Quantifying Criticality of Dependability-Related IT Organization Processes in CobiT

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***Abstract*—With ever-growing complexity of computer and communication systems analytical methods do not scale, especially with respect to dependability assessment of information technology (IT) organization. Generic reference models can be used as an alternative to analytical approaches by focusing on transforming qualitative assessment into quantitative evaluation of IT organization. In this paper, we examine the reference models IT Infrastructure Library (ITIL) and the Control Objectives for Information and Related Technology (CobiT) to derive a quantifiable concept for estimating the criticality of dependability-related IT organization processes in CobiT. After systematically analyzing ITIL processes and deriving properties that are relevant to dependability, those processes are mapped onto CobiT processes. Furthermore, we propose a process criticality index (PCI) which reflects the significance of each dependability-related process within a particular reference model. The PCI is based on the graph theory concept of betweenness centrality and uses a directed graph where nodes represent dependability-related processes and edges relations among them. Finally, using cycle and sequence analysis we are able to identify for every process which processes have to be implemented a priori. This provides an efficient strategy for implementing most significant processes first, according to the ranking based on the PCI.**

***Keywords*-availability; dependability; IT organization; process criticality; reference models**

I. INTRODUCTION

The capacity of information technology (IT) systems has grown considerably in the last decades and at the same time their dynamics and complexity. Hence, the expenses caused by system failure have increased. Moreover, the demand for controlling instruments regarding critical business processes, IT revision and IT consolidation is on the rise. In addition to complexity, another main reason for this situation is the addition of new functionalities, often by cumulative integration of already existing legacy systems. This is being done without sufficient comprehension of the interaction among the components. In a nutshell, traditional methods to capture and analyze the system state or to enhance its dependability are not keeping up with the high complexity and interconnectivity growth of industrial systems. Analytical approaches do not scale up as necessary for real systems and often fail because of a prohibitive number of degrees of freedom [1].

IT organizations such as data centers are expected to have their IT processes implemented in accordance with well-established standards. Implementing IT processes in an organized manner as proposed in generic reference models such as the IT Infrastructure Library (ITIL) or Control Objectives for Information and Related Technology (CobiT) guarantees their traceability, assessability and comparability and, therefore, typically results in higher dependability.

One of the main applications of IT is running services to support business processes. These services not only have to be technically implemented but also organizationally deployed, maintained and executed to be able to react flexibly to changing needs and occurring failures. High-quality processes and sequences of operation supported by qualified staff and appropriate software tools are necessary for the successful handling of such IT services. Current approaches to service dependability evaluation are focused mainly on hardware and software resources [2] [3]. A comprehensive evaluation is only possible if IT organization, including infrastructure and personnel, is considered as well.

Generic IT reference models have been developed to describe business processes in idealized form (best practice). One of the important models – CobiT [4] – addresses dependability as an umbrella term. Other generic reference models such as ITIL [5] or the Capability Maturity Model Integration (CMMI) [6] address subtopics of dependability, e.g. reliability. In addition, *availability*, which frequently is an important property to clients, is part of dependability. The reference models provide companies with the opportunity to conduct their activities more effectively and efficiently, especially with respect to IT organization processes. Those standardized approaches serve as an idealized model and have to be specifically adjusted for every given use case.

Problems arise when evaluating the dependability of IT process organization in practice. On one hand, we are faced with mathematical models that precisely determine the reliability or availability of individual components. However, because of their complexity and a level of detail those models are not very useful for most industrial systems. On the other hand, generic reference models for IT process organization have a high level of abstraction and, therefore, do not allow exact dependability evaluation.

This paper proposes the application of analytical methods to the CobiT-like approaches in order to quantitatively evaluate IT organization. We do this by systematically analyzing IT organization processes within the reference models to derive the ones that are relevant to dependability. By examining the dependency structure among them, we are then able to judge the significance of individual processes for the overall IT organization dependability. Each process is quantified by a single number, called the *process criticality index* (PCI). The PCI allows ranking of significance of each process while masking the complexity of its assessment.

