An Artificial Neural Network Based DSS to Prioritize Information Technology and its Complementary Investments in Industrial Firms

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Abstract

The impact of IT usage on performance and other organization’s outputs is an important issue for both practitioners and academics. Evidence shows that despite a vast percentage of firm’s budget which has spent on IT is continuing increasingly, there are some failures of firms in obtaining the benefits of these expenditures within expected period. To solve this problem, managers have to consider complementary investments. In this paper a decision support system is developed for prioritizing investments on the Information Technology (IT) and its complementary using data of 102 car part suppliers in Iran. This software is developed using an artificial neural network and reults are validated finally. One of the main specifications of this DSS is investigating on IT aspects at the firm level, which can help top management during decision making process to allocate budget properly in the most significant aspects of IT investment inside their own company.

Key Words: Information Technology - Complementary investment – Process Orientation - Decision support system - Neural network – Ranking

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1. Introduction

Intense competition in markets, more demanding, forceful customers and fast advancement of technology, have forced organizations to look for ways to attain a sustained competitive advantage (Joiner et al., 2009). From 1990\textsuperscript{th}, there was a substantial increase in the rate of investment in organizations on information technology (Indjikian and Siegel, 2005, Seggie et al., 2006). This is a fast growth and changing business models and organizations are spending a substantial amount of resources for such a technology to enhance their performance (Heim and Peng, 2010). Explaining the reasons for this huge investment is a simple and important idea: “Positive and significant effect of information technology on organization performance” (Ross and Ernstberger, 2004). Thus, one of the major challenges of managers and researchers is to study these ideas to make it turns out as a true debate, and that is why from the first years of utilizing information technology in organizations, discussing the effect of IT on organization performance has been raised. Generally, investment in any type of technology should be able to effect in the improvement of performances (Wu and Chen, 2006) and also information technology is no longer an exception. Companies and organizations are going to spend a lot of time and money on implementation of such an automated system without clarifying the performance of IT and its impact on organizational structure and effectiveness of this system on cost, time, human resource management and business processes (Sobol and Klein, 2009). Naturally, organizations expect more efficiency and effectiveness in their process by using IT tools in their cycles and processes; however, sometimes they have faced opposite results. They invested more money in adopting information technology than improving their organizational infrastructure, which is the foundation of information technologies. Therefore, the research problem is formulated to gain a better performance from implementation and using information technologies in firms
and identifying complementary that investment on them would lead companies
to solve their problem of productivity paradox (Brynjolfsson et al., 1996).

The organizations assets and resources are limited and keeping this limitation
in mind, organizations are forced to choose the best options for their investment. One of the practical issues of executive managers and researchers is that “IT
complementary asset and different aspects of IT are the same while they play
the same role in improving organizational performance”. The other problem is if
importance of different aspects of using IT and its complementary factors are
not the same, how they could be ranked according to their importance? The
answers to these questions would be significantly helpful for managers to
optimize their investments.

Previous researches in this field have investigated IT and performance at the
industry level using a statistical sample of firms and they didn’t offer anything
for each firm separately. In this study, an ANN based DSS is presented to
investigate this relationship at the firm level. Thus, we can briefly state the aim
of this research as bellow:

To Introduce an intelligent system for ranking of different aspects of IT and
its complementary factors in order to optimize allocation of organizational
resource in IT science at the firm level.

2. Literature review

In this section, some earlier researches on the relationship between IT usage
and performance are discussed. Also process-oriented approach and its effect on
IT productivity paradox are presented.

2.1. IT and performance

Nowadays there is an intense competition in globalized and unstable markets.
To survive in such a dynamic environment, organizations need to understand
the role of different factors in their performance (Cocca and Alberti, 2010).
Many studies have performed on the effect of information technology on the
performance of organizations. They believe that information technology
provides an additional dimension to evaluate firm performance (Hyvonen,
2007). Some studies tried to evaluate the relationship between information
technology and financial performances, while others are investigating the
relationship between the use of Information Technology and implementation of
organizations strategies (Chang et al., 2003), market performances (Seggie et
al., 2006) or performance in supply chain of corporations (Byrd et al., 2006).
While some researches proved that investment in IT helps to enhance firm
performance (Chari et al., 2007), in many other researches a significant relation
between the use of information technology and organization performances was
not found even in some cases negative relation was reported. These researchers
believe that the cost of money and time for ineffectual IT is a significant cost for organizations (Wilkin, 2007). This, in turn, led to a concept presented “IT Productivity Paradox” (Albadvi et al., 2006). This concept is referred to some enterprises that received negative results in performance despite high investments in IT implementation (Kobelsky et al., 2008). Brynjolfsson and Hitt (2000) present four major reasons to justify this phenomenon including: Incorrect measurement of inputs and outputs, Lag time due learning and adaptation, Abuse of information technology management, Re-distribution and waste of resources. Also Results of other researches showed that parts of IT paradox come from improper management of resources in organizations (Stratopoulos and Dehning, 2000) and absence of a meaningful relation between using IT and organization performance could be a result of ignorant management behaviour (Strassmann, 1999).

