require the use of digital marketing to review and optimize the existing strategies of industrial enterprises, adapting them to new challenges and needs. This will ensure the improvement of online business efficiency for industrial enterprises, the growth of their incomes and profits, will contribute to the activation of digitalization of business activity, as well as the improvement of the use of IT products and services.

5. DISCUSSION

The use of economic-mathematical modelling in determining the integration impact of ICT on e-commerce development of industrial enterprises acquires the greatest importance under the conditions of applying a system of methods for its evaluation [31]. This is both an advantage and a disadvantage when obtaining research results. The advantage lies in the mutual complementation of the results of the assessment of ICT impact on e-commerce development. A systematic approach based on the use of the method of summarizing statistical information, the analytical method, the method of comparative analysis, tabular and integral methods of analysis and evaluation of ICT use in enterprises, regression analysis when constructing the mathematical dependence of e-commerce development on the level of ICT use will allow to obtain a comprehensive picture of the possibilities of their development, and the results obtained on the basis of their application will make it possible to outline promising directions for e-commerce development. The disadvantage of the implementation of such modelling is a certain subjectivity of the combination of qualitative and quantitative assessments to obtain conclusions. Another limitation is the impossibility of avoiding regression analysis when applying an integrated assessment of ICT use by industrial enterprises.

At the same time, the use of exclusively quantitative indicators in the implementation of an integral assessment of the level of ICT use is debatable. In particular, the method of integral assessment within which a quantitative approach and cross-group structuring using structural equation modelling is applied, in which a random sampling technique and a self-administered questionnaire are combined for data collection may have certain advantages [53]. This approach allows solving the potential problem of lack of normality of the data. When studying ICT impact, other evaluation criteria can be distinguished, unlike those proposed in this research. In particular, combining the three main components of ICT, knowledge management processes, and innovation can complement suggested methodology in order to empirically investigate their components [54]. However, it is more appropriate to use it in a modified form as a self-assessment tool for managers.

The study of cause-and-effect relationships between the dynamics of the integral indicator of ICT use and the change in the share of the volume of sales of products obtained from e-commerce by industrial enterprises also requires special attention. The results of the calculations revealed a strong level of correlation between indicators (correlation coefficient 0.73), but it is not sufficient. To increase the level of correlation between researched variables, a much larger range of the studied period should be chosen. In this case, it became impossible due to the peculiarities of statistical information processing in Ukraine during martial law.

Determination of promising directions for e-commerce development of industrial enterprises, based on conducted research results, reveals the peculiarities of the e-commerce market of Ukraine and the insufficient level of ICT use. At the same time, the defined directions of e-commerce development may differ significantly for enterprises located in countries with a developed market

economy or for countries with a high or high-middle income level [37].

Presented results of the research in this work can contribute to the further growth of interest in the use of economic and mathematical modelling in various areas of business to solve issues of increasing the validity of management decisions.

6. CONCLUSIONS

Assessing ICT impact on e-commerce development of industrial enterprises can create a favourable basis for the further determination of positive/negative factors of influence and prospective directions of e-commerce development. The key idea in the work was to combine the use of integration and regression modelling to obtain research results, which helps to understand ICT impact on e-commerce development better, in particular, on its effectiveness, ensuring the necessary level of validity of the research results. System advantages of the combination of such modelling is based on the principles of universality, optimization, multiple statistical calculation and accuracy, determine its attractiveness for the formation of an methodological approach, which allows determining the degree of integration ICT impact on e-commerce development of industrial enterprises.

The research results had many similarities with previously applied scientific approaches, but differed in reflecting the perspective of practical implementation and expectations. The successful development and use of integration and regression modelling, along with the applied auxiliary methods, in particular the generalization of statistical information, the analytical method, the method of comparative analysis, convincingly proves the feasibility of their application for related fields of economic knowledge that require studying the effect of ICT use.

Research results proved that ICT should be considered as an integrating factor influencing e-commerce development of industrial enterprises, the dynamics of which is determined by the level of their access to the Internet, the degree of enterprises' use of the Internet, server services of their providers, technologies for analysing large amounts of data and additive technologies. At the same time, it can be argued that for industrial enterprises characterized by a satisfactory level of ICT use, an insufficient level of values of e-commerce indicators is observed.

The developed and implemented regression model for evaluating ICT impact on the change in the volume of products sold by industrial enterprises online revealed that an improvement in the ICT use by enterprises at the rate of 0.1 causes an increase in the share of the volume of online sales of products by 1.820. The results indicate the importance of using ICT to increase the effectiveness of e-commerce and commercial activity of enterprises in general.

