Neural Network Modeling of E-Government Development and the Socio-Economic Environment

Gavkalova Nataliia, Lola Yuliia, Prokopovych Svitlana, Sybirtsev Volodymyr, Diachek Vitalii

Abstract— : Many studies are devoted to the peculiarities of the information society, new level of interaction between government, business and citizens, assessment of the E-government progress in developed and developing countries. This paper examines the influence of the e-government development on the economic, social and political activities of modern society. The correlation and regression analysis and Neural network modeling has been used to identify the relationship between the E-Government Development Index (EGDI), the Doing Business (DB), the Global Competitiveness Index (GCI) and the Democracy Index (DI). The results demonstrate that there is a close link between the level of e-Government development and the countries' economic, social and political attractiveness. However, it is not equal for different countries.

Keywords: the E-Government Development, the Democracy Index, the Doing Business, the Global Competitiveness Index.

I. INTRODUCTION

In the 21st century, no country in the world can stay away from the process of global informatization of the society. The development of the Internet technologies is getting to a level where it requires transformation of interaction among community, government and business. One of the tools of such transformation is the introduction of e-government service. E-government makes the administrative process convenient, efficient, transparent, and fully accountable to the community in each country. The mechanism for measuring its progress and level of development, as well as predicting its impact on the socio-economic and political situation of the countries of the world, is especially relevant for the development of the world e-government.

II. THEORETICAL DEVELOPMENT AND HYPOTHESES FORMULATION

In the 20th century the most developed countries gradually entered the state of information society and it is expected that within a matter of a few decades the majority of the world's population will be living and working in a global information society [1].

The Global Brain proposes a positive vision for a more sustainable society. The Global Brain can be defined as the distributed intelligence emerging from all human and technological agents as interacting via the Internet. It plays the role of a nervous system for the social superorganism [2].

ICT carries the potential of opening economic opportunities, promoting social and political changes in society, providing access to knowledge, creating stimulus and a field for best practice sharing in all areas of life, the actual processes of informatisation across the globe are quite asymmetrical [3]. Without internet access, which facilitates economic development and the enjoyment of a range of human rights, marginalized groups and developing States remain trapped in a disadvantaged situation, thereby perpetuating inequality both within and between States [4].

The statistical data points on the fact that it is necessary to increase the awareness of population regarding possibilities offered by using of ICT and e-Government in Latvia [5]. Goal of e-government is to create more public values that will bring varieties of utility for multi-stakeholders, and also take social equity into account. This fact was already mentioned by [6].

There has been a proliferation of e-readiness assessment measures in recent years that each one has a certain objective. Based on definitions, objectives, dimensions, methods and approaches, the measures are categorized and finally, a measure for e-readiness assessment is presented. The convergence measure for e-readeness assessment include some common indicators: infrastructure and access, access to and use of ICT by households and individuals, E-businesses, E-education, E-government, basic enabling indicators [7].

With the increasing importance of trends such as cloud computing, open (big) data, participation tools or social media, new indicators and approaches need to be introduced in the measuring of the e-government development, and the existing indices should to be updated, redefined and restructured [8].

The concept of e-government service quality has eight contributing dimensions: system quality, reliability, security, accessibility, information quality, service capability, interactivity, and responsiveness. Perceived service value is a powerful mediator between service quality and citizens' continuous-use intention [9].

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The findings of the correlation and the cluster analysis confirmed that the global recession and the Eurozone crisis have influenced the progress of the e-Government in the evaluated years [10].

Hypothesis 1. Development of e-government has non-line influence the economic and socio-political level of societies in the countries.

III. METHODS

In order to study the influence of E-Government development of the countries on their economic, socio-political state, the following algorithm of the research has been proposed:

Stage 1. Selection of the initial variables, methods of research.

Stage 2. Application of correlation and regression analysis methods for compiling the system of simultaneous linear equations.

2.1. Assessing the link between the indicators.

2.2. Construction of a system of simultaneous equations.

2.3. Assessment of the quality of the model.

3.1 Choosing the network type, activation functions, and network learning algorithm.

3.2. Assessment of the quality of the model.

3.3. Prediction of the change of target variables depending on the influence of the selected predictor.

To carry out the research, the global indices and variables of economic and socio- political development were selected: The Democracy Index [11], The Doing Business [12], The Global Competitiveness Index [13], E-Government Development Index [14]. Please verify that the figures and tables you mention in the text actually exist..