There are different approaches and methods for assessing the kind of relationship and correlation between IT and business performance. But these approaches can be grouped into three main perspectives (Keramati and Albadvi, 2006). They include examining direct, intermediary and complementary impact of IT on financial and non-financial criteria and other performance/ productivity criteria in enterprises.

In this section we describe each approach generally.

2.1.1. Approach of direct impact of IT on performance

This approach highly emphasizes on direct criteria of productivity such as partial productivity, total factor productivity, asset productivity, profitability and decrease in costs (Keramati and Albadvi, 2006). IT mostly uses financial criteria such as rate of return on investment, sale quantity and amount of output to input that is referred to traditional description of productivity.

Regarding to this approach, many researchers concluded that investment in IT would enhance these indexes; ironically other researchers revealed that IT investment wouldn’t necessarily increase these indexes. As mentioned before, this issue is known as IT productivity paradox in IT literature in many studies (Davern and Kauffman, 2000). Thus another approach is appealed to researchers.

2.1.2. Approach of intermediary impact of IT on performance

Researchers who were searching for a solution to productivity paradox and organizational performance regarding to IT investment, turned their attention to other productivity criteria (Keramati et al., 2007). These criteria which were mainly about management style/behaviour or method of taking advantage of using capacities were determined as IT intermediary criteria (Hitt and Brynjolfsson, 1996). This approach doesn’t directly deal with financial data and
firm’s balance sheets, but it also faced the paradox problem either. Because of these paradoxes, some complementary items must be studied in investigating role of IT in productivity and business performance. These items lead to generation of a third approach described below.

2.1.3. Approach of IT complementary impact on productivity and performance

While many researchers tend to use the two mentioned approaches, some believe that IT investments lead to higher performance, if complementary investments are done. They believe we should focus on IT capabilities in order to create a new form of values, instead of emphasizing on traditional criteria for measuring performance and productivity. In this approach, IT is not a simple tool for business process automation, but it drives organizational changes which lead to higher level of productivity. Investments on issues like organizational redesign, organizational strategies, essence of management in organization, working on management skills, training the employee and revision in evaluating employee performances can have a great effect on capability of IT in improving the performance. The parameters mentioned above, are in fact some of known parameters that complete information technology (Belleflamme, 2001, Hunter and Lafkas, 2003, Pinsonneault and Kraemer, 1997, Pinsonneault and Rivard, 1998).

Table 1 summarizes some prior researches on the relationship between IT and performance.

Table 1 here

2.2. Process-Oriented approach

As mentioned before most of the studies examine the impact of information technologies on firms from view of output and financial measures. Recently there are few researchers have argued that unlike much of previous research on IT impacts, we should evaluate IT at the level it has the major impact: the process level (Keramati et al., 2010). Such process level assessment can offer considerable insight how and in what manner IT interact with organizational processes to create process capabilities, which in turn can help firms in deriving differential business value from IT investments. This approach in which the impact of IT on business processes is assessed is called process-oriented approach (Radhakrishnan et al., 2006). Some researchers refer to application of this approach to examine the effects of IT on performance (Bharadwaj, 2000). They indicate that relationship between IT investment and financial performance is mediated by processes performance which is called process-model (Shah and Shin, 2007). In recent years process orientation (PO) has developed and many firms choose to be process-oriented (Keramati et al.,
2011). Process refers to a specific sequence of work activities across place and time, with a beginning, an end, and clearly identified inputs, and outputs (Davenport, 1993). Therefore PO is defined as focusing on business process ranging from customer to customer rather than emphasizing on hierarchical structures (Reijeres, 2006). It also emphasizes on process in contrast to hierarchies with particular focus on outcomes, especially customer satisfaction (Kohlbacher, 2010). In other words process oriented approach can be described as effect of IT on business processes and capabilities and the degree, which these capabilities will be enhanced. Researchers in this field -concerning operational and managerial processes as a mediator between IT and performance- assert that enabling processes by the aid of IT interaction leads to IT capabilities and values (Radhakrishnan et al., 2008). When firms understand and effectively set up standard IT into their operational and management process they create differentiated operational and management process capabilities. Since these capabilities are valuable, rare, appropriable, inimitable, immobile and non-substitutable, firms which use information technologies extensively enjoy better performance than their counterparts (Shah and Shin, 2007). Table 2 presents some previous studies to assess the relationship between IT investment and process level.