The obtained research results convince that the application of economic and mathematical modelling is an important tool for determining the prospects of ICT usage to improve the efficiency of online business management.

REFERENCES:

[1] V. Babenko, O. Syniavska, "Analysis of the current state of development of electronic commerce market in Ukraine", *Tech. Aud. and Prod. Res.,* Vol. 5, 2018, pp. 40-45.

[2] A.G. Aliyev, "Problems of Regulation and Prospective Development of E-commerce Systems in the Post-coronavirus Era", *Information Engineering and Electronic Business,* Vol. 6, 2022, pp. 14-26.

[3] A. Rizaldi, Z. Madany, "Impact of E-Commerce in Industry", *International Journal of Research and Applied Technology (INJURATECH)*, Vol. 1, No. 2, 2021, pp. 283-288.

[4] I. Kryvovyazyuk, I. Britchenko, S. Smerichevskyi, L. Kovalska, V. Dorosh, P. Kravchuk, "Digital Transformation and Innovation in Business: the Impact of Strategic Alliances and Their Success Factors", *Economic Studies (Ikonomicheski Izsledvania),* Vol. 32, No. 1, 2023, pp. 157-172.

[5] I. Vakhovych, I. Kryvovyazyuk, N. Kovalchuk, I. Kaminska, Y. Volynchuk, Y. Kulyk, "Application of Information Technologies for Risk Management of Logistics Systems", *62nd International Scientific Conference on Information Technology and Management Science,* Riga Technical University (Latvia), October 14-15, 2021, pp. 1-6.

[6] I. Roshchyk, O. Oliinyk, H. Mishchuk, Y. Bilan, "IT Products, E-Commerce, and Growth: Analysis of Links in Emerging Market", *Transformations in Business & Economics*, Vol. 21, Issue 1, 2022, pp. 209-227.

[7] Y. Bilan, H. Mishchuk, N. Samoliuk, O. Grishnova, "Ict And Economic Growth: Links And Possibilities Of Engaging", *Intellectual Economics,* Vol. 13, No. 1, 2019, pp. 1-12.

[8] A. Yousefi, "The impact of information and communication technology on economic growth: evidence from developed and developing countries", *Economics of Innovation and New Technology*, Vol. 20, Issue 6, 2011, pp. 581-596.

[9] Z. Xing, "The impacts of Information and Communications Technology (ICT) and E-commerce on bilateral trade flows", *Int Econ Econ Policy,* Vol. 15, 2018, pp. 565-586.

[10] J.A. Sava, "Information technology (IT) spending forecast worldwide from 2012 to 2023, by segment", STATISTA. URL: https://www.statista.com/statistics/268938/global-it-spending-by-segment/ (Accessed 03 January 2023).

[11] D. Coppola, "E-commerce as share of total retail sales worldwide 2015-2026". STATISTA. URL: https://www.statista.com/statistics/534123/e-commerce-share-of-retail-sales-worldwide/ (Accessed 03 January 2023).

[12] I.V. Kryvovyazyuk, Y.M. Kulyk, "Problems in application of information technologies for managing enterprise's logistics system", *Actual Problems of Economics,* Vol. 12, No. 150, 2013, pp. 83-90.

[13] A. Krstić, D. Rejman-Petrović, I. Nedeljković, P. Mimović, "Efficiency of the use of information and communication technologies as a determinant of the digital business transformation process", *Benchmarking: An International Journal*, Vol. ahead-of-print No. ahead-of-print, 2022.

[14] E.F. Tongora, "Factors Intricate the Adoption of e-Commerce by Small-medium Sized Enterprises (SMEs) in Tanzania", *European Journal of Technology*, Vol. 6, No. 3, pp. 49-60.

[15] A. Asaul, M. Voynarenko, L. Yemchuk, L. Dzhulii, "New realities of the enterprise management system information support: Economic and mathematical models and cloud technologies", *Journal of Information Technology Management,* Vol. 12, Issue 3, 2020, pp. 44-60.

[16] A. Saltelli, "A short comment on statistical versus mathematical modelling", *Nature Communications,* Vol. 10, 2019, 3870.

[17] N. Hritonenko, Y. Yatsenko, "Mathematical modeling in economics, ecology and the environment", 2nd Edition, Springer Optimization and Its Applications 88, New York: Springer Science & Business Media, 2013, p. 1.

[18] E.N. Veduta, T.N. Dzhakubova, "Economic science and economic-mathematical modeling", *Mathematical modeling in economics,* Vol. 3-4, No. 9, 2017, pp. 10-22.