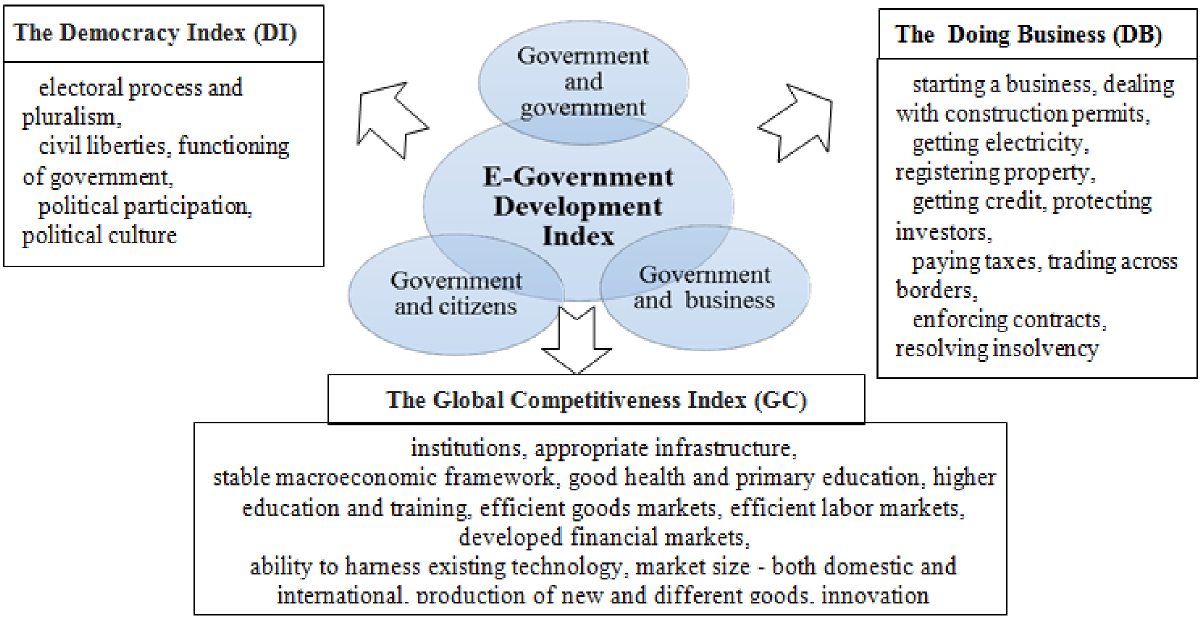

Fig.1. The connection between EGDI and DI, DB, GC

The objects of research are 105 countries of the world. The variables are the data for 2017. The countries without sufficient data were excluded from the database.

During the implementation of the first step of the second stage of the study, a pair correlation matrix was constructed (Tabl. 1). Marked correlations are significant at p < ,05000 N=105 (casewise deletion of missing data).

Table- I: The pair correlation matrix

Indicator	GC	DB	DI	EG					
GC	1,0000	0,7209	0,6535	0,8646					
DB	0,7209	1,0000	0,6226	0,8000					
DI	0,6535	0,6226	1,0000	0,7158					
EG	0,8646	0,8000	0,7158	1,0000					

Such high values of the even correlation coefficients make it possible to assume that there is a fairly close direct linear relationship between all indicators. The closest linear relationship exists between EG and GC and the weakest (0.6226), but also statistically significant - between DI and DB. The graphic image of this link is shown in fig. 2.

To study the effect of EG on GC, DB, and DI we construct a complex linear regression using STATISTICA package. Unknown parameters are estimated with the help of ordinary least squares method (OLS). The following results have been obtained:

$$\begin{cases} \widehat{GC} = 2.4711 + 2.9928 \cdot EG, \\ \widehat{DB} = 36.201 + 47.6066 \cdot EG, \\ \widehat{DI} = 1.7543 + 7.1079 \cdot EG, \end{cases}$$

The data of regression equations are statistically significant on the whole by Fisher criterion $F_{GC}(1; 103) = 305.07$, $F_{DB}(1; 103) = 183.14$, $F_{DI}(1; 103) = 108,20$), and by certain parametres by Student's criterion ($t_{a_{10}} = 22.45$, $t_{a_{11}} = 17.46$, $t_{a_{20}} = 16.02$, $t_{a_{21}} = 13.53$, $t_{a_{30}} = 3.997$, $t_{a_{31}} = 10.40$). The coefficients of multiple correlation $R_{GC} = 0.865$, $R_{DB} = 0.80$, $R_{DI} = 0.716$), determination coefficient ($R^2{}_{GC} = 0.748$, $R^2{}_{DB} = 0.64$, $R^2{}_{DI} = 0.512$) prove high quality of the model..