Table 2 here

2.3. Ranking

Based on complementary approach, it is essential to focus on IT complementary investment for solving IT productivity paradox. Therefore the selection of IT aspects and supplements is an important issue for organizations to improve their performance and the decision of which specific requirements should be selected is critical for managers (Sobczak and Berry, 2007). The most important purpose of IT supplements determination is to match IT investment and organizational needs (Flaatten et al. 1992). Making correct decision is usually very difficult for most organizations. Often it is impossible to know which aspect is right or wrong to choose before its implementation. Therefore it is necessary to rank IT supplements and aspects according to their effectiveness and importance (Albadvi, 2004). In the literature analysis of IT requirements, it is described as a process which includes three steps: first, determining the properties of existing system, second, data collection for identifying IT aspects and third, ranking of IT aspects and requirements (Shi, 1996). The most important advantages of ranking IT supplements include (Sobczak and Berry, 2007):
- Cost reduction by appropriate allocation of resources.
- Time reduction by earlier agreement on the required aspects.
- Better IT productivity by focusing on critical supplements.
- Help managers to make better decisions of selecting appropriate requirements.
Many works on ranking IS/IT requirements ranked different aspects based on ranking of their respondents and researchers didn’t use a specific method (such as: Multi-Criteria Preliminary Requirements Ranking Technique (MCPRRT), Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS), Weighted Sum Model (WSM), etc.) for ranking (for instance: Dutia & Evrard, 1999; Stratopoulos & Dehning, 2000, Daramola et al., 2010). Other researchers who present a method for ranking different IS/IT aspects usually suggest their method at the economy level or at the industry level (for instance: Salmeron and Herrero, 2005; Albadvi, 2004; Sobczak and Berry, 2007). To overcome this shortcoming, in this study we present a DSS which ranks IT supplements at the firm level and show its performance using a case study.

Anyway, the conceptual model used in this research is depicted in Figure 1. Instructions regarding the way how each one of these parameters has been measured are presented in appendix.

Figure 1 Here

3. Research Method

In this section, we will present the method used in the research. First, we will explain data collection method and then continue with study of properties of neural network which is used.

3.1 Data

The data used for this research are collected by (Albadvi et al., 2007) research work. They studied more than 100 companies in automotive industry. Choice of automotive industry is based on the fact that automotive industry has a progressively developing nature in Iran and there is an increasing level of competency between products of different manufactures. Since use of information technology has a dramatic growth in these companies, they have strived to reach higher core competency compared to other competitors by applying modern information technologies. Therefore importance of ease of information flow in these companies’ supply chains is another reason for using more IT in this industry.

3.2 Problem solving Idea

The main purpose of problem introduced in the first section is to achieve a system which can determine the best solution for investment on different elements of IT and its supplements. Hence the main question is:

\[ \text{Which aspect of IT and its supplements should be boosted to have maximum improvement in performance?} \]

The main idea of solving such problem is using a method like sensitivity analysis. In fact to answer this question we have to increase usage level of each
aspect of IT and its supplements to a specific value about 10% in ongoing situation of company. Then using a trained neural network which is capable of accounting for different specifications of each corporation, we can estimate performance level in each case with respect to an increase in value of effective variables. Comparing the result of achieved estimations, we are able to determine the most important complimentary factor and the most important aspect of information technology that has to be focused.

Relationships between variables are so complex and nonlinear. So we have to utilize a method that can model such relationships. On the other hand statistical methods like regression analysis and even more sophisticated methods such as structural equations with interaction of hidden variables cannot be helpful. These later methods try to model the relationships in a linear manner and they eventually can help us judge about the whole statistical population and won’t give any appropriate perspective regarding specifications of each company.

