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Investigation of the Cobit Framework's Input\Output Relationships by Using Graph Metrics

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***Abstract*—The information technology (IT) governance initiatives are complex, time consuming and resource intensive. COBIT, (Control Objectives for Information Related Technology), provides an IT governance framework and supporting toolset to help an organization ensure alignment between use of information technology and its business goals. This paper presents an investigation of COBIT processes' and inputs/outputs relationships with graph analysis. Examining the relationships provides a deep understanding of COBIT structure and may guide for IT governance implementation and audit plans and initiatives. Graph metrics are used to identify the most influential/sensitive processes and relative importance for a given context. Hence, the analysis presented provide guidance to decision makers while developing improvement programs, audits and possibly maturity assessments based on COBIT framework.**

I. Introduction

INFORMATION technology has become a vital and integral part of many business activities and also in the support, sustainability, and growth of enterprises. Business and IT departments, must understand each other and make the strategic / tactical plans together for achieving goals of the organization. IT should provide the necessary services to business, plan, manage existing services, be ready for agile developments, store and protect the data, consider operational jobs and so on. Managing that kind of complex organizations is very hard and to achieve well established management, a set of policies and processes are needed on corporate level [1]. IT governance is the structure of relationship and processes that ensure the effective and efficient use of IT to achieve organizational goals.

IT governance includes decision making structures, alignment processes and communication tools [2]. Demands of business departments, by force of competitive market, must be aligned with the plans of IT [3] [4]. IT needs to monitor all services, their life-cycles, and resources by considering the business expectations. To achieve this, enterprises seek for practical knowledge and well defined guidelines. The best known and generally accepted IT governance framework is COBIT. COBIT, now in its fifth edition, describes a set of good practices for the board and senior operational and IT management [5]. According to the ISACA COBIT 4.1 has been downloaded more than 100.000 times over 160 countries. Although COBIT version 5 is published, COBIT 4.1 is still in use in most organizations and widespread so that we use COBIT 4.1 as source in this research.

COBIT provides a governance framework, supporting toolset and maturity model to help an organization ensure alignment between use of information technology and its business goals in the areas of risk management, resource management, performance measurement, value delivery and regulatory compliance. It is based on best practice in IT management and control. COBIT framework defines 34 processes under four domains and also 318 detailed control objectives and associated audit guidelines. The framework identifies seven information criteria such as effectiveness, efficiency, confidentiality, integrity, availability, compliance and reliability as well IT resources as people, applications, information and infrastructure [6] [7] [8].

COBIT version 4.1 management guidelines provides a section, describe inputs and outputs for each process. These input and output tables represent a brief description for the processes' relationships. Examining the relationships provides a deep understanding of COBIT structure and may guide for IT governance implementation and audit plans and initiatives. In this paper, an investigation of COBIT processes' and inputs/outputs relationships with graph analysis is presented. We aim to analyze the relative importance of processes based on graph metrics hence provide information to decision makers for developing improvement programs, audits and maturity assessments based on COBIT framework.

This paper is organized as follows. Section 2 provides literature on analysis on COBIT processes. Section 3 presents the method used to obtain the COBIT graph. Section 4 and its sub-sections provide the results of graph metrics used. The last section summarizes the main findings.

II. Related Work

Although COBIT and its related sources have been investigated widely such as comparison with other frameworks, detailed investigation of a specific area like security or project management etc. there are not much published papers concerning the inputs and outputs of COBIT processes. In paper [9] Tuttle and Vandervelde examine the conceptual model of COBIT in an audit setting. They used data from COBIT assessments made by a panel and confirmed the internal consistency of COBIT. But their perspective was IT audits and used the data from the experts not from the COBIT itself. In [10] Bernroider and Ivanov investigated COBIT for specifically project management control (PO 10). They also used an empirical survey as data source similarly as Tuttle and Vandervelde.