The rest of the paper is organized as follows. In Section 2 we state the problem of quantitatively assessing IT organization processes and describe existing approaches. Section 3, after a short overview of CobiT (specifically v4.1), presents new methods to overcome CobiT's existing problems. Two analytical approaches are proposed to answer an important question in CobiT: Which processes are more important than others for improving dependability and what is the best strategy of implementing those processes? We conclude this work in Section 4.

II. BASIC PROBLEM, RELATED WORK AND APPROACHES

Currently, there exists no scientifically established method capable of quantitative dependability evaluation of IT organization processes. This paper is most likely the first attempt in this direction although there were several works indicating such need in general.

As an important milestone, the necessity to convey a quantitative evaluation of IT organization is described in [7]. This study reports results of a large-scale field study on process maturity in 51 organizations from eight developed and developing countries. The objective of this study is to take the first step in quantifying the level of process maturity based on the CobiT reference model.

At present there exist tools for qualitative self-assessment of IT organization, such as SPiCE Lite [ITSM] (IT service management). It was developed by Nehfort IT Consulting KEG in cooperation with HM&S, SynSpace and TU Graz [8] [9] [10]. It works on the basis of processes of the ITILv2 reference model with focus on service support and service delivery. In the nutshell, SPiCE Lite [ITSM] supports the guided assessment of ITIL IT organization processes.

SPiCE applies its own maturity level model to ITIL processes. It thus provides a qualitative evaluation of process maturity in accordance to the SPiCE-process maturity model (ISO/IEC 15504) [11]. The tool consists of a preparatory part and an examination part. The preparatory part contains 37 questions referring to the different processes. It covers the whole software development process. Different process attributes are requested in each question. The auditor assigns a completion level between 0% and 100% or, respectively, the completion level N (not achieved from 0% to 15%), T (partly achieved from 16% to 50%), G (mainly achieved from 51% to 85%) or V (completely achieved from 86% to 100%).

Another IT organization modeling and assessment tool (ITOMAT) on the basis of CobiT was developed by [12]. It was designed to overcome the problems of validity, reliability and cost that are commonly associated with such methods and has been applied thoroughly in four case studies. The model can be used to predict the effect of changes in IT processes on their maturity level. One of the benefits of ITOMAT is that the person performing the assessment does not necessarily have to be an IT governance expert, since the analysis part is performed automatically.

III. ASSESSMENT OF DEPENDABILITY-RELATED IT ORGANIZATION PROCESSES

As mentioned in Section II, there are currently no possibilities to quantitatively evaluate dependability of the IT organization processes. In this section, we propose a systematic quantification method for IT organization processes significance based on qualitative assessment of IT processes as defined in CobiT and ITIL. IT organization processes are implemented based on established standards. Therefore, it is possible to explore the generic reference models with the goal of identifying every management process that concerns dependability. CobiT refers to control objectives. These have to be considered and implemented in an organization to ensure a reliable use of IT. For that purpose CobiT defines seven criteria arranged in the following three classes:

1) Quality of IT
    - Effectiveness
    - Efficiency
2) Security
    - Confidentiality
    - Integrity
    - Availability
3) Reliability
    - Compliance
    - Dependability

The administration of IT resources in CobiTv4.1 is divided into four IT domains as seen in Table I. CobiT describes the central IT processes and associated activities in every domain. Hence, it belongs to the generic reference models covering the whole field of IT management, engineering and operation.

The selection of all processes in CobiT relevant to dependability was carried out as follows. First, nine dependability-related processes were systematically identified in ITILv3. This step is described in detail in [13]. In the next step, a process mapping was carried out to map these nine identified processes in ITILv3 onto similar processes in CobiTv4.1. Out of the total of 34 processes in CobiT, the mapping left 29 processes that were relevant to dependability. These

Table I: Four IT domains in CobiT v4.1

Domain	Process	Description
Plan and Organize	PO1 - PO10	Strategical levels ascertaining how the IT can contribute to the achievement of business ambitions
Acquire and Implement	AI1 - AI7	Realization of IT and integration in the business process
Deliver and Support	DS1 - DS13	Effective supply of the desired attendances
Monitor and Evaluate	ME1 - ME4	Monitor and Evaluate