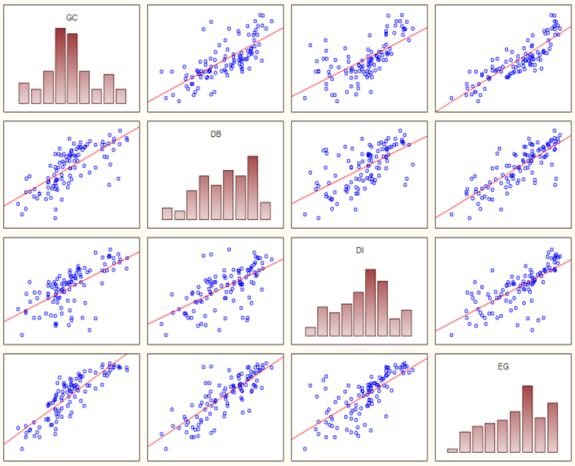

Fig. 2. Relationship between EG, GC, DB, DI

There is no autocorrelation of mistakes (statistics of Darbin-Watson approximately equals to 2, and cyclic coefficient of autocorrelation is rough 0). So we draw a conclusion that the given model can be used for analysis.

It can be noted that increase in EG by one, will provoke increase in the GC index approximately by 2.9928, index DB – by 47.6066 unities, and index DI – by 7.1079 units.

This influence is direct and statistically significant.

Let us consider the results of the implementation of the stage 3. The methods of neural network modeling were used to solve the link regression problems between e-government development and the indicator of different society spheres. Despite the fact that we consider the system of three one-factor models neural network modeling was chosen, because it allows us to find high quality models that are built automatically without the expert's involvement during the training process. These methods were implemented with the StatSoft's software package STATISTICA Automated Neural Networks (SANN).

The data set contains three target changes (GC, DB, DI) and one predictor (EG). To teach the network, we set its type – a multi layer perceptron (MLP*)*, that is a feed forward neural network architecture with unidirectional full connections between successive layers. It`s the most popular network architecture in use today.

As a result of training we received a set of 10 constructed networks. Two of the best were selected. Table 2 shows the architecture, training and test performance, error, and connection type for the two of the best neural networks for predicting targets (GC, DB, and DI).

Table- II: Summary of active networks

Index	Net. name	Training perf.	Test perf.	Validation perf.	Training error	Test error	Validation error	Training algorithm	Error function	Hidden activation	Output activation
1	MLP 1-6-3	0,8297	0,7479	0,8108	24,589	26,102	27,198	BFGS 100	SOS	Logistic	Exponen.
9	MLP 1-9-3	0,8273	0,7491	0,8128	24,568	26,238	26,727	BFGS 164	SOS	Exponen.	Exponen.

The performance is characterized by the coefficient of determination (the closer it is to 1, the better the approximate data in the model). SANN uses the determination coefficient between the targets of the data and the outputs (predictions) of the network as a performance measure. As can be seen from the table 2 the values of all the determination coefficients on the training, test, and validation samples have quite high values (greater than 0.74).

The selection of the best networks was carried out according to the values of the test and validation sample correlation coefficients. Thus, the following networks were chosen as the best with architecture: MLP 1-6-3 (fig. 3).

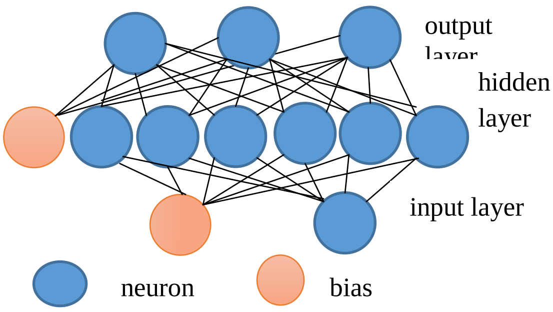

Fig. 3. A schematic diagram of a fully connected MLP 1-6-3

This network includes one input, 3 output, and 6 neurons in hidden layer. The hidden activation function is Logistic sigmoid: $1/(1 + e^{-a})$;

MLP 1-9-3. This network includes one input, 3 output, and 9 neurons in hidden layer. The hidden activation function is Exponential function: e^{-a}.

In both cases the output activation functions are Exponential function. The quality of the constructed models can also be estimated using correlation coefficients.

