A Process Based Model for Measuring Process Quality Attributes

A. Selcuk Guceglioglu and Onur Demirors

Informatics Institute, Middle East Technical University, Inonu Bulvari, 06531, Ankara, Turkey, +90 312 210 3741
aselcuk@ieee.org, demirors@metu.edu.tr

Abstract. Organizations frequently use product based organizational performance models to measure the effects of information system (IS) on their organizations. This paper introduces a complementary process based approach that is founded on measuring business process quality attributes. These quality attributes are defined on the basis of ISO/IEC 9126 Software Product Quality Model. The new process quality attributes are applied in an experiment and results are discussed in the paper.

1 Introduction

IS capabilities have been advancing at a rapid rate and motivating organizations to investment in IS. In 2002, $780 billion was spent for IS in the United States alone [1]. Although IS expenditures seem quite high, there are few systematic guidelines to measure the organizational impact of IS investments [2], [3]. Available studies on organizational impact of IS focus on the product based organizational performance models to manage IS investment. These studies provide organizations with guidelines for measuring cost and time related issues, but they have some constraints in identifying IS effects, isolating the contributions of IS effects from other contributors and using the performance measures in specific categories of organizations such as in public organizations. DeLone & McLean IS Success Model, one of the most well known models for measuring the IS effects, states these difficulties and emphasizes that the studies for measuring IS effects on the organizations are at the initial stage and much work is needed [2], [4].

In this paper, a complementary process-based approach, developed to measure the effects of IS on business process, is discussed. This new approach focuses on the quality aspects of the processes. As business processes are one of the most fundamental assets of organizations, modifications performed on them whether in the way of improvements or innovations cause immediate effects on the success of the organizations. This approach therefore enables organizations to get early feedback for the potential IS investment.

Our studies in the literature demonstrated the lack of business process attribute based frameworks for measuring process quality. As there are close relationships between software and business processes [5], we also investigated software quality frameworks as a potential to measure process quality. ISO/IEC 9126 Software

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Product Quality Model [6] is one of them. This model presents a comprehensive specification and evaluation framework for ensuring software product quality. The structure of the model that we have developed is based on the ISO/IEC 9126. After the evaluation of the ISO/IEC 9126, some software quality metrics that can be used for measuring process quality are chosen. The business process quality attributes are defined according to these selected metrics and then, guidelines of how they can be measured are detailed. In order to observe the applicability of the model and to measure the attributes, the model is applied to a sample business process.

In the remaining chapters of the paper first, related search is summarized as a background to depict the relation of our model within the IS literature. The business process concept is summarized and IS effects on business process are defined. Secondly, the new model is introduced and its measurement categories are given. Thirdly, implementation of the model and its results are summarized. Finally, conclusions and future works are stated.

2 Background

2.1 Measuring the Effects of IS

There are some models for measuring the effects of IS in the literature. One of the most widely known of them is DeLone and McLean IS Success Model [2], [4]. With this model, they introduce a comprehensive taxonomy to organize different research studies as well as to present a more integrated view of the IS success concept. This taxonomy has six major dimensions of IS success as System Quality, Information Quality, Information Use, User Satisfaction, Individual Impact and Organizational Impact. Available studies in Organizational Impact dimension include organizational performance based models and measures. These studies concentrate on the effects of IS for creating organizational changes and relations of these changes with the firm level output measures such as productivity growth and market value [3]. There are some limitations in these present studies for measuring IS effects. The first one is limited understanding of the IS effects. The focus on the firm level output variables, while important, does not clearly identify IS effects on organizations and its working. The second one is difficulty of isolating contributions of the IS effects from other contributors on the organizational performance. The third one is difficulties of using the organizational performance measures in public organizations. As the economic criteria are not so meaningful for these nonprofit organizations, especially government agencies, only productivity gains can be used to measure the effects of IS on the such organizations [7]. In this circumstance, DeLone & McLean IS Success Model states that the studies in Organizational Impact dimension are at beginning stage and much work is required to be done in categorizing and measuring the changes in the organizations and work practices, and to establish their relations with IS.