[19] A. Trad, D. Kalpić, "Using Applied Mathematical Models for Business Transformation", Hershey: IGI Global, 2019.

[20] O. Zybareva, I. Kravchuk, Y. Pushak, L. Verbivska, O. Makeieva, "Economic and Legal Aspects of the Network Readiness of the Enterprises in Ukraine in the Context of Business Improving", *Special Issue: Innovation in the Economy and Society of the Digital Age,* Vol. 39, No. 5, 2021, pp. 1-19.

[21] T. Zatonatska, O. Rozhko, N. Tkachenko, "Modern Trends of Impact on Economic Development of Countries: E-Commerce and R&D", *Marketing and Management of Innovations,* Vol. 4, 2018, pp. 129-135.

[22] I.V. Kryvovyazyuk, R.M. Strilchuk, "Strategic opportunities management at engineering enterprises", *Actual Problems of Economics,* Vol. 183, No. 9, 2016, pp. 144-155.

[23] S. Sulova, M. Kasheva, N. Filipova, P. Peneva, Y. Alexandrova, "Electronic Business. Business Modeling. Analysis and Development of Business Information Systems", Varna: Publishing house „Science and Economics", 2015.

[24] M.C. Duica, N.V. Florea, A. Duica, V. Toplicianu, "The role of mathematical modeling in analyzing the impact of the Internet on commercial activities", *JOSA*, Vol. 4, 2017, pp. 503-522.

[25] N. Roztocki, H.R.Weistroffer, "Conceptualizing and researching the adoption of ICT and the impact on socioeconomic development", *Information Technology for Development*, Vol. 22, Issue 4, 2016, pp. 541-549.

[26] N. Roztocki, P. Soja, H. R. Weistroffer, "The role of information and communication technologies in socioeconomic development: towards a multi-dimensional framework", *Information Technology for Development,* Vol. 25, Issue 2, 2019, pp. 171-183.

[27] S. Rizvi, J. Mitchell, A. Razaque *et al.*, "A fuzzy inference system (FIS) to evaluate the

security readiness of cloud service providers", *Journal of Cloud Computing,* Vol. 9, 2020, 42.

[28] O. Kwon, N. Lee, B. Shin, "Data quality management, data usage experience and acquisition intention of big data analytics", *International Journal of Information Management,* Vol. 34, Issue 3, 2014, pp. 387-394.

[29] L. Chen, Y. He, Y. Yang *et al,* "The research status and development trend of additive manufacturing technology", *The International Journal of Advanced Manufacturing Technology*, Vol. 89, 2017, pp. 3651-3660.

[30] C.-Ch. Chou, W.T. Lin, C. Lee, X. Tao, Z. Qian, "The impacts of information technology and E-commerce on operational performances: A two-stage dynamic partial adjustment approach", *Journal of Industrial and Production Engineering,* Vol. 38, Issue 4, 2021, pp. 291-322.

[31] V. Ha, "Enhancing the e-commerce application in SMEs", *Management Science Letters*, Vol. 10, Issue 12, 2020, pp. 2821-2828.

[32] S. Arsić, Đ. Nikolić, I. Milošević, M. Jevtić, I. Jovanović, "The Role of Advanced Technologies on ECommerce Sales During (Covid-19) Pandemic Time", *Proceedings of 19th International Conference on Management, Enterprise, Benchmarking,* Óbuda University (Hungary), June 18-19, 2021, pp. 1-15.

[33] N.V. Florea, C.A. Ionescu, M.C. Duică, S. Căpușneanu, L. Paschia, S.G. Stanescu, M.D. Coman, "Trends and Perspectives of Romanian E-Commerce Sector Based on Mathematical Simulation", *Electronics*, Vol. 11, No. 15, 2022, 2295.

[34] O. Popelo, S. Tulchynska, G. Krasovska, O. Kostiunik, L. Raicheva, O. Mykhalchenko, "The impact of the national economy digitalization on the efficiency of the logistics activities management of the enterprise in the conditions of intensifying international competition", *Journal of Theoretical and Applied Information Technology,* Vol. 101, No.1, 2023, pp. 123-134.

[35] A.W. Scott, E.A. Regan, "Factors Influencing e-commerce Adoption and Use by Small and Medium Businesses", *Electronic Markets,* Vol.15, Issue 4, pp. 438-453.

[36] K. Zong, Y. Yuan, C.E. Montenegro-Marin, S.N. Kadry, "Or-Based Intelligent Decision Support System for E-Commerce", *Journal of Theoretical and Applied Electronic Commerce Research*, Vol. 16, No. 4, 2021, pp. 1150-1164.