One of the methods that can be used in predicting and estimating different values of performance is neural network.

According to the study on different candidate methods that could be used in this case, finally we decided to utilize neural networks to estimate performance of companies.

4. Using ANN to develop a DSS

In this section, firstly the concept of artificial neural network (ANN) is presented. Afterward the network structure of this study is offered. Then training method and network validation are discussed and finally a decision support software (DSS) is developed to give priority to different aspects of information technology and its supplements.

4.1. Artificial Neural Network

Artificial neural networks are accounted as mathematical models for modeling of sophisticated systems. They can be used for classification and regression problems. These networks are huge complexes of parallel processors called Neuron which are acting coordinately for problem solving and transfer the data through synapses (electromagnetical connections). Transferring the input data into the meaningful outputs is the aim of neural network. These networks have got the ability to learn and system learns to revise its errors through some algorithms. Learning is done in a comparative way in these systems, i.e. through the examples the synapses weight is changed in way that system will give a reasonable answer in case of new input data (Basheer, 2000).
Neural networks are non-linear learning mathematical systems. Each of the neural networks would pass three steps of learning, validating and implementing. In fact neural networks may be used in problems in which there is no certain correlation between inputs and outputs.

Relative position of cells in networks (numbers and grouping and connection type) is called topology or network architecture. In fact, topology is the hardware connection of neurons to each other which is paired with respective software (mathematical method of data flow and weights estimation) will nominate the functionality of the neural network.

Artificial neural networks include three layers called input layer, hidden layer and output layer (Figure 2). The input layer shows the input of the model and the output layer shows the output of the model. The hidden layer is built out of some nodes that try to map the input model on the outputs in the optimization process. There exist many architectonics for the neural networks, but there is a special emphasis on the most used one (the multi-layer perceptron (MLP) in this investigation.)

Figure 2 here

4.2. Network Structure
Structure, arrangement, or in other words network topology is meaning of how various a neural network components communicate with each other. Numbers of structures that are more used in the literature of neural networks are known to specific affairs subject to a type of networks. In this study we have faced limitations to use some existing structures to solve the problem.

The first issue is concerned the number of available data for network training. In neural network, similar to any other statistical model, it is necessary to allocate proportion between some unknown factors that are estimated during network training, with the existed number of available data for training. In other words, here as in any statistical model the number of available degree of freedom to estimate parameters are important. Considering the vast amount of parameters that must be estimated in the model, our data number is not enough for network training. In other words, if we want to have layered network, while the elements of each layer is connected to next layer (full connected network), the number of parameters which must be estimated for the model training will be much greater than less connected network. Therefore, the full layered structures cannot be used normally (Hassoun, 1995).

Other problem in the network structure is that regarding the statistical and conceptual models in the literature, the cause and effect route is almost distinct between different variables. Hence, in case that no information is available
about network’s connection, starting with a complete network will cause network trying to find connection itself during training and from expected training data set, and this means; more data needs to be trained.

So the idea about network structure is that according to existing statistical and conceptual model in literature, we can set the network structure. Thus we find out Figure 3 structure.

**Figure 3 here**

Presented structure in Figure 3 was obtained after simulation and testing of different networks in accordance with the structural equation modeling. This network uses two layers for analysis. Intended function for each node is hyperbolic tangent, which is obtained after numerous tests on various functions and considering the results of cross-accreditation.

### 4.3. Training Method

There are several methods for training neural network. The most famous method which usually used for training the neural network is feed backward (Derakhshani et al., 2009); in the present network the same method is used. Training neural network for the parameters is recursive method. Different criteria for the completion of the network training are available. One of the existing criteria is using the total square errors of inputs. This method can lead to networks more training.

This situation occurs when in the training process, network starts to train data collection which is entered for learning, and in this stage network will lose the appropriate mode of its prediction. Considering series is another criterion that can be used for validation of the trained network. In this situation we can estimate values of network error in data collection considered for accreditation to be calculated and during the network’s training when the network’s error to estimate output data collection as for accreditation will start to increase, learning process stops (Haykin, 1994). All of the criteria which have been explained here are used for complete learning process of the target network in this article. Since the expected outputs for the network in five different modes were considered (the output of each of four different aspects of performance and mean of all aspects), results of training process were not the same in all cases. But the use of total cross-accreditation criteria can provide better results and so this method is considered for network’s training.