Morimoto argues that COBIT is too general-purpose and requires expert knowledge to implement [11]. Morimoto was interested in only security part of framework and tried to create a new framework from existing frameworks. For that aim he used combination of ISO/IEC 12207 and ISO/IEC 27002 with COBIT. Morimoto is not the only one argued COBIT is very abstract and hard to implement and control objectives are fundamental examples. There are numerous papers mentioned that abstraction in such papers as [10], [12] and [13].

In [14] Abu-Musa has made an empirical survey using self-administered questionnaire among 500 Saudi organizations and 127 valid respond was collected. His findings claims that banks and financial organizations show more concerns to IT governance than other industries. Paper also provides us important processes over domain level according to the respondents. PO7 (Manage IT Human Resource) is subtracted being the most important process in the plan and organize domain. PO1, PO2, PO5, PO10 and PO11 are important processes, as well. AI1, AI2 and AI4 are the most important processes in acquire and implement domain. For delivery and support domain most important process is DS5. ME1 is important in monitor and evaluate domain. According to the results of paper it can be concluded that the importance of COBIT processes may change so far as industry and organizations' aims. That variation of importance may be observed in Kerr and Murthy investigation, also. On the other hand COBIT's provides e.g. management guidelines, control objectives, RACI charts and inputs/outputs section. There are some fundamentals information may be used during in case of an implementation.

In [12] inputs and outputs of processes in COBIT 4.1 investigated directly. They used the number of inputs and outputs as inputs and investigated the importance of processes according to these numbers. Their findings includes the most influential processes that are sending more artifacts to all other processes as PO4, PO6, PO7 and PO8. It is claimed that any improvement plan sequence should include PO4, PO6, PO7 and PO8 in its initial phase. They also produced some key analyses such as sensitivity that is sum of total inputs. In that sensitivity graph ME1 is the top process due to many inputs from other processes to monitor their performance. Besides calculating the summation of all inputs and outputs of a process interconnection is measured. This research`s aim is similar with our paper. But they just used the total numbers of inputs and outputs of processes. In our research, we convert the relationships between processes among by inputs and outputs into a graph differentiating the inputs and outputs. Neto, Fonseca and Webster's approach aligns with degree calculations in this research and outcomes are exactly similar based on degree. On the other hand we go further than that, using other graph metrics. These findings may help developing improvement programs, audits and maturity assessments based on COBIT framework to optimize resources and time.

III. GRAPH BASED ANALYSIS OF COBIT

A. COBIT Graph

COBIT contains Management Guidelines, including Maturity Models, Critical Success Factors, Key Goal Indicators and Key Performance Indicators for each of the 34 processes that are under four domains (see Appendix A) COBIT also provides inputs and outputs on the management guidelines section of each processes. For 34 processes, input output information of each process' control objective by two different tables is also presented For example, Table I. represents the input output relation for the PO1 (Define IT strategic Plan) process. However, it is difficult to obtain any holistic information from these tables, 34 processes and their input/output table turned into a relationship matrix. Then that matrix is converted to a graph to be able to investigate the overall framework.

Using Gephi [1] the matrix is converted to a graph as Figure 1. To create the graph 34 processes represented as vertices or nodes and their relationships as edges or arcs. Three IT requirements, going outside of COBIT, also represented as vertices as OTHER1, OTHER2, and OTHER3. One output to the outside of COBIT represented as a node as OUTSIDECOBIT. So in Figure 1 there are process-like items as OTHER1, OTHER2, OTHER3 and OUTSIDECOBIT. The definitions of external requirement or outputs as shown below.

- OTHER1 is Business strategy and priorities, an input for PO1 (Define a Strategic IT Plan).
- OTHER2 is Programme portfolio, an input for PO1 (Define a Strategic IT Plan).
- OTHER3 is Legal and regulatory compliance requirements, an input for ME3 (Ensure Compliance with External Requirements)
- OUTSIDECOBIT is Classification procedures and tools, an output from PO2 (Define the Information Architecture)

[1] Gephi is an open-source software for network visualization and analysis and provides built-in functions to explore, manipulate and analyze the data. The software is for Exploratory Data Analysis goals to make hypothesis, to discover patterns by using visuality.

