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Impact of information technology on business performance: Integrated structural equation modelling and artificial neural network approach

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Abstract. In today's globalizing world, also called the information age, information and information technologies are becoming increasingly important for businesses and have become an indispensable part of economic and social life. Nowadays, it is impossible to think of a business that is far from information technology; in addition, it is important to find not only information, but also the highly accessible and reliable information. The important thing is to use information technologies effectively and efficiently. Therefore, it is expected that the effective usage of information technology will have significant positive effects on business performance. The aim of this study is to examine and analyze the impact of the intensive usage of information technologies on business performance in the supply chain process. A sequential, multi-method approach, integrating Structural Equation Modelling (SEM) with neural network analysis, was employed in this research. The information technology usage performance network was formed by using the SEM model, and the ANN model was used to predict a relationship between information technology usage levels and business performance by using these network outputs. Furthermore, the validity and reliability tests of the relevant model data were performed.

1. Introduction

With the transition from the industrial to information society, rapid and incredible developments in information technologies have removed the borders in the globalizing world and rebuilt the world under the roof of information societies, which are in constant communication and competition with each other. Developments in computer and communication technologies bring about a change in business activities in terms of cost, time, quality, and service. In particular, changes experienced in information technologies cause significant changes in the business structure and lead businesses to new ways of penetrating new markets, presenting their products and services, enhancing the efficiency of their processes, customer acquisition, and ensuring customer loyalty [1]. Information technology can be considered as all tools, applications, and services that are used to provide information to organizations, which are rapidly developing [2]. As a result, information technology is best defined as "a general purpose technology", not as a traditional capital investment [3]. There have been significant developments in information technologies over the last 20 years. With these technologies, data

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processing has become faster and costs reduced and more reliable than ever [4]. The increasing usage of information technologies has resulted in the need to assess the effects of these technologies on productivity.

In the literature, the level of the use of information technologies in businesses operating in different industries has been examined, and the effects of the use of information technologies on the organizational performance of these businesses have been investigated [5-12]. Furthermore, the relationship among information technology, organizational transformation, and business performance has been examined in different studies [13-19]. Different from the studies in the literature, the effect of the use of information technologies on business performance has been investigated in this study with an integrated model. Supply chain management as a concept has been widely accredited to a Booz Allen consultant named Keith Oliver who, in 1982, defined the concept as follows: "Supply Chain Management (SCM) is the process of planning, implementing, and controlling the operations of the supply chain with the purpose of satisfying customer requirements as efficiently as possible. Supply chain management spans all movement and storage of raw materials, work-in-process inventory, and finished goods from point-of-origin to point-of-consumption". The role of information technology in SCM was highlighted in the past; for example, integrated information systems can lead to the improved business performance of companies in a supply chain [20]. At the intersection of information technology and SCM, three studies deal with a wider domain by addressing the use and effects of information technology for SCM [21-23]. In fact, SCM is the management of a set of interrelated issues that is in line with customers' satisfaction [24]. For this purpose, in this study, a network of the relationships between the usage of information technologies and performance was established with the SEM model, and the relationship between the information technology usage levels and business performance was predicted by using the outputs of this network with the ANN model. Furthermore, the validity and reliability tests of the data were performed, and the analyses were performed with the related models.

2. Research method

The independent variable of the study was determined to be the usage of information technologies, the dependent variable to be the business performance, and the mediator variable to be the information quality (Figure 1). Path c in Figure 1 (Hypothesis 4) can also be defined as the indirect effect of the independent variables on the dependent variable through the mediator variable [25,26]. After the participation of the mediator variable, in addition to the direct effect

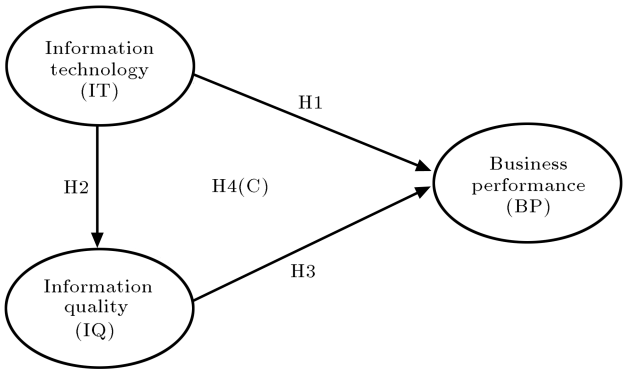

Figure 1. The proposed conceptual model and research hypotheses.