The correlation coefficient measures how close the prediction of a network is to the target (dependent) data. The correlation coefficients for all dependent variables in all samples (train, test, and validation) are shown in table 3.

Table- III: Correlation coefficients

Network	GC - Train	GC - Test	DB - Train	DB - Test	DI - Train	DI - Test
1.MLP 1-6-3	0,911	0,837	0,815	0,768	0,762	0,638
9.MLP 1-9-3	0,908	0,833	0,815	0,767	0,758	0,646

To assess the adequacy of the constructed networks, we constructed histograms of residual scattering for each indicator of each neural network. Fig. 4-6 shows the histograms of residuals for the model MLP 1-9-3.

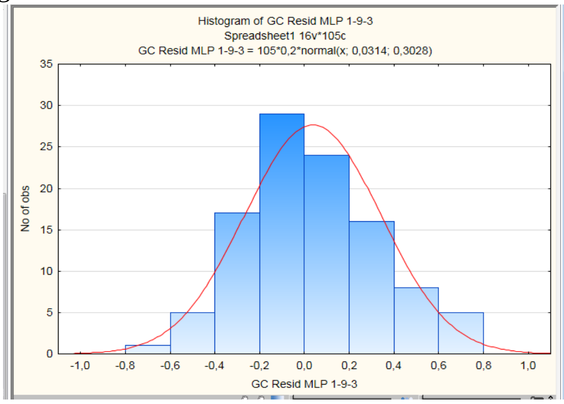

Fig. 4. Histograms of GC residuals

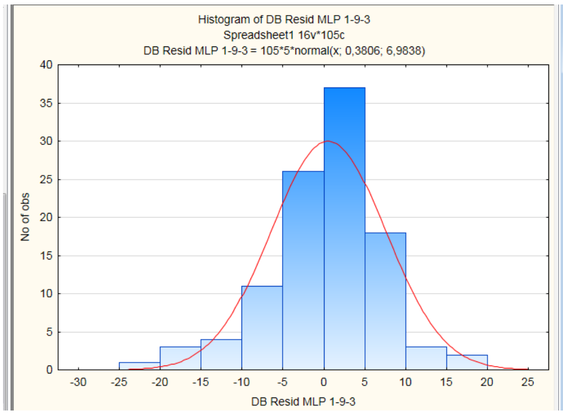

Fig. 5. Histograms of DB residuals

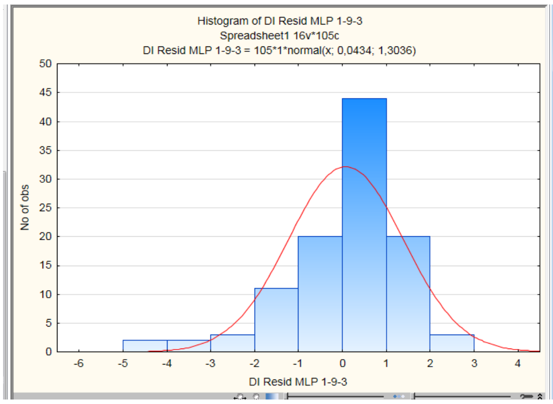

Fig. 6. Histograms of DI residuals

As it can be seen in Fig. 4-6 the residues are distributed very close to the normal distribution law, which indicates the high quality of the model.

We can use the scatterplot of the observed and predicted values to visually inspect how well a target is related to the network outputs. The graph is a visualization of the correlation coefficient, which plays a central role in network selection.

Since more than one network is selected in the grid of active neural networks, an overlapping scatterplot is created. These graphs give opportunity to visually evaluate in three-dimensional space how well a target is related to the network outputs: GC, DB, DI. Overlapping scatterplot for MLP 1-6-3 are presented in Fig.7-9.