TABLE I

INPUT&OUTPUT SECTION OF PO1 PROCESS.

From	Inputs	Outputs	To
PO5	Cost-benefits reports	Strategic IT plan	PO2, PO3, PO4, PO5, PO6, PO8, PO9, AI1, DS1
PO9	Risk assessment	Tactical IT plans	PO2, PO3, PO4, PO5, PO6, PO9, AI1, DS1
PO10	Updated IT project portfolio	IT project portfolio	PO5, PO6, PO10, AI6
DS1	New/updated service requirements; updated IT service portfolio	IT service portfolio	PO5, PO6, PO9, DS1
*	Business strategy and priorities	IT sourcing strategy	DS2
*	Programme portfolio	IT acquisition strategy	AI5
ME1	Performance input to IT planning		
ME4	Report on IT governance status; enterprise strategic direction for IT		

To observe all interactions over COBIT the external IT requirements are included. Finally, The Graph has 38 nodes which are processes basically, 311 edges which are relationships between processes. The graph is a directed and weighted graph which means there can be a path from PO1 to PO2 but not counter wise. Edges have weights that the numerical value of edge shows actual number of edges from one process to another. If PO1 has two different outputs to PO2 that means the edge between PO1 and PO2 has a weight of 2.

Table III demonstrates betweensess centrality metrics as size of nodes. Visualization is prepared by force-atlas algorithm provided by Gephi in layout section. Visualized graph seems to be understood easier. Processes that not include in framework are out of the heart-like shape. And strong relationships between all processes may be concluded directly. Using graph metrics will provide a deeper understanding of COBIT structure and may guide for IT governance implementation initiatives. For this purpose in the following section, the graph metrics and obtained results are presented.

IV. GRAPH METRICS BASED ANANLYSIS

A. Degree

In a graph *degree* is total number of the edges belongs to a specific vertex. Degree is essential and effective measure to decide the importance of a node. In a directed graph two types of degree comes out, in-degree and out-degree. In-degree for a vertex v is the number of edges that v is the terminal vertex. Similarly out-degree of a node v is the number of edges that v is initial vertex. Degree basically, shows the strength of relationships between processes. In COBIT I/O graph the average degree is 8.184 that means approximately any process can have relationship with 8 other processes. But the graph is directed and weighted so average weighted degree is 10.842. As shown some of vertices have high degree, some of them have low degree. According to average weighted degree lowly linked and highly linked nodes can be noticed.

For a full degree list table II can be analyzed. PO4, PO6, PO7 and PO8 are the top four processes based on degree. But our graph is directed and weighted so both degree and weighted degree values have to be considered, respectively in table II. PO4 has the highest rank in total degree but in weighted degree list PO6 is in the number 1 rank. Moreover comparing table II it can be concluded that plan and organize processes dominates degree list.

From high level perspective can be concluded at domain level. PO (Plan and Organize) has the largest number of output information. So PO domain may be considered as a good starting point for governance initiatives. Then DS (Delivery and Support) domain is in the second rank.

Moreover COBIT governance initiatives can start based on their strategies not only domain level but also process level. For example implementation can start with DS 5 (Ensure System Security) and then continue with PO7. While these 2 processes are in progress monitoring should be active. So that parallel works can be done such as PO1 (Define a Strategic Plan), DS1 (Define and Manage Service Levels) can be in parallel. Also PO4 and PO7 enactment programs can be simultaneous. Hence, from the viewpoint of initiating governance programs the question of groupings of process may arise.

B. Centrality Metrics

Centrality is an important structural attribute of a graph meaning a centrality score is about how a node fits within a graph overall. Vertices that have highest centrality are likely to be key conduits of information. Low centrality modes can be named as peripheral. Lower centrality can be associated with less work overload in an organization [15]. Centrality of a vertex is the relative importance within a graph. There are two common and widely used centrality metrics which are betweeness and eigenvector centrality.