Another well-known model is Seddon’s IS Effectiveness Matrix [8]. He proposes a two-dimensional matrix for classifying IS effectiveness measures. The first dimension is the type of system studied and the second dimension is the stakeholder whose interest the system is being evaluated. This matrix emphasizes that different stakeholders in an organization may validly come to different conclusions about the success of the same IS and, therefore, he suggests measuring IS effectiveness of the systems according to the stakeholders' criteria. In similar to the DeLone & McLean model, this model focuses on the organizational performance based measures such as firm growth, return on assets, percent change in labor, and market share.

In addition to the product based models mentioned in IS Success Models, there are also process oriented studies for assessing IS effects on the organizations. Mooney's study is of them [9]. Although IS effects on business processes are dealt with in this study, it is not precisely defined to measure these effects on the process. The changes occurred in organizations due to IS effects are given in conceptual level. The other process based approaches [10], [11], [12] assess the IS effects on the organizations, but they do not focus on the process attributes in detail for measuring the IS effects.

2.2 Business Process and IS Effects

Davenport [13] defines process as "a structured, measured set of activities designed to produce a specified output for a particular customer or market," and business process as "a set of logically related tasks performed to achieve a defined business outcome." These definitions imply a strong emphasis on how work is done within an organization. Another implication is about measurement of the activities. On the other hand, Hammer [14] concentrates on the importance of the business process oriented thinking and emphasizes that organizations must arrange and manage themselves around the axis of the business process, in order to achieve the performance levels that customers now demand.

There are some factors which affect business processes, and IS is one of the most considerable of them [9]. When available studies are investigated, it is noticed that few of them have focused on interactions between the IS effects and business processes. However, IS affects both operational and managerial processes. IS influences operational processes by automating them with providing technologies of work flow systems, flexible manufacturing, data capture devices, imaging and computer aided design tools (CAD). IS can improve the efficiency of the operational processes through automation or enhance their effectiveness and reliability by establishing linkage among them. Similarly, IS influences managerial processes by providing electronic mail, database and decision support tools. These tools improve the efficiency and effectiveness of communications and decisions. These examples clarify the effects of IS on business processes, especially in process improvement studies, but the effects of IS are not limited to only automational supports in process improvement. IS is also recognized as having a critical role in business process reengineering efforts, primarily as an enabler of new operational and managerial processes [13].

The effects of IS on the business processes can be categorized. For instance, Davenport [13] concentrates on the effects of IS in business process reengineering perspective and identifies nine opportunities for business process innovation through IS effects as automational, informational, sequential, tracking, analytical, geographical, integrative, intellectual, and disintermediating. In another categorization [9], IS can have three separate but complementary effects on business processes. First, automational effects refer to the efficiency perspective in the business process changes with the role of IS effects. The automational effects are derived primarily from impacts such as productivity improvements, labor savings, and cost reductions. Second, informational effects emerge primarily from IS's capacity to collect, store, process, and disseminate information. Following these operations, effects are accrued from improved decision quality, employee empowerment, decreased use of resources, enhanced organizational effectiveness, and better quality. Third, transformational effects refer to the business process changes with IS's ability to facilitate and support process innovation and transformation. The business process changes associated with these effects will be manifested as reduced cycle times, improved responsiveness, downsizing, and service and product enhancement.