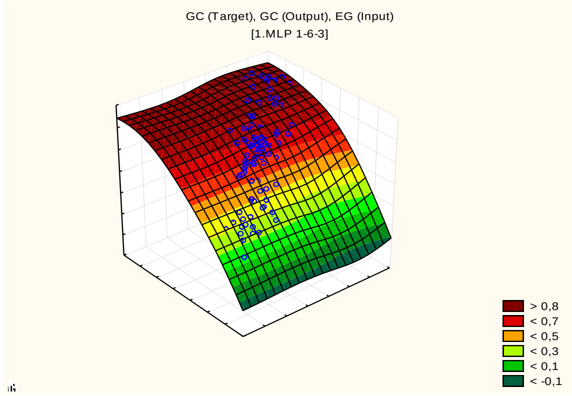

Fig. 7. Overlapping scatterplot GC

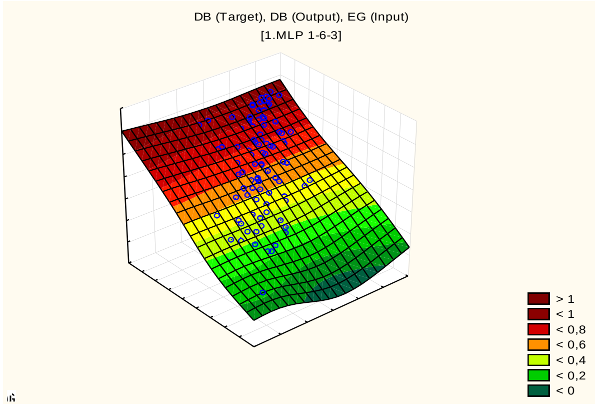

Fig. 8. Overlapping scatterplot DB

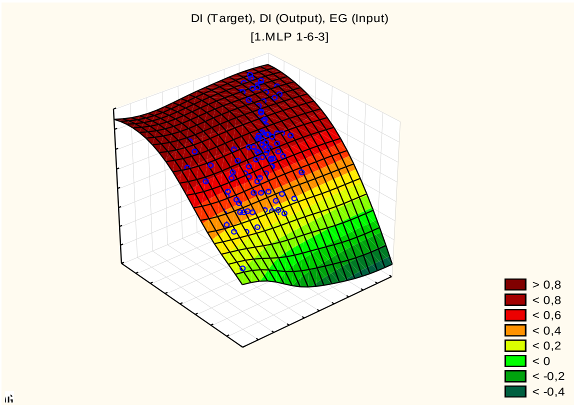

Fig. 9. Overlapping scatterplot DI

Due to high quality of the constructed neural networks, we can use them for making predictions, namely, we can implement the last step of the Stage 3 of the proposed research algorithm.

Three countries were selected as objects for search for predicted values: Uganda, Ukraine and The United States of America. They represent three continents: Africa, Europe and America. It was suggested that the value of the EG index in the forecast period will increase by 1 and 5% for each country compared to 2017. The predicted values of the independent and dependent indicators are given in Table 4.

Table- IV: The predicted values of independent and dependent indicators

Country	EG	MLP 1-6-3		
		GC_(t)	**DB_(t)**	**DI_(t)**
Uganda (1%)	0,4096	3,7127	55,1247	4,8008
Ukraine (1%)	0,6227	4,1404	65,0420	5,6773
The USA (1%)	0,8857	5,4973	77,3109	8,8890
Uganda (5%)	0,4258	3,8304	57,5064	4,6879
Ukraine (5%)	0,6473	4,3383	67,4961	5,9691
The USA (5%)	0,9207	5,5101	78,7459	9,2887
The line model				
Uganda (1%)	0,4096	3,6969	55,7	4,6656
Ukraine (1%)	0,6227	4,3347	65,8456	6,1803
The USA (1%)	0,8857	5,1218	78,3661	8,0497
Uganda (5%)	0,4258	3,7454	56,4718	4,7808
Ukraine (5%)	0,6473	4,4083	67,0167	6,3552
The USA (5%)	0,9207	5,2265	80,0324	8,2985

As it can be seen in Tab. 4 the predicted values of the linear model are quite significantly different from meanings that gives neural networks for predicting targets (with using logistic function). It should be noted that the gradual development of e-government leads to the gradual improvement of ease of doing business, socio-economic attractiveness and development of democracy in countries.

IV. RESULT AND DISCUSSION

Implementing e-government reduce the cost of delivering government services, and ensure better contact with citizens in all areas, stimulate the emergence of local e-cultures and strengthen democracy. To study the influence of e-government on different society development factors were used correlation and regression analysis (for the linear model) and the neural network modeling. The results showed that there is a close relationship between the development of e-government and the development of the economic, social and political sphere of society. The constructed nonlinear model has higher quality than the linear model system.

This research study provides insights that may be useful in improving the e-Government resource and services.

Further studies require an analysis of the changing impact of e-Government development on the economic, social and political level of country development over a period of time. Moreover, attention should be paid to the fact that e-government progress can affect different spheres of society over time. This is due to the fact that informatization of the society is a complex uneven process that requires modern technical equipment and acquisition of information competencies by civil servants and potential users of electronic services.

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