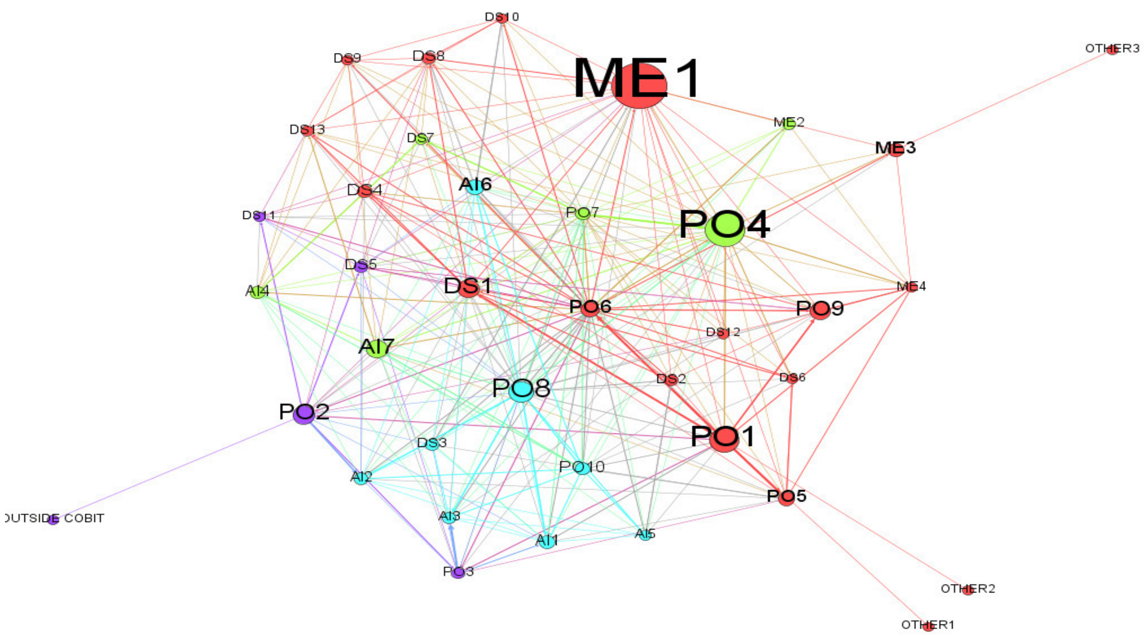

Figure 1 the Final Graph of I/O

C. Eigenvector Centrality

Eigenvector centrality or Gould index of accessibility [16] is calculated by assessing how well connected a node is to the parts of the network with the greatest connectivity. Eigenvector centrality is similar to the degree centrality but there is a difference that is eigenvector measures the importance of a node by the importance of its neighbors. A node receiving many edges does not mean receiver node has a high eigenvector centrality. Moreover, high eigenvector centrality node is not necessarily highly linked. That node may have a few edges to the other but they may be all important nodes.

Table III shows the eigenvector measurement. ME1 (Monitor and Evaluate IT Performance) has the highest score for eigenvector centrality. ME1 has a strong relationship with other processes as expected. But in the second rank is DS8 (Manage Service Desk and Incidents). DS8 gives outputs to AI6, DS10, ME1 and DS7. ME1 and AI7 have neighbors that have many connections and also takes inputs from 9 processes. As a conclusion DS8 is important because of its neighbor's importance. When top 5 processes are considered, they are similar in a manner. DS8 is for service desk, DS1 is for service levels, AI6 is to manage changes and finally PO9 is for risk management. These 4 processes are responsible to improve IT information criteria effectiveness and efficiency.

D. Betweenness Centrality

Betweenness centrality is a measure that is derived from shortest paths between nodes in a graph. The number of times a node acts as a cutpoint in the shortest point between two other nodes. In COBIT I/O graph that metric will show critical nodes to collaborate through all processes for spread of information. Algorithm in [17] is used to measure the centrality metric.