3 A Process Based Model for Measuring IS Effects on Business Process Quality

The definitions of business process quality attributes constitute main point of our model. At the beginning, Goal Question Metric (GQM) method [15] was used to find out these attributes. Some of the attributes were defined such as complexity, dependency, and accuracy, but, in order to present a more complete and widely acceptable attribute set, we extended our model by utilizing ISO/IEC 9126 Software Product Quality Model [6]. The close relationships between software product and business process [5] helped us. For instance, both of them have logical structures with inputs, operations and outputs whether in the form of functions or activities. The "software product" logically matches with "business process", and "function" of software product with "activity" of business process. A similar relation between software product and function exists in the business process and activity as "activity is one of the subunits or functions of the business process and represents a logical completeness in its context." They constitute a part of the whole and have interactions with other parts. In addition, high quality is of prime importance for both of them.

3.1 Measurement Structure of the Model

The model is designed in four-leveled structure that is similar to the ISO/IEC 9126. The first level is called as category. There is one category as "quality". The second level is called as characteristic. The quality category includes Functionality, Reliability, Usability and Maintainability characteristics. The third level is for subcharacteristics and finally, fourth level is for metrics to measure the business process quality attributes. The quality category is given with its levels in Figure 1.

Functionality characteristic is defined for evaluating the capability of the process to provide functionality properties in the subcharacteristics of Suitability, Information Technology (IT) based Functionality, Accuracy, Interoperability and Security. Suitability metrics are used for ensuring that business process activities are complete and adequate for performing the tasks. IT-based Functionality metrics examine the IT usages in the process activities. Accuracy metrics investigate the capability of the process to achieve correct or agreeable results. Interoperability metrics investigate the capability of the process interactions with other processes and problems experienced during the interactions. The interoperability can be seen as dependency of a process

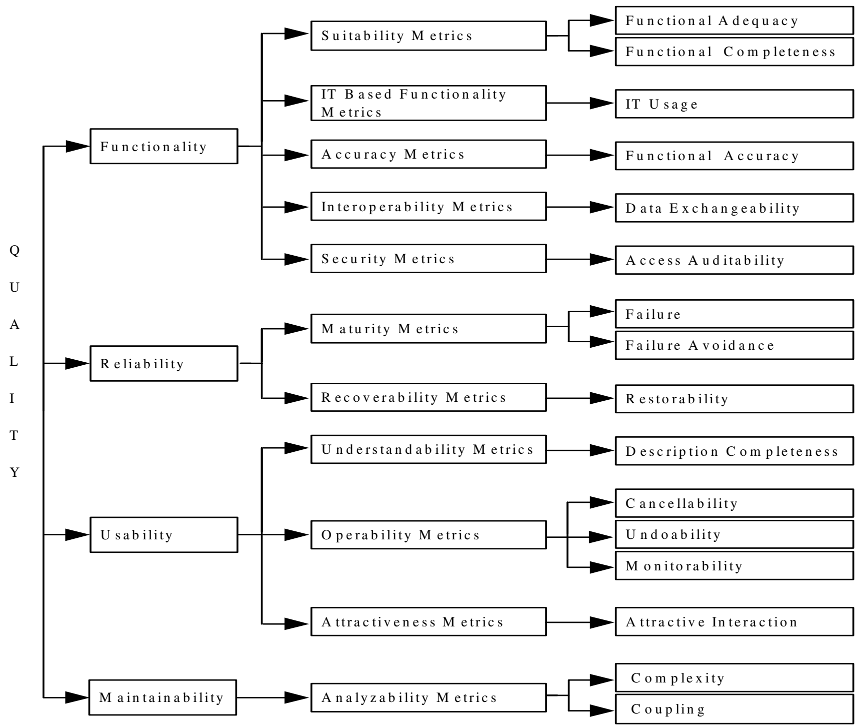

Fig. 1. Measurement categories and metrics of the model

to other processes. Security metrics investigate protecting information and data so that unauthorized persons or systems cannot read or modify them and authorized persons or systems are not denied access to them.

Reliability characteristic is used for evaluating the capability of the process to provide reliability properties in the subcharacteristics of Maturity and Recoverability. Maturity metrics investigate the failures that may happen in the process activities and failure avoidance mechanisms employed for preventing from the failures. Recoverability metrics investigate the capability of the process to continue with minimum data lost when abnormal events occur. The restorability mechanisms provide re-establishing an adequate level of performance and recovering the data in case of a failure.