of the independent variable on the dependent variable, the indirect effect arising from the mediator variable emerges. Moreover, the variance change introduced by the indirect effect can be evaluated [27]. The statistical significance of the indirect effect is obtained by the Sobel test statistic (http://www.danielsoper.com /statcalc3/calc.aspx?id=31). The following hypotheses were tested with the research model:

- Hypothesis 1 (H1): There is a positive relationship between information technologies and business performance;
- Hypothesis 2 (H2): There is a positive relationship between information technologies and information quality;
- Hypothesis 3 (H3): There is a positive relationship between information quality and business performance;
- Hypothesis 4 (H4): Information quality has a mediator role in the relationship between information technologies and business performance.

The aim of this study is to examine and analyze the effects of the intensive use of information technologies on business performance in a supply chain process. Therefore, an integrated model was created by developing a Structural Equation Model (SEM) and an Artificial Neural Network (ANN) model considering the outputs of this model. The network of the relationships between the usage of information technologies and performance was established with the SEM model, and the relationship between the information technology usage levels and business performance was estimated by using the outputs of this network with the ANN model. The survey technique was used as a data collection tool in the study. In this study, within the scope of the reliability and validity studies of the scales, the confirmatory factor analysis was performed with AMOS 22.0, and item analyses were performed with the SPSS 21.0 program.

In addition, the structural equation model and artificial neural networks have been integrated in many studies, and successful results have been achieved. Some of these are as follows: the estimation of the use of social media in higher education [28], supply chain [29], health supply chain [30], customer satisfaction and loyalty [31], mobile learning [32], open Inter-Organizational Systems (IOS) adoption [33,34], the determinants of NFC-enabled mobile credit [35], m-commerce adoption [36,37], cognitive engagement [38], and adoption of mobile entertainment services [39].

While structural equation modelling is often used to test hypothetical relationships, it sometimes simplifies the complexities of relationships that may exist between variables [31,35-37,40]. This article uses a two-step SEM and neural network model to characterize the relationships between the variables. Whereas the SEM is a widely used statistical model to test linear relationships between the proposed hypotheses, the method may not be useful if the relationship between decision variables is not linear. Under these conditions, neural network modelling helps to understand linear and nonlinear relationships between related decision variables. This is one of the frequent advantages of neural network modelling. It is difficult to use neural network models to test hypotheses and understand causal relationships [28,0,41]. For this reason, this study integrates structural equation modelling with the artificial neural network analysis to better understand the factors that determine the impact of information sharing in business performance measures.

3. Methodology

The businesses included in the study were randomly selected from the first 1000 large companies determined by ISO, and prepared questionnaire forms were sent to the businesses via e-mail. As of the beginning of 2016, a total of 220 companies returned; however, since 17 of these were filled in the questionnaire in an incomplete and inappropriate way, data of the remaining 203 companies were analysed. Thus, 20.3% of the main mass was taken into consideration within the scope of the study (Table 1). The survey questions were prepared on a 7-point Likert-type scale to provide a more precise assessment. In this part of the study, the IT usage levels in ISO 1000 businesses and how IT usage levels varied according to the company characteristics were investigated. Hypotheses created for this purpose were tested with appropriate statistical methods.

The ANN model was created by taking into account the variables for which the meaningful relationships between them were proved with the SEM model. ANNs are mathematical systems that mimic the way in which the human brain works [42]. Moreover, the artificial neural network is generally an information processing system and a computer program that imitates the neural network system of the human brain [43-45]. The ANN is made up of interconnected processing units called neurons. The applied artificial neural network has three layers: the input layer, the hidden layer, and the output layer [46]. The nodes in each layer after zero are assigned weights (synaptic weight), and a layer or a node has an associated linear or non-linear activation function [5,36]. ANN models have capabilities to capture linear as well as non-linear relationships between independent variables and a dependent variable. The ANN models have been shown to perform better than traditional statistical models such as MLR and logistic regression [47]. The ANN also has some disadvantages; for example, it is not suitable for testing research hypotheses because of its 'Black Box' operations [39]. The ANN research is based on learning from data to mimic the biological capability of linear and nonlinear problem solving [48].

4. Analytical methods and results

This study adopted the multi-analytic approach by combining the SEM with neural network analysis derived from Scott and Walczak [38]. The SEM examined the reliability and validity of the measures, and the neural network was used to predict business performance in 1000 ISO manufacturing businesses. In order to have a good quality neural network, it is vital to determine the required input variables. Similar to

Table 1. Sectoral distribution of companies participating in the study.