There are different criteria to calculate the error rate of the network. The simplest and most common criterion is the use of variance between estimated mean squares and expected value by the networks. Also this criterion is used for different scenarios used for the same network training.
For network design and network training NeuroSolutions 5 software is used.

4.4. Network Validation

Each trained neural network must work with acceptable error after the training process. From the available methods for checking network validity, cross-validation method can be mentioned (Simpson, 1990). In this method, the total dataset which is considered for training the network is dividing into two groups. The first group is used for training the network and second for estimating power values of the network which has not been dealt with, during training process.

In this study, in order to validate trained network the same method is used. The data were divided into two groups. The first group includes about 95 companies were used for training and second contain 7 companies that were conducted for validation.

In this method of validation different criteria can be considered for dividing data collection into two parts. About the specific network which is considered in this article, as the small amount of data is available for training the network, consequently it was not possible to use a large collection of data for network validation.

Table 3 shows the values of error in prediction model, and also the correlation between estimated values by the network and expected values for cross validation. As can be observed, for the overall performance of the company the error is 10 percent and the correlation is 73 percent.

Table 3 here

Whereas the neural network developed in this article will be used as a model to predict and estimate in the part of a sensitivity analysis process, the absolute value of estimated function under this section is less important and actually what important is to correct diagnosis of performance changing trend in accordance with changes in different aspects of information technology and its supplements usage. Therefore, criteria correlation here is more important than absolute error, and correlation value of 70 in this particular application seems to be good. However, the decision support software developed based on this network present error rate in each particular case as for the result of related question to the performance of organization.

4.5. Decision support software

Regarding the idea raised for solving the problem, software was developed to give priority to different aspects of information technology and its supplements in order by using the neural network method. Developing this software for
optimizing the investment which is done on the IT and its supplements is not seen in the relevant literature review, in fact it is considered as one of the innovations of this research. This software has many advantages, including that you can use it on prioritizing information technology investment and determine its supplements in such a way to have the most effect on performance, and in fact this prioritizing unlike the statistical methods and internal audit focuses on both internal and external aspects of the company (industry). In other words, since in this ranking the neural network which is used has been trained by industry data, characteristics of the industry will be considered on that and on the other hand because of the intelligent system is used which for each specific company present specified rating regarding its conditions, the status of company is considered in ranking.

5. Case Study: Gilan Glass Co.

In this section to display software performance and evaluation of solving method idea, we solve an example using developed software. The studied company in this section is Gilan Glass Company, one of the glass manufacturer suppliers of Iran Khodro automotive industrial group. Figure 4 displays how to create a new file by the software.

Figure 4 here

After creating a new file for this company, it is necessary to complete information of Company’s questionnaires. Completed questionnaire has been displayed in figure 5.

Figure 5 here

After completing the company information in considered sector in software, by pushing analysis button, data analysis based on the method of Figure 6 is done and the result will shown as a report in html format.

Figure 6 here

In this report, six separate sections are considered. First five sections, each consisting of a table and a chart, ranking of the different aspects of information technology and its supplement displays the effect on the performance of each of the five aspects including: Customer Satisfaction, Staff Satisfaction, Operational Performance, Growth and Development and Overall Performance (for example see figure 7). The last section of the report provides a table that can yield the model performance in estimation for each aspect of performance. By use of table information it is possible to find out ability of the model in analyzing each specific case, on the other hand by using this table it will detect situation if somehow it processes the outlier data.
5.1. Results

The results provided by the software include six tables and five charts that due to space limitations here only survey the performance model with covered overall company performance.

As it is shown in table 4, first rank in this regard is organizational infrastructure of process management and customer relationship. The second and third ranks are changes in effective business processes in technology and leadership organizational infrastructure. Next rank in this table is related to the use of information technology in administrative affairs. However, based on the provided estimates for the performance, it can be observed that all these estimates are so close together.

One of the main advantages of using this decision support software in comparison with statistical methods for ranking, is providing improvement recommendations for each specific case. For example, if we are looking at statistical ranking by the Albadvi et al. (2007), then we will notice the difference between statistical rankings and presented ranked results for Gilan glass Co. In presented statistical ranking, use of information technology in decision making is presented as the most important factor, while in provided ranking by the software for the Gilan glass Co., use of information technology in administrative affairs is the most important aspects of information technology, and after that use of information technology in production and operation. This study shows that the investigated company as for the current status of its internal processes, athwart the statistical community, it is necessary to improve their internal processes and operations through the use of information technology rather than using large scale of information technology in macro management. In fact this can indicate the case by case software’s ability for analyzing different companies.