Usability characteristic is used for evaluating the capability of the process to provide usability properties in the subcharacteristics of Understandability, Operability and Attractiveness. Understandability metrics investigate the understandability of the process activities. This subcharacteristic assesses that new users can understand whether the process is suitable, and how it can be used for particular tasks. Operability metrics investigate the capability of the process to be operated and controlled. The possibility of the process activities cancellability prior to completion of the activity, the possibility of the process activities undoability after completion of the activity and the monitoring the status of the process activities are investigated in the scope of this subcharacteristic.

Attractiveness metrics investigate the capability of the process to attract the users with its documents' structures and/or user interfaces' designs.

Maintainability characteristic is used for evaluating the capability of the process to provide maintainability properties in the subcharacteristic of Analyzability. Analyzability metrics investigate the maintainer's or user's spent effort and resources in trying to diagnose for deficiencies or causes of failure, or for identification of parts to be modified in the process. The measurement of this subcharacteristic gives insights about the comprehensibility of process activities and interconnections between other processes.

In the model, all attributes are defined and tabulated with the information of metric name, purpose, application, measurement and interpretation. In order to present a short summary, only four sample metrics, one example metric for each characteristic, are given in Table 1. The full detailed descriptions about categories, characteristics, subcharacteristics and metrics are given in the Technical Report [16].

Table 1. Additional information about four sample metrics

Metric Name	Purpose	Application	Measurement	Interpretation
Functional Adequacy	Investigating the business process for determining functional adequacy	Count the number of activities that are not functionally adequate, and compare with the number of activities	X=1-A/B A= Number of activities in which problems about functional adequacy are detected in evaluation, B= Number of activities	0 <= X <= 1 The closer to 1, the more functional adequacy of the business process
Failure Avoidance	Investigating the business process for determining failure avoidance mechanisms	Count the number of mechanisms that will provide failure avoidance	X=Number of failure avoidance mechanisms	The higher value of X, the more failure avoidance of the business process
Monitorability	Investigating the business process for determining monitorability status	Count the number of activities whose status can not be monitored and compare with the number of activities	X=1- A/B A=Number of activities whose status can not be monitored, B=Number of activities	0 <= X <= 1 The closer to 1, the better monitoring capability of the business process
Complexity	Calculating the complexity of the business process	Find complexity of the business process by means of cyclomatic complexity technique [17]	X=Cyclomatic complexity of the business process (number of decision points)	The lower value of complexity, the better

4 The Implementation of the Model for Measuring IS Effects on a Sample Business Process

4.1 Information About the Implementation

The implementation of the model is accomplished on a sample business process in an organization [16]. In the implementation, a business process, named as "Meeting Material Request", is selected from Warehouse Department of the organization. In addition to Warehouse Department, this organization has 5 more departments. Each department has its own head manager, secretary and other staff in sections according to their duties. While the departments are performing their tasks, they meet material needs from the Warehouse Department. For this purpose, department secretaries communicate with Warehouse department secretary to inform the material requests. Warehouse Department is organized to meet these material requests and also purchase new material, repair and maintain existing material and produce special purpose material. It has approximately 40 staff and 7 basic business processes about material operations including Material Purchasing, Material Counting, Material Registration, Material Record Deletion, Material Return, Material Repair and Maintenance.

In the implementation of the model, static business process definitions were used. The implementation was performed in the two stages. In the first stage, the current state (AS-IS) of the process, Meeting Material Request, was taken into consideration. This process has 29 activities. Each activity was clearly identified by explaining with actors who took part in, forms, tools and applications that were used in. Unified Modeling Language (UML) Activity Diagram was used for modeling the process. When the modeling of the process was examined, it was recognized that the process had document based manual works and nonintegrated software tools. The same data is kept in more than one place such as in private inventory records. All departments keep their material movements in department stock cards in addition to Warehouse Department. These problems increase the number of activities and cycle time. The new model was applied to the AS-IS modeling of process and quality attributes were measured by evaluating its activities and the attributes definitions in the model. The quantified attributes' values address the hidden problems and duplications in the process.