Sector	Frequency	%	Sector	Frequency	%
Wood, packaging, furniture	16	7.9	Chemistry	13	6.4
White goods, electronics industry	8	3.9	Mining	7	3.4
Construction, non-metal industry	37	18.2	Metal and Metal Goods Industry	28	13.8
Energy	8	3.9	Automotive	13	6.4
Food	31	15.3	Textile	29	14.3
Other	13	6.4	Total	203	100.0

Table 2. Descriptive statistics of the variables.

Scale and subdimensions	Number of items	Mean	St. Dv.	Skewness	Kurtosis	Cronbach's alpha
Information quality	7	6.01	0.81	-0.74[a]	0.85	0.89
Information technologies	16	5.40	1.01	-0.69	0.49	0.92
Cost performance	4	4.57	1.32	0.11	0.16	0.89
Flexibility performance	3	4.83	1.26	0.27	-0.67	0.87
Response performance	3	5.11	1.20	-0.21	-0.39	0.84
Delivery performance	6	5.07	1.10	0.14	-1.13	0.77
Financial performance	5	4.66	1.07	0.55	0.49	0.90

[a]: After the inversion and square root transformation

Table 3. Model fit indices [25,26] and the results of the DFA and reliability analysis.

Model compliance indexes (acceptable)	Model compliance indexes (good very good)	Model compliance index	Information quality	Information technology	Business performance
$X^2/\text{df} < 5$	$X^2/\text{df} < 3$	X^2/sd	3.42	2.08	2.34
$0.05 \leq \text{RMSEA} \leq 0.08$	$0.00 \leq \text{RMSEA} \leq 0.05$	RMSEA	0.10	0.07	0.08
$0.05 \leq \text{SRMR} \leq 0.08$	$0.00 \leq \text{SRMR} \leq 0.05$	SRMR	0.04	0.05	0.06
$0.90 \leq \text{GFI} \leq 0.95$	$0.95 \leq \text{GFI} \leq 1.0$	GFI	0.94	0.90	0.85
$0.90 \leq \text{NFI} \leq 0.95$	$0.95 \leq \text{NFI} \leq 1.0$	NFI	0.94	0.88	0.85
$0.90 \leq \text{NNFI} \leq 0.95$	$0.95 \leq \text{NNFI} \leq 1.0$	NNFI	0.93	0.92	0.90
$0.90 \leq \text{CFI} \leq 0.95$	$0.95 \leq \text{CFI} \leq 1.0$	CFI	0.96	0.94	0.91
		Factor load range	0.61-0.87	0.48-0.78	0.57-0.90
		Error variance interval	0.09-0.18	0.16-0.25	0.06-0.12
		Fit	Good fit	Good fit	Good fit

the approach of Scott and Walczak [38], the inputs to the neural network are derived from the SEM's significant and reliable hypothesized variables. The next sections discuss the results of both the SEM and neural network. The descriptive statistics of the independent and dependent variables of the study are presented in Table 2.

4.1. Structural model results

Table 3 shows the fit index values obtained as a result of the confirmatory factor analysis of the Information Quality Scale (IQ), Information Technology Scale (IT), and Business Performance Scale (BP). The results of research Models 1 and 2 are presented in Table 4. As a result of the covariance linkages made in accordance with the modification suggestions, it was determined that the fit indices reached acceptable levels and the models adjusted well. It was found that the scales and a single factor structure were appropriate, factor loadings were adequate, and t-values were significant at 0.01 for all items.

4.2. Artificial neural network results

The Multi-Layer Perceptron (MLP) training algorithm was used to train the neural network. MATLAB was used as the software package to perform the neural network test. Cross-validations were made to avoid excessive mismatch of the model. As there is no heuristic way for determining the number of hidden nodes in a neural network, a preliminary network was examined using 1-10 hidden nodes. The Root Mean Square Error (RMSE) was used to measure the accuracy of the model over ten confirmations. It was found that using two hidden nodes was complex enough to map the datasets without incurring additional errors to the overall model. The input variables consisted of the two significant variables from the SEM, while the output layer was business performance. Table 5 and

Table 4. Results of the research model.