In another part of the report, the table contains the results of model performance in estimation of organizational performance is presented. Gilan Glass Company information is shown in Table 5.

As you can see, the model’s error in estimation of company’s overall performance is about 6% and this amount for desired applications seems quite appropriate here.
5.2. Managerial Implications

It seems necessary to improve company overall performance; it needs to perform balance investment on the use of information technology in administrative affairs and technology. However, as shown in table 4, process management and customer relationship management ranked first among all five factors thus infrastructure such as customer relationship management and organizational leadership need to have more investment and concern.

Moreover, in presented statistical ranking, use of information technology in administrative affairs is the most important aspects of information technology, and use of information technology in production and operation are ranked after that. Thus it is necessary to improve internal processes and operations of the organization through the use of information technology rather than using large scale of information technology in macro management.

6. Conclusion

To solve IT productivity paradox, it is essential to take into account complementary/process-oriented approach. In order to do so, choosing the best options for investment is critical. In this study, a decision support software was developed for ranking and optimizing use of information technology and its supplements in organizations. In this model for the first time we used a neural network which is able to estimate the performance error of 10 percent. However, for the first time we are performed ranking for different aspects of information technology and its supplements at company levels. Previous researches in this field have investigated IT and performance at the industry level using a statistical sample of firms (Albadvi et al., 2007, Keramati et al., 2009) and they didn’t offer anything for each firm separately. In this study, an ANN based DSS is presented to investigate this relationship at the firm level. To compare with previous researches (Keramati et al., 2009) that concerning on mediating and moderating roles of IT complementary factors with use of LMS method investigating on community level or other analysis method such hierarchical regression (Boyer et al., 1997, Grover et al., 1998) that had limitation in ranking the different factors of IT aspects, this study will be very useful for company’s CEO and also remove the limitation of ranking the IT factors. With the help of developed intelligent decision support system in this study, it leads the analysis level from statistical community to the company and thus can be presented the capability of each company analysis more accurate and independently.

6.1. Limitations and future research directions
This study has some limitations that should be taken into consideration, especially due to the fact that more data in ANNs can prevent the possibility of biases. Subsequent research can explore these issues using a broader research sample.

The other limitation of this study is its performance error estimation. Although 10 percent error can be satisfactory for the first time development of this software, it is obvious that lesser error percentage can be more pleasing. Thus future researches can improve the model of this study to develop a DSS with lesser error estimation.

Finally, the case of this study has conducted in a developing country. This fact may affect the results. Therefore more researches can be conducted to enhance the validity of the suggested DSS. Also In this research particular industries were investigated. In future research, similar method can be conducted in other industries. So it’s feasible to research on similar specific aspects of information technology (For example, the use of information technology in Customer Relationship Management).
References


Figure 1: model of relations between relevant factors in the research (Albadvi et al., 2007)

Figure 2: Multi-Layer Perceptron Structure
**Figure 3: Layers of designed network**

**Figure 4: Create new file**
Figure 5: Completed questionnaire for Gilan Glass Co.

[Diagram showing workflow steps]

1. Receiving raw input data
2. Calculate the mean and necessary input information of neural network
3. Producing necessary data to perform sensitivity analysis
4. Performance estimating by using neural network
5. Output ranking for different aspects of performance
6. Create and store the necessary charts
7. Create software report as html file

Figure 6: Software’s Workflow
Figure 4: Chart provided by the software of the estimated overall performance with 10% improvement of each aspects of information technology and its supplements.