In the second stage, a new form (TO-BE) of process was modeled according to specifications of an IS project. In the IS project, an integrated workflow was defined and endorsed by a software application and a central database. The numbers of document-based works are decreased and data is kept only in one place that can be accessed by users in accord with their privileges. There is also decline in the number of activities (from 29 to 24). Similar to the first stage, the process modeling of the new process was drawn and quality attributes were calculated. The new values of the attributes depict the effects of IS on the process.

4.2 Results of the Implementation

The results of the first characteristic, functionality, are given in Table 2. The common desirable features of the functionality metrics are their closeness to the 1.

Table 2. Results of the functionality characteristic

Subcharacteristic	Attribute	AS-IS	TO-BE
Suitability	Functional Adequacy	0.793	0.916
	Functional Completeness	0.759	0.875
IT Based Functionality	IT Usage	0.241	0.667
Accuracy	Functional Accuracy	0.518	0.792
Interoperability	Data Exchangeability	0.857	1
Security	Access Auditability	0.931	1

AS-IS results of the functional characteristics can reveal some beneficial insights about the present state of the process. Access Auditability of the activities is near to 1. It can be considered as satisfactory. The accesses of the users to the resources such as reading or updating inventory records and document record books are under the control. Unlike the Access Auditability, IT Usage is the most far away from 1. This low value shows improvement opportunities. On the other hand, another low value is about Functional Accuracy. It shows that process has critical functional accuracy problems and needs to be improved. The results of Functional Adequacy and Functional Completeness are close to each other and also to 1. It can be said that process activities are almost adequate and complete. The last result is for Data Exchangeability. Its value emphasizes that the business process can be interoperable with other processes in the Warehouse Department.

When TO-BE results of the functional characteristics are compared with the AS-IS counterparts, some improvements take attention. The most improved results are about IT Usage and Functional Accuracy. The use of workflow in software system with a central database provides controlled and consistent environment to the users. This reduces the user based errors and misconceptions. The use of material code, automatic inventory record update and sharing resources instantaneously guide users. The effects of IS can also be observed in Access Auditability and Data Exchangeability values. As users are defined in the system with proper roles and responsibilities and their accesses to the resources are performed with the username and password, Access Auditability attribute equals to 1. Data Exchangeability also equals to 1 as it has no problems during the interactions between Material Purchase and Material Registration processes. The inputs and outputs between the processes are automated and also can be monitored by users. Other improvements occurred in Functional Adequacy and Functional Completeness attributes. The process activities are redefined and their incompleteness are reduced and more compact activities are formed.

AS-IS results of the reliability characteristics are given in Table 3. Failure attribute shows the number of user based errors. These errors hinder the process from reaching the expected results. According to the measurement, 23 failures may be happened in the process (one activity may have more than one failure). When the failures are investigated, it is recognized that most of the failures are originated from users such as writing incorrect material name, updating incorrect material number and delivering wrong material. The second attribute is Failure Avoidance. 6 Failure Avoidance mechanisms are detected in the current state of the process such as using the previous document template. The last attribute is about Restorability. There is 1 Restorability mechanisms as daily backups of inventory records to floppy disks.

In the TO-BE column of the reliability, failure attribute value decreases to 11. The IS project on the process limits the number of user based errors. For instance, user cannot deliver a material that is not selected in Material Request Form, and software itself accomplishes automatic inventory records updating. Another improvement occurs in the second attribute. New Failure Avoidance mechanisms can be defined in the workflow of the software such as selecting material code from Material Catalogue rather than writing material name and its characteristics. The value of third attribute, Restorability, seems not changed after the implementation of IS project. Although it has the same value, the process has more sophisticated daily database backup utility and also instantaneous transaction logs.