[37] S. Dutta, B. Lanvin, "The Network Readiness Index 2021", Washington: Portulans Institute, 2021, p. 30.

[38] I. Kryvovyazyuk, I. Vakhovych, I. Kaminska, V. Dorosh, "Managerial innovations in methodology of solving export-import activity problems and ensuring international corporations business excellence", *Quality - Access to Success,* Vol. 21, No. 178, 2020, pp.50-55.

[39] UNSTAD, "THE UNCTAD B2C E-COMMERCE INDEX 2020. Spotlight on Latin America and the Caribbean", *Technical Notes on ICT for Development,* No. 17, 2021, pp.1-22.

[40] State Statistics Service of Ukraine, "Use of information and communication technologies at enterprises: e-commercein", 2022, available at: https://ukrstat.gov.ua/ (Accessed 20 January 2023).

[41] State Statistics Service of Ukraine, "Use of information and communication technologies at enterprises: use of internet network, social media, cloud calculation", 2022, available at: https://ukrstat.gov.ua/ (Accessed 20 January 2023).

[42] State Statistics Service of Ukraine, "Use of information and communication technologies at enterprises: e-commerce, big data analysis, ICT specialist and ICT-related skills, use of 3D printing", 2022, available at: https://ukrstat.gov.ua/ (Accessed 22 January 2023).

[43] State Statistics Service of Ukraine, "Use of information and communication technologies at enterprises: use of internet network, cloud calculation, robotics", 2022, available at: https://ukrstat.gov.ua/ (Accessed 22 January 2023).

[44] A.J. Silva, P. Cortez, C. Pereira, A. Pilastri, "Business analytics in Industry 4.0: A systematic review", *Expert Systems*, Vol. 38, Issue 7, 2021, e12741.

[45] I. Kryvovyazyuk, G. Otlyvanska, L. Shostak, T. Sak, L. Yushchyshyna, I. Volynets, O. Myshko, I. Oleksandrenko, V. Dorosh, T. Visyna, "Business diagnostics as a universal tool for stady of state and determination of corporations development directions and strategies", *Academy of Strategic Management Journal,* Vol. 20, Issue 2, 2021, pp. 1-14.

[46] UNCTAD, "Technology and Innovation Report 2021. Catching technological waves: Innovation with equity: Innovation with equity", Geneva: UNCTAD, 2021, pp. 137-138.

[47] C. Ratcliff, B. Martinello, V. Litos, "Digital Agenda for Europe", 07.2022, available at: https://www.europarl.europa.eu/factsheets/en/sheet/64/digital-agenda-for-europe (Accessed 25 January 2023).

[48] V. Misyukevich, N. Trushkina, Y. Shkriggun, "E-commerce in global digital space: new challenges and directions of development", *Formation of the internal trade system of Ukraine: theory, practice, innovation,* 2020, Poltava: Puet, pp.150-162.

[49] O. Polous, "System analysis of digitalization indices of Ukrainian enterprises", *Economic analysis",* Vol. 30, No. 1, Part 2, 2020, pp.118-124.

[50] O. Storozhuk, "E-commerce market 2022: trends, tools and needs of online buyers", LEAGUE. Blogs, 05.01.2022. URL: https://blog.liga.net/user/astorozhuk/article/42890 (Accessed 12 February 2023).

[51] I. Hula, "Prospects of development of ukrainian electronic commerce", *Proceedings of the 4th International Scientific-Practical Conference "Formation of the mechanism of national economic systems competitive positions strengthening in global, regional and local dimensions",* Ternopil Ivan Puluj National Technical University (Ukraine), March 31, 2020, pp. 82-84.

[52] O. Syniavska, "Electronic trade in Ukraine: trends and prospects for development", *The Journal of V. N. Karazin Kharkiv National University. Series: International Relations. Economics. Country Studies. Tourism*, Vol. 9, 2019, pp. 126-132.

[53] H. Cuevas-Vargas, S. Estrada, E. Larios-Gómez, "The Effects of ICTs As Innovation Facilitators for a Greater Business Performance. Evidence from Mexico", *Procedia Computer Science,* Vol. 91, 2016, pp. 47-56.

[54] Q. Jarmooka, R.G. Fulford, R. Morris, L. Barratt-Pugh, "The mapping of information and communication technologies, and knowledge management processes, with company innovation", *Journal of Knowledge Management*, Vol. 25, Issue 2, 2021, pp. 313-335.