Table 1: Summary of researches in IT & performance

<table>
<thead>
<tr>
<th>researchers</th>
<th>year</th>
<th>Methodology</th>
<th>results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpar &amp; Kim</td>
<td>1990</td>
<td>Develop a methodology based on the microeconomic theory of production and apply the model to data from the banking industry</td>
<td>Reasoning about information technology value based on key ratios may be misleading, especially when the figures are only calculated for a cross-section of data</td>
</tr>
<tr>
<td>Newman &amp; kozar</td>
<td>1994</td>
<td>An experimental study to use IT for an organization to solve its problems</td>
<td>The use of IT enhanced organization’s productivity</td>
</tr>
<tr>
<td>Lee &amp; Ye</td>
<td>1999</td>
<td>An empirical research to test the moderating role of environmental dynamism, firm strategy, and CEO/CIO arrangement on the impact of IT investment on firm performance</td>
<td>IT investment appears to have a stronger positive impact on financial performance when there are greater environmental changes, more proactive company strategy, and closer CEO/CIO ties.</td>
</tr>
<tr>
<td>Tanriverdi</td>
<td>2006</td>
<td>Building on the resource-based view (RBV) and the economic theory of complementarities, the study identifies the relatedness and complementarity of IT resources as two major sources of cross-unit IT synergy</td>
<td>The diversification level of the firm moderates the relationship between IT synergies and corporate performance</td>
</tr>
<tr>
<td>Koellinger</td>
<td>2008</td>
<td>An empirical research to analyse the relationship between the usage of Internet-based technologies, different types of innovation, and performance at the firm level</td>
<td>IT is an important enabler of innovation and it results in turnover and employment growth</td>
</tr>
<tr>
<td>Badescu &amp; Garces</td>
<td>2009</td>
<td>Using a Cobb–Douglas function to measure the contribution of IT capital to labour productivity</td>
<td>The sensitivity of labour productivity to changes in technological capital intensity is positive and significant when firm-specific effects are corrected</td>
</tr>
</tbody>
</table>
The impact of IT on firm performance increases when the IT budget is shared with the profit generation process.

Table 2. Studies to assess the relationship between IT spending and process level

<table>
<thead>
<tr>
<th>Study</th>
<th>Process Variables</th>
<th>Firm-level variables</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mukhopadhyay et al.</td>
<td>Inventory levels; quality</td>
<td>ROA; ROS</td>
<td>IT (use of EDI) has positive impact on intermediate variables; mixed results on final performance measures</td>
</tr>
<tr>
<td>Barua et al.</td>
<td>Capacity utilization; inventory turnover; relative price; quality of product</td>
<td>Market share; ROA</td>
<td>IT has a positive impact on some intermediate variables (such as capacity utilization, inventory turnover) but that the effect was too small to measurably make positive impact on all the final SBU level variables</td>
</tr>
<tr>
<td>Shin</td>
<td>Coordination cost</td>
<td>Firm’s output level</td>
<td>Higher IT spending is related to lower coordination costs and at the firm level, higher IT spending led to higher output level</td>
</tr>
<tr>
<td>Mukhopadhyay et al.</td>
<td>Process quality; output of facility</td>
<td>Nil</td>
<td>Investments in sorting application system led to higher output of mail sorting facilities and better process quality</td>
</tr>
</tbody>
</table>

Source: (Radhakrishnan et al., 2006)

Table 3: Neural network performance in prediction

<table>
<thead>
<tr>
<th>Prediction Item</th>
<th>Correlation (%)</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor</td>
<td>Estimated performance</td>
<td>Factor Name</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Rank 1</td>
<td>5.929</td>
<td>INPC</td>
</tr>
<tr>
<td>Organizational infrastructure:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>process management and customer relationship</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rank 2</td>
<td>5.899</td>
<td>BPTE</td>
</tr>
<tr>
<td>Changes in effective business processes in technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rank 3</td>
<td>5.891</td>
<td>INLE</td>
</tr>
<tr>
<td>Organizational infrastructure:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leadership</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rank 4</td>
<td>5.867</td>
<td>ITAD</td>
</tr>
<tr>
<td>Use of information technology in administrative affairs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rank 5</td>
<td>5.857</td>
<td>ITPO</td>
</tr>
<tr>
<td>Use of information technology in production and operations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 4: Part of the output software for Gilan glass

### Table 5: Model’s output for the case Gilan Glass Co.

<table>
<thead>
<tr>
<th>Field</th>
<th>Customer Satisfaction</th>
<th>Staff Satisfaction</th>
<th>Operational Performance</th>
<th>Growth &amp; Development</th>
<th>Overall Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questionnaire Results</td>
<td>7</td>
<td>5.5</td>
<td>6.333</td>
<td>5.5</td>
<td>6.166</td>
</tr>
<tr>
<td>Estimated Performance</td>
<td>6.349</td>
<td>5.297</td>
<td>6.253</td>
<td>5.591</td>
<td>5.802</td>
</tr>
<tr>
<td>Error %</td>
<td>9.292</td>
<td>3.683</td>
<td>1.267</td>
<td>1.663</td>
<td>5.897</td>
</tr>
</tbody>
</table>