High betweenness nodes often don't have the shortest path to other nodes, but they have the greatest number of shortest path that have to go through them. Vertices that have high betweennes centrality metric, are critical to collaborate between other nodes. They are traders of information through the graph. Table III shows all nodes' betweeness centrality..

ME1 process has the highest betweenness centrality, PO4 follows it. DS6 (Delivery and Support domain – Identify and Allocate Cost) has the lowest betweenness centrality so that it can be inferred DS6 is an isolated process. DS6 is not a good point to maintain the spread of new information

TABLE III
FULL LIST OF DEGREE RESULTS

Process	Weighted Degree	Weighted In-Degree	Weighted Out-Degree	Degree	In-Degree	Out-Degree
PO6	75	9	66	39	6	33
PO4	53	15	38	42	9	33
PO8	52	7	45	39	6	33
PO7	46	7	39	37	4	33
PO1	42	15	27	25	12	13
ME1	33	26	7	30	23	7
DS1	32	14	18	23	11	12
PO10	30	10	20	20	7	13
PO2	24	11	13	17	9	8
PO5	24	16	8	19	12	7
PO9	23	14	9	19	11	8
AI7	23	14	9	18	10	8
AI6	23	16	7	19	12	7
AI1	23	16	7	17	10	7
AI3	23	16	7	16	9	7
AI2	22	16	6	16	10	6
PO3	21	11	10	14	8	6
AI4	20	12	8	17	10	7
DS8	20	15	5	17	13	4
DS4	19	11	8	17	9	8
DS5	17	11	6	15	9	6
ME4	17	11	6	13	8	5
DS3	16	8	8	14	7	7
DS13	16	13	3	13	10	3
AI5	16	13	3	12	10	2
DS2	15	12	3	11	8	3
DS7	14	12	2	10	8	2
DS9	13	8	5	12	7	5
DS10	13	9	4	11	8	3
DS11	13	11	2	11	9	2
DS6	13	11	2	9	7	2
ME2	11	7	4	10	6	4
ME3	9	6	3	8	5	3
DS12	9	8	1	8	7	1
OTHER1	1	0	1	1	0	1
OTHER2	1	0	1	1	0	1
OTHER3	1	0	1	1	0	1
OUTSIDE	1	1	0	1	1	0

TABLE II
FULL LIST OF CENTRALITY RESULTS

Process	Eccentricity	Betweenness Centrality	Eigenvector Centrality
OUTSIDE COBIT	-	0.00	0.05
PO4	2	181.18	0.42
PO8	2	87.23	0.32
PO6	2	44.07	0.27
PO7	2	19.66	0.17
PO1	2	115.34	0.52
ME1	2	280.42	1.00
AI1	2	27.50	0.44
PO10	3	24.90	0.31
DS1	3	65.24	0.58
PO9	3	59.79	0.54
AI7	3	61.91	0.43
ME4	3	5.17	0.32
ME2	3	13.26	0.31
ME3	3	34.00	0.14
PO5	3	34.29	0.49
DS3	3	15.64	0.30
AI6	3	42.55	0.53
PO3	3	11.15	0.34
DS4	3	22.79	0.43
DS5	3	16.71	0.42
DS9	3	5.90	0.29
DS8	3	16.13	0.60
DS2	3	10.73	0.37
DS10	3	1.53	0.36
DS7	3	5.14	0.38
DS13	3	6.77	0.44
OTHER1	3	0.00	0.00
OTHER2	3	0.00	0.00
DS6	3	0.40	0.30
DS11	3	3.04	0.41
DS12	3	1.86	0.30
PO2	4	67.04	0.46
AI3	4	15.64	0.37
AI2	4	18.08	0.44
AI4	4	23.51	0.42
AI5	4	6.39	0.43
OTHER3	4	0.00	0.00

E. Eccentricity

The eccentricity [18] is the distance of a starting node to the farthest node in a graph. COBIT graph here is weighted so that distance is a fundamental indice. In a graph minimum eccentricity value is its radius and maximum value is its diameter. In COBIT graph radius is 2 and diameter is 4. In Table III eccentricity values can be seen. PO4, PO6, PO7 and PO8 are in the list with value 2. But AI1 (Identify Automated Solutions), PO1 and ME1 are also in the list. Using eccentricity values it can be concluded that PO1, PO4, PO6, PO7, PO8, ME1 and AI1 are central vertices of the graph.