Path			Direct impact		Mediator variable	Indirect impact			Hypothesis
			β (SE)	R^2		IS	SBT	R^2	
IT	→	BP	0.23** (0.10)	0.05					H1: **Accepted**
IT	→	IQ	0.26** (0.07)	0.07					H2: **Accepted**
IQ	→	BP	0.06 (0.11)	0.01					H3: Rejected
IT	→	BP			IQ	0.02	0.74	0.09	H4: Rejected
X^2/df: 1.56, RMSEA: 0.05, SRMR: 0.06, GFI: 0.85									

Note: IS = Impact Size; SBT: Sobel test statistic; *: $p < 0.05$; **: $p < 0.01$;

IT: Information Technology; IQ: Information Quality; BP: Business Performance.

Table 5. Model of artificial neural networks.

	Model	Output element (dependent variable)	Input element (element independent)
Performance measures	1	Information Quality (IQ)	Information Technology (IT)
	2	Business Performance (BP)	Information Technology (IT)

Figure 2 show the neural network structure designed in this study. The figure shows that the six predictors from the SEM significant variables were used as inputs for the neural network. In this study, it was attempted to take advantage of both advanced statistical models (SEM-ANN modelling). Ten-fold cross-validation was performed whereby 75% of the data were used as the training net, leaving the remaining 25% of the data used to measure the prediction accuracy of the trained network.

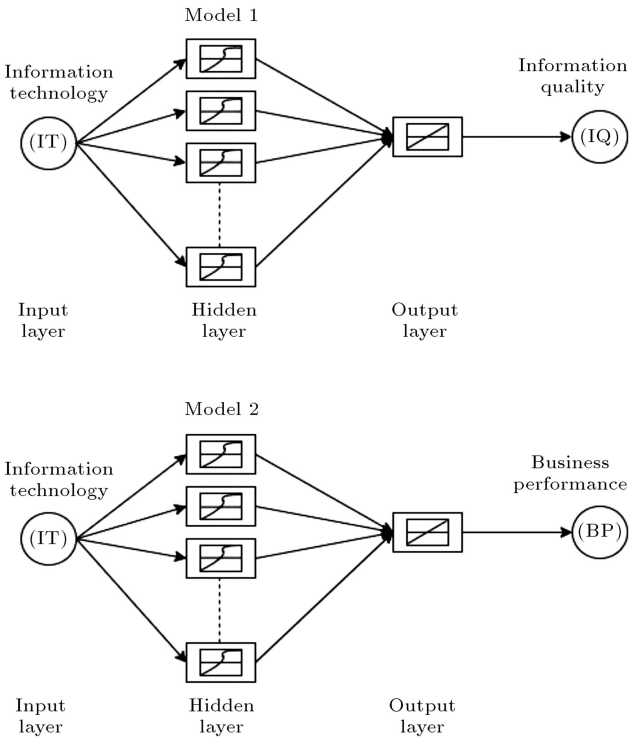

Figure 2. Artificial neural network architectures for proposed Models 1 and 2.

Table 6 lists the performance values for the training and test data of the ANN model, starting from neuron 1 to neuron 10. As the number of neurons increases, the performance for training data increases, while it decreases for the test data. The estimated performance (RMSE) changes for the training, and test data of the ANN model in the case of the use of 10 neurons are indicated in Figure 3. Figures 4 and 5 show a graph of the change in the real output values and the estimated values of Models 1 and 2. Except for some points, error values usually occur around the value of 0. The proximity of the error value to zero means that the value estimated by the model in return for the related input values is close to the real value.

5. Conclusion and recommendations

Nowadays, it is not possible to think of a business that is far from information technology, and it has become important not only to access information, but also to access it in the fastest and most reliable way. In this study, the effects of the intensive usage of information technologies in the supply chain process on business performance were examined. In order to examine the model, a sequential, multi-method approach integrating both the Structural Equation Modelling (SEM) with the neural network analysis was employed. The network of the relationships between the usage of information technologies and business performance was established with the SEM model, and the relationship between the information technology usage levels and business performance was estimated by using the outputs of this network with the ANN model. With the SEM model created, it was proved that there was a significant positive relationship between information technologies and business performance as well

Table 6. MSE and RMSE values of artificial neural networks.