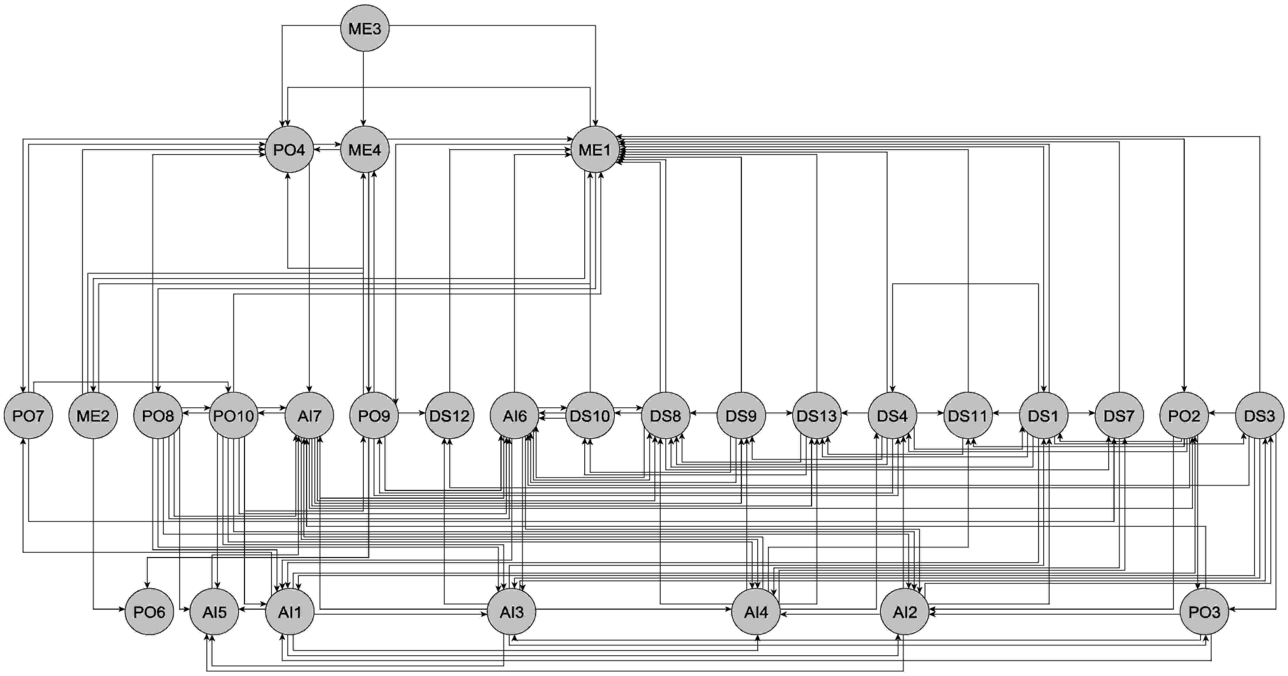

Figure 1: Relations among CobiTv4.1 processes concerning dependability. A detailed description of the individual processes is presented in Table III.

processes are analyzed in this paper. A description of the processes is given in Table III.

Every process has a set of inputs and outputs which were taken from the CobiT documentation. To further analyze the processes and their interdependencies, we generated a graph based on the inputs and outputs of selected processes that is shown in Figure 1. As can be seen the CobiT reference model is represented by a directed, cyclic graph. In the following sections, we will quantitatively evaluate this graph using theoretical methods. This is accomplished by extracting information valid for our goal of identifying processes and relations among processes that are relevant to dependability assessment.

A. *Computation of Process Criticality Index*

Graph theoretical concepts allow to determine the relative importance of vertices in a linear graph. We propose to evaluate the processes in Figure 1 by applying the betweenness centrality measure. The betweenness centrality identifies the importance of vertices with respect to the number of flows (path traversals) [14]. It is based on distance, i.e., it refers to the number and length of the shortest paths between pairs of vertices. The higher the betweenness centrality of a vertex, the higher is the significance of the process that is represented by the vertex since more business processes are dependent on the process being implemented. In our context, to reflect this correlation we call the betweenness centrality absolute *process criticality* (PC).