AS-IS results of the third characteristic, usability, are given in Table 4. According to the results, Description Completeness attribute is near to 1. It can be said that process can be understandable with its current definitions. This thought may be supported by Attractiveness Interaction attribute with its high value. The other attributes that are close to 1 are Cancellability and Undoability. These attributes show that the process activities can be undone or canceled before they are completed. On the other hand, Monitorability attribute has the lowest value. This indicates that status of the process activities cannot be monitored satisfactorily.

Table 3. Results of the reliability characteristic

Subcharacteristic	Attribute	AS-IS	TO-BE
Maturity	Failure	23	11
	Failure Avoidance	6	9
Recoverability	Restorability	1	1

In the TO-BE column, the most increase happens in the value of Monitorability attribute. The users can now follow the status of their request easily in the software such as following Material Request Form's status (as "initial", "met", "rejected", "to be delivered" and "to be bought"). There are other increases in the values of Description Completeness and Attractive Interaction. The users have more complete activity descriptions and user-friendly interfaces. Some of the fields in the forms are filled by the software automatically such as form number, date and department name. The other fields are whether selected from combo boxes such as material code or entered by users. This new environment presents users more understandable process activities. Although there are increases in most of the attributes' values, the values of Cancellability and Undoability attributes slightly decrease. The new form of the process presents users more controlled activities with cancellability and undoability facilities.

Table 4. Results of the usability characteristic

Subcharacteristic	Attribute	AS-IS	TO-BE
Understandability	Description Completeness	0.828	0.875
Operability	Cancellability	0.793	0.792
	Undoability	0.793	0.792
	Monitorability	0.138	0.584
Attractiveness	Attractive Interaction	4 good, 4 very good	8 very good

AS-IS results of the fourth characteristic, maintainability, are given in Table 5. Complexity attribute indicates the number of decision points as 3. The other attribute, Coupling, implies the number of business processes that are communicated as 2. As the number of decision points and number of communicated processes do not change in the new form of the process, TO-BE values of the attributes are same with the AS-IS values.

Table 5. Results of the maintainability characteristic

Subcharacteristic	Attribute	AS-IS	TO-BE
Analyzability	Complexity	3	3
	Coupling	2	2

In order to give additional information about the process, cycle time and cost values are measured. Cycle time is calculated by adding the elapsed time in each activity. According to the results, there is a considerable decrease, from 260 minutes in AS-IS to 144 minutes in TO-BE. The reasons of this improvement are decrease in the number of activities (from 29 to 24), increase in the operations that are performed by the software automatically such as updating inventory records, filling some of the fields in the forms (e.g. formal number, date, department name, material name) and monitorability of the activities status (users can learn the status of their requests by following the status field in the software rather than making telephone conversation). The other information is about cost. Although cost includes wide range coverage, we only calculate actors' salary-based cost. The actors' (e.g. department secretary, department manager, store section manager) salary (converting one month salary to minute salary) and elapsed time in each activity are multiplied to find the cost. As there is decrease in cycle time, cost also reduces from $25.340 in AS-IS to $16.075 in TO-BE for one cycle.

5 Conclusions

In this paper, a new process based model is developed as a complementary to the available product based models to measure the quality of processes. The model is implemented in an organization to calculate the quality attributes on the sample process. When the effects of IS on processes are considered in process improvement scope, the implementation of the model shows that the new model can be useful in process improvement studies. The changes in the process quality attributes after implementation of a process improvement study demonstrate the impacts of the study. The results of a process improvement study can be used for directing the designs of evolving process improvement studies for decreasing the value of specific attributes (e.g. complexity, and coupling) or increasing the other ones (e.g. IT usage, restorability). In this way, organizations can control process quality attributes and have gradual improvements.