	Model 1					Model 2				
	Training data			Test		Training data			Test	
Neuron	MSE	RMSE	R^2	MSE	RMSE	MSE	RMSE	R^2	MSE	RMSE
1	0.1421	0.3769	0.0505	0.1738	0.4169	0.0889	0.2982	0.0374	0.0972	0.3118
2	0.1357	0.3684	0.0932	0.1857	0.4309	0.0879	0.2964	0.0488	0.0993	0.3151
3	0.1401	0.3742	0.0640	0.1751	0.4185	0.0877	0.2961	0.0508	0.0973	0.3119
4	0.1333	0.3651	0.1094	0.1806	0.4249	0.0855	0.2925	0.0738	0.1036	0.3219
5	0.1327	0.3643	0.1132	0.1802	0.4245	0.0858	0.2929	0.0711	0.1011	0.3179
6	0.1321	0.3634	0.1173	0.1809	0.4253	0.0823	0.2869	0.1089	0.1093	0.3305
7	0.1319	0.3632	0.1186	0.1840	0.4290	0.0839	0.2896	0.0918	0.1047	0.3236
8	0.1315	0.3626	0.1213	0.1861	0.4314	0.0830	0.2882	0.1009	0.1079	0.3285
9	0.1315	0.3626	0.1213	0.1862	0.4315	0.0817	0.2857	0.1159	0.1090	0.3302
10	0.1311	0.3620	0.1241	0.1893	0.4351	0.0835	0.2890	0.0960	0.1036	0.3219

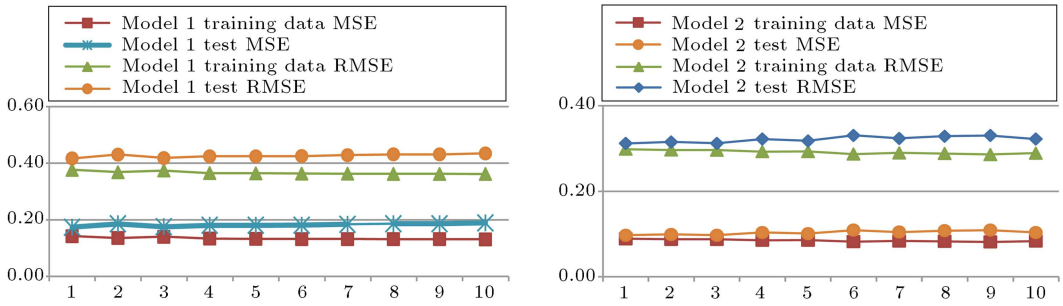

Figure 3. Performance change (MSE and RMSE) according to the number of neurons in Models 1 and 2.

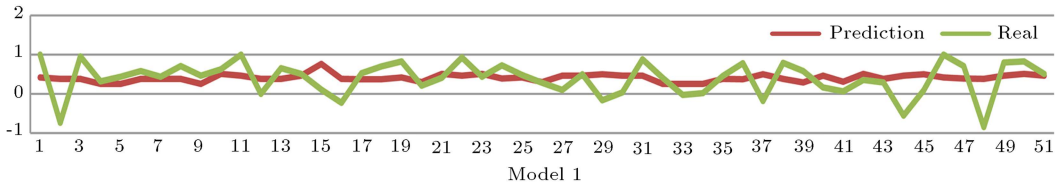

Figure 4. Real values and the change in estimations made according to Model 1.

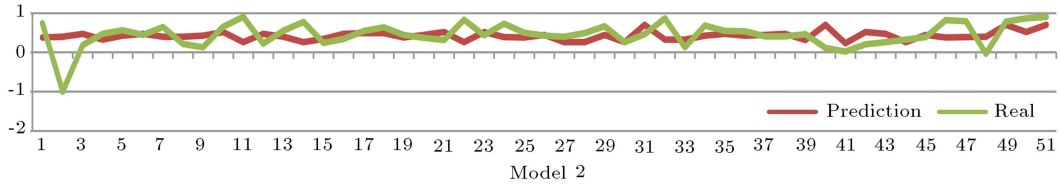

Figure 5. Real values and the change in estimations made according to Model 2.

as between information technologies and information quality. On the other hand, estimations with the low error level were obtained for business performance with the ANN model created in the framework of these significant relationships. With the predictive analytic SEM-ANN approach [31-34,36,38,39], the study may also provide a methodological contribution to statistical analysis techniques.

This study has several limitations. Firstly, this study was carried out on the ISO 1000 manufacturing firms in Turkey; therefore, its results may not be generalizable to other companies. As a result of these limitations, future research may be conducted by performing a comparative study of other manufacturing firms. Secondly, a cross-sectional research approach was used, and the effect of time was not examined. It

is suggested that a longitudinal study be carried out in the future. Finally, the study also examined the effect of information technology on business performance with the SEM-ANN model. Future research can increase the model's power by using artificial intelligence technologies such as fuzzy logic, genetic algorithms, and expert system with SEM.

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