We use this measure to also compute the normalized PC of each process in Figure 1. Since not every process has equal criticality, we propose a ranking of them. Our hypothesis is that this ranking reflects the relative impact of each process on IT organization dependability. Moreover, we can make a statement to what percentage the theoretical maximum has been reached. The theoretical maximum for CobiT's IT organization dependability requires a complete graph as seen in Figure 1. In reality, we might be faced with components (disconnected subgraphs) because some processes are not implemented at all.

To calculate the absolute PC it is necessary to construct a distance matrix for CobiT based on the graph in Figure

1. Each vertex is characterized by a number of shortest paths traversing over it. To characterize these vertices it is necessary to find all shortest paths for every pair of vertices v_j and $v_k, j \neq k$. Afterwards, it has to be checked how many times another vertex $v_i, i \neq j \neq k$ lies on all of the shortest paths between v_j and v_k. The j-k betweenness $b_{jk}(v_i)$ (for vertices v_j and v_k) of a given vertex v_i is a ratio of the number $g_{jk}(v_i)$ of shortest paths passing through the vertex v_i to the number g_{jk} of all shortest paths between a pair of vertices v_j and v_k.

$$b_{jk}(v_i) = \frac{g_{jk}(v_i)}{g_{jk}} \; for \; j \neq k \neq i \tag{1}$$

In order to compute b_{jk} for all processes, it is necessary to have the number of paths m_d for every distance $d, d > 1$. Using the CobiT example in Figure 1 the distance d has a maximum of 4 which means that every vertex can reach every other vertex within maximum four steps. Considering only those cases where $d > 1$ is essential because the betweenness can only be defined when a given vertex actually intermediates a flow between two other vertices. Three scenarios for the determination of the number of paths m_d are possible in this case:

Distance $d = 2$

$$m_2 = \sum_i (\exists \overbrace{(v_j, v_i)}^{1} \wedge \exists \overbrace{(v_i, v_k)}^{1}) \tag{2}$$

Let v_i be the vertex for which the absolute PC has to be calculated. Equation 2 describes the number of all possibilities that any vertex v_j reaches v_i in one step and v_i reaches any other vertex v_k in one step.

Distance $d = 3$

$$\begin{aligned} m_3 = & \sum_i (\exists \overbrace{(v_j, v_i)}^{1} \wedge \exists \overbrace{(v_i, v_k)}^{2}) \\ & + \sum_i (\exists \overbrace{(v_j, v_i)}^{2} \wedge \exists \overbrace{(v_i, v_k)}^{1}) \end{aligned} \tag{3}$$

Equation 3 describes the number of all possibilities that v_j reaches v_i in one step and v_i reaches v_k in two steps plus the number of all possibilities that v_j reaches v_i in two steps and v_i reaches v_k in one step.

Distance $d = 4$

$$\begin{aligned} m_4 = & \sum_i (\exists \overbrace{(v_j, v_i)}^{1} \wedge \exists \overbrace{(v_i, v_k)}^{3}) \\ & + \sum_i (\exists \overbrace{(v_j, v_i)}^{3} \wedge \exists \overbrace{(v_i, v_k)}^{1}) \\ & + \sum_i (\exists \overbrace{(v_j, v_i)}^{2} \wedge \exists \overbrace{(v_i, v_k)}^{2}) \end{aligned} \tag{4}$$

Equation 4 describes the number of all possibilities that v_j reaches v_i in one step and v_i reaches v_k in three steps plus the number of all possibilities that v_j reaches v_i in three steps and v_i reaches v_k in one step plus the number of all possibilities that v_j reaches v_i in two steps and v_i reaches v_k in two steps.