The model can also be used with product based models to evaluate different IS investment alternatives. For this purpose, organizations can apply the model in the evaluations of IS investment alternatives. The product based measurements and results of the model can help the organizations for selecting the most suitable alternatives to their processes.

As a prerequisite, organizations must model their business processes to apply the new model. It may be thought as a possible restriction, but, today, organizations should already have modeling of their processes to follow and improve them. Another possible restriction may be high number of process. This makes difficult the implementation of the model. In this case, a sample business process set can be formed according to the criticality of the processes before applying the model.

In the future, further experiments will be performed to improve the model. These studies provide significant feedbacks to the model. The definitions of the attributes will be more clear and concrete. New measurement categories or attributes can be added to extent the scope of the model. The correlations between the attributes can also be examined and defined. Therefore, the benefits of the model to organizations will increase and organizations will benchmark their quality attributes with other organizations' processes.

References

1. Jeffery, M., Leliveld, I., Best Practices in IT Portfolio Management, MIT Sloan Management Review (2004)
2. DeLone, W.H., McLean, E.R., Information System Success: The Quest for the Dependent Variable, Information Systems Research, 3, 1 (1992) 60-95
3. Brynjolfsson, E., Hitt L., The Three Faces of IT Value: Theory and Evidence, Proceedings of the Fifteenth International Conference on Information Systems, Vancouver, BC (1994) 263-276
4. DeLone, W.H., McLean, E.R., The DeLone and McLean Model of Information Systems Success: A Ten-Year Update, Journal of Management Information Systems, Vol. 19, No. 4 (2003) 9-30
5. Osterweil, L., Software Processes are Software Too, Proceedings of the Ninth International Conference on Software Engineering, Monterey, CA (1987) 2-13
6. ISO/IEC FCD 9126-1.2: Information Technology - Software product quality -Part 1: Quality model

7. Danziger, J. N., Politics, Productivity and Computers: A Contingency Analysis in Local Governments, Proceeding of the Ninth Annual Society for Management Information Systems Conference (1987) 213-221
8. Seddon P.B., Staples S., Patnayakuni R., Bowtell M., Dimensions of Information Systems Success, Communications of the Association for Information Systems, Vol.2 Article 20 (1999)
9. Mooney J.G., Gurbaxani V., Kraemer K.L., A Process Oriented Framework for Assessing the Business Value of Information Technology, The Data Base for Advances in Information Systems, Vol. 27, No. 2 (1996)
10. Beath, C. M., Goodhue, D. L. Ross, J. R., Partnering for business value: The shared management of IS infrastructure. In J. I. DeGross, S. L. Huff and M. C. Munro (Eds.), Proceedings of the Fifteenth International Conference on Information Systems, Vancouver, British Columbia, (1994) 459-460
11. Sambamurthy, V. and Zmud, R. W., IT management competency assessment: A tool for creating business value through IT. Working Paper, Financial Executives Research Foundations (1994)
12. Soh, C. and Markus, M. L., How IT creates business value: A process theory synthesis. Proceedings of the Sixteenth International Conference on Information Systems, Amsterdam, The Netherlands, (1995) 29-42
13. Davenport, T.H., Process innovation: reengineering work through information technology, Boston, Mass: Harvard Business School Press, 062117110523 (1993)
14. Hammer, M., Steven S., The reengineering revolution, New York: Harper Business, 062117110523 (1994)
15. Basili, V.R., Software modeling and measurement: The Goal/Question/Metric paradigm, Technical Report, CS-TR-2956, Department of Computer Science, University of Maryland, College Park, MD 20742 (1992)
16. Demirors, O., Guceglioglu, A.S., A Model for Using Software Quality Characteristic to Measure Business Process Quality, Technical Report, METU/II-TR-2005-08, Department of Information System, University of METU (2005)
17. McCabe, T. J., A Complexity Measure, Software Engineering SE-2, 4 (1976) 308-320