The overall results based on graph metrics are presented in Table IV.

V. CONCLUSION

Business dependency for IT services has been more crucial than ever. When the organization grows that dependency is increasing, too. To achieve organization's plans and business requirements IT governing the IT becomes tougher. Implementing an effective IT governance framework model becomes a necessity. Although providing a framework and toolset, it is hard to implement COBIT improvement initiatives. This study provides useful information about COBIT 4.1 framework from a holistic perspective. The findings presented in this paper can be used to develop a roadmap to plan the IT governance or audit initiatives.
Especially, plan and organize domain is found to be the most influential domain and processes PO4, PO6, PO7 and PO8 are particularly important. These processes produce many information items for the others, therefore these processes should be considered in first phase of the COBIT improvement initiatives. However it is important for an enterprise to decide based on specific objectives. The importance of the process implementation may change for the specific organization's approach. If the organization's aim may be to improve the current situation, then starting with PO2 process can be a good point, or the organization's aim may be to improve security then DS5 followed by AI6 and PO9 can be a starting point.

Also it is important to consider already enacted processes. Higher maturity level processes may produce mature outputs and in reverse processes that have lower maturity levels may be needed first as they may be central in the information flow. Using eccentricity values it can be concluded that PO1, PO4, PO6, PO7, PO8, ME1 and AI1 are central vertices of the graph.

As mentioned in the introduction, COBIT version 5 has been published. As a further research, we are planning to investigate COBIT5 in near future. In addition, usefulness of findings should be verified in practice.

VI. REFERENCES

[1] M. N. Kooper, R. Maes and E. Roos Lindgreen, "On the governance of information: Introducing a new concept of governance to support the management of information," *International Journal of Information Management,* vol. 31, pp. 195-200, 2011.

TABLE IV

OVERALL RESULTS

Metric	Description	Outcome
Eccentricity	The distance of a starting node to the farthest node	AI1,ME1,PO1,PO4,PO6,PO7,PO8
Closeness Centrality	Close center node can communicate with the other without need of many inder-mediaries	PO4,PO6,PO8,PO7
Betweenness Centrality	The number of times a node is in the shortest path between other two nodes	ME1
Eigenvector Centrality	The summation of the centrality values of a nodes that is connected to	ME1
Degree	Total number of edges of a node	PO4
Weighted Degree	Total number of edges of a node with weights in each edge	PO6
In-Degree	The number of edges that node is terminal itself	ME1
Out-Degree	The number of edges that node is initial itself	PO4,PO6,PO8,PO7
Weighted In-Degree	Total number of edges that node is terminal itself with weights in each edge	ME1
Weighted Out-Degree	Total number of edges that node is initial itself with weights in each edge	PO6

[2] P. Weill and J. W. Ross, IT govarnance How top performers manage IT decision rights for superior results, Boston: Harvard Business School Press, 2004.

[3] J. C. Henderson and N. Venkatraman, "Strategic alignment: Leveraging information technology for transforming organizations," *IBM Systems Journal,* vol. 32, no. 1, pp. 4-16, 1993.

[4] R. Hirschheim and R. Sabherwal, "Detours in the path toward strategic information systems alignment," *California Management Review,* vol. 44, no. 1, pp. 87-108, 2001.

[5] ISACA, COBIT 5: A Business Framework for the Governance and Management of Enterprise IT, Rolling Meadows: ISACA, 2012.