Finally, the individual betweennesses have to be summed up to derive the betweenness centrality which reflects the absolute PC C_B for a given vertex v_i in the graph [15]:

$$C_B(v_i) = \sum_j^n \sum_k^n b_{jk}(v_i) \; for \; j \neq k \neq i \tag{5}$$

$C_B(v_i)$ is a non-normalized measure and therefore difficult to compare. For that it has to be transformed in such a way that its value is always between 0 and 1. In order to normalize $C_B(v_i)$ we divide it by the maximum number of shortest paths in a graph without vertex v_i:

$$C_{Bmax} = \frac{(n-1)(n-2)}{2} = \frac{n^2 - 3n + 2}{2} \tag{6}$$

So the normalized PC is:

$$C'_B(v_i) = \frac{2 \sum_j^n \sum_k^n b_{jk}(v_i)}{n^2 - 3n + 2} \; for \; j \neq k \neq i \tag{7}$$

The absolute and normalized PC of the individual dependability-related IT organization processes in CobiT can be seen in Table II. They are ordered by the normalized PC.

To better reflect the significance of each process, we now propose the *process criticality index* (PCI) that is directly computed as a percentage from the normalized PC and reflects the impact size a specific dependability-related process has on dependability of the entire system. In Table III, the ranking of processes is displayed according to the computed PCI. On basis of the PCI it is possible to derive to what extent the information flow inside the graph is influenced by a missing vertex. In real scenarios a missing vertex can be exemplified by a missing or flawed implementation of a process. This is important for a subsequent classification of processes with respect to maturity levels. It also provides the possibility to calculate to what extent the

Table II: Absolute and normalized process criticality (PC) of dependability-related processes in CobiT

Process	Absolute PC ($C_B(v_i)$)	Normalized PC ($C'_B(v_i)$)
ME1	218,409	0,578
AI7	91,699	0,243
PO9	58,844	0,156
DS1	58,096	0,154
AI6	55,283	0,146
PO10	54,107	0,143
PO2	48,627	0,129
PO4	41,284	0,109
PO8	40,219	0,106
DS4	37,136	0,098
AI4	37,101	0,098
AI3	30,049	0,079
AI1	28,358	0,075
AI2	23,494	0,062
DS8	23,095	0,061
DS3	16,536	0,044
PO7	15,141	0,040
DS13	10,788	0,029
ME4	10,319	0,027
DS7	9,913	0,026
ME2	9,833	0,026
DS9	9,823	0,026
PO3	6,817	0,018
DS12	4,154	0,011
DS11	2,482	0,007
DS10	1,958	0,005
AI5	1,433	0,004
PO6	0	0
ME3	0	0

Table III: Significance of dependability-related processes in CobiT based on process criticality index (PCI)

Process	PCI	Description
ME1	23,11%	Monitor and Evaluate IT Performance
AI7	9,70%	Install and Accredit Solutions and Changes
PO9	6,23%	Assess and Manage IT Risks
DS1	6,15%	Define and Manage Service Levels
AI6	5,85%	Manage Changes
PO10	5,73%	Manage Projects
PO2	5,15%	Define the Information Architecture
PO4	4,37%	Def. IT Processes, Organization, Relationships
PO8	4,26%	Manage Quality
DS4	3,93%	Ensure Continuous Service
AI4	3,93%	Enable Operation and Use
AI3	3,18%	Acquire & Maintain Technology Infrastructure
AI1	3,00%	Identify Automated Solutions
AI2	2,49%	Acquire and Maintain Application Software
DS8	2,44%	Manage Service Desk and Incidents
DS3	1,75%	Manage Performance and Capacity
PO7	1,60%	Manage IT Human Resources
DS13	1,14%	Manage Operations
ME4	1,09%	Provide IT Governance
DS7	1,05%	Educate and Train Users
ME2	1,04%	Monitor and Evaluate Internal Control
DS9	1,04%	Manage the Configuration
PO3	0,72%	Determine Technological Direction
DS12	0,44%	Manage the Physical Environment
DS11	0,26%	Manage Data
DS10	0,21%	Manage Problems
AI5	0,15%	Procure IT Resources
PO6	0,00%	Communicate Management Aims & Direction
ME3	0,00%	Ensure Regulatory Compliance

is-condition deviates from the theoretical maximum. Using only a single comparable value, the PCI gives an indication of the significance of a process in relation to all other processes at a glance.

B. Cycle and Sequence Analysis

Due to the interdependence of processes in CobiT an enormous number of cycles is expected to exist in the graph. The software CONSIDEO Modeler® [16] was used to identify those cycles. The processes $PO6$ and $ME3$ attain a criticality index of 0. As can be seen in Figure 1, $ME3$ merely is a data source and $PO6$ was identified as a data sink. Both processes could be ignored in the following cycle analysis because obviously no cycles can include either $PO6$ or $ME3$. The analysis revealed 127.930 cycles. Based on the initializing process $AI1$ the information flow passes, for example, processes $PO2$ and $PO3$ and continues back to $AI1$. Hence, the information flow proceeds in a stringent order.

With the help of *Sequence Pattern Discovery*, a tool of the IBM Bioinformatics Group [17], we were able to find out which sequences were traversed most frequently in all cycles. *Sequence Pattern Discovery* has implemented the Teiresias algorithm [18] [19] which was used in this paper to find recurring patterns in process sequences. Such sequences were generated by the CONSIDEO Modeler® tool.

In a last step the most frequent sequences of the remaining 27 (without $PO6$ and $ME3$) processes relevant to IT organization dependability were analyzed. Only sequences of length two to ten were examined. This is sufficient for the analysis, since those sequences amount to 89% of the total number of sequences. The analysis enabled us to identify the individual processes which have to be implemented first to reach any other process in the graph. Hence, this makes it possible to prioritize the implementation of processes in CobiT and provides an efficient strategy when implementing significant processes that were selected based on the PCI. Table IV displays the results for each process.

IV. CONCLUSIONS

A dependency graph was constructed based on the respective dependencies of processes in CobiT. The set of processes was reduced to include only selected processes concerning IT organization dependability, which was done by extracting dependability-related processes in ITIL and mapping them onto CobiT processes.

Next, the dependency graph was analyzed using graph theoretical properties. The proposed *process criticality index* (PCI) reflects the intermediation of a vertex in the graph. Hence, it describes the relative importance of the process represented by this vertex within the CobiT reference model. By using graph analysis to derive the PCI, it is now possible

Table IV: Prioritization of the processes

Process	Processes which should be implemented a priori
PO2	AI7, AI1
PO3	PO2
PO4	PO9, PO8, PO7
PO7	AI1, PO4
PO8	PO10, ME1
PO9	ME4, DS4, PO10, ME1
PO10	AI7, PO7, PO8
AI1	PO3, AI6, PO8
AI2	PO3, AI6, PO8, PO2, AI1
AI3	AI6, PO8, DS2, PO10
AI4	AI2, DS7, AI3, AI7
AI5	AI2, AI3
AI6	DS8, PO9, DS10, DS9, DS2
AI7	AI4, AI5, PO4, AI3, AI6
DS1	AI3, DS4, AI2, ME1, PO2
DS3	DS1, AI3
DS4	PO9, AI4, DS1, PO2
DS7	DS8, PO7
DS8	DS13, DS10, DS9, AI7, AI6
DS9	DS4, AI7, AI4
DS10	DS13, DS8, DS9
DS11	DS1, DS4
DS12	AI3, PO9
DS13	DS11, DS9, AI7, DS1
ME1	DS7, DS8, DS10, ME4, DS13, AI6, DS2, DS11, DS12
ME2	ME1
ME4	PO4, ME2

to quantify qualitative measures based on CobiT and ITIL processes. It might also help to evaluate IT organization dependability.

Consequently, the individual processes were prioritized, to answer the question: What processes are more important than others and what processes need to be implemented ahead of them? This question is relevant in practice because a given company is able to focus on the processes which should be implemented first in order to achieve higher dependability more efficiently and effectively.

With our approach one can perform comparative analysis of qualitative and quantitative evaluation. Dependencies between quantitatively assessed dependability and qualitatively assessed maturity and capability levels can be examined. The proposed approach will allow more precise and objective evaluation of IT organization dependability based on qualitative indicators and maturity levels of reference models such as CobiT and ITIL. Using the proposed method, we can also analyze and rank the processes of other reference models such as CMMI, MOF or SPiCE.

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