[6] J. Lainhart, "COBIT: a methodology for managing and controlling information and information technology risks and vulnerabilities," *Journal of Information*

[7] G. Bodnar, "What's new in COBIT 4.0.," *Internal Auditing,* vol. 21, no. 4, pp. 37-44, 2006.

[8] G. Hardy, "Using IT governance and COBIT to deliver value with IT and respond to legal, regulatory and compliance challenges," *Information Security Technical Report,* vol. 11, no. 1, pp. 55-61, 2006.

[9] B. Tuttle and S. D. Vandervelde, "An Empirical Examination of COBIT as an Internal Control Framework for Information Technology," *International Journal of Accounting Information System,* vol. 8, pp. 240-263, 2007.

[10] E. W. Bernroider and M. Ivanov, "IT Project Management Control and the Contol Objectives for IT and Related Technology(COBIT)," *International Journal of Project Management,* pp. 325-336, 2011.

[11] S. Morimoto, "Application of COBIT to Security Management in Information System Development," in *International Conference on Frontier of Computer Science and Technology*, Shangai, 2009.

[12] J. S. Neto, H. V. Fonseca and I. L. & Webster, "Importance of Inputs/Outputs Within COBIT Processes," *COBIT Focus,* vol. 3, pp. 6-9, 2009.

[13] S. J. Hussain and S. S. Muhammed, "Quantified Model of COBIT for Corparate IT Governance," in *First International Conference on Information and Communication Technologies*, Karachi, 2005.

[14] A. Abu-Musa, "Exploring the Importance and Implementation of COBIT processes in Saudi Organizations An Emprical Study," *Information Management & Computer Security,* vol. 17, no. 2, pp. 73-95, 2009.

[15] L. C. Freeman, "Centrality in Social Networks," *Social Networks,* vol. 1, no. 3, pp. 215-239, 1978-1979.

[16] P. Gould, "On the Geographical Interpretation of Eigenvalues," *Transactions of the Institute of British Geographers,* vol. 47, pp. 53-86, 1967.

[17] U. Brandes, "A Faster Algorithm for Betweenness Centrality," *Journal of Mathematical Sociology,* vol. 25, no. 2, pp. 163-177, 2001.

[18] P. Hage and F. Harray, "Eccentricity and centrality in networks," *Social NEtworks,* vol. 17, pp. 57-63, 1995.

APPENDIX A: COBIT PROCESSES

Plan and Organize(PO)	PO1 Define a Strategic IT Plan	DS1 Define and Manage Service Levels	Delivery and Support(DS)
	PO2 Define the Information Architecture	DS2 Manage Third-party Services	
	PO3 Determine Technological Direction	DS3 Manage Performance and Capacity	
	PO4 Define the IT Processes Organization and Relationships	DS4 Ensure Continuous Service	
	PO5 Manage the IT Investment	DS5 Ensure Systems Security	
	PO6 Communicate Management Aims and Direction	DS6 Identify and Allocate Costs	
	PO7 Manage IT Human Resources	DS7 Educate and Train Users	
	PO8 Manage Quality	DS8 Manage Service Desk and Incidents	
	PO9 Assess and Manage IT Risks	DS9 Manage the Configuration	
	PO10 Manage Projects	DS10 Manage Problems	
Acquire and Implement(AI)	AI1 Identify Automated Solutions	DS11 Manage Data	
	AI2 Acquire and Maintain Application Software	DS12 Manage the Physical Environment	
	AI3 Acquire and Maintain Technology Infrastructure	DS13 Manage Operations	
	AI4 Enable Operation and Use	ME1 Monitor and Evaluate IT Performance	Monitor and Evaluate(ME)
	AI5 Procure IT Resources	ME2 Monitor and Evaluate Internal Control	
	AI6 Manage Changes	ME3 Ensure Compliance With External Requirements	
	AI7 Install and Accredit Solutions and Changes	ME4 Provide IT Governance	