Complex information systems configuration using ISACA Design Guide into an Axiomatic Design approach

Eugen Purice¹, Petru Dusa¹,*, Laurentiu Cretu², Adrian Cacu¹, Oana Dodun¹, and Laurentiu Slatineanu¹

¹“Gheorghe Asachi” Technical University of Iasi, Iasi, Blvd. D. Mangeron, 39 A, 700050, Romania
²Gentec Data srl, Street Gh. Titeica, 121 C, Bucharest, 020295, Romania

*pdusa@tcm.tuiasi.ro

Abstract. This paper describes the process of designing a customized governance solution for an enterprise information system using COBIT framework guidelines and an axiomatic design approach. COBIT (Control Objectives for Information and related Technology) is a generally accepted framework created by the ISACA (Information Systems Audit and Control Association) for governing and managing enterprise information and technology (IT). COBIT framework can be applied to any organization in any industry and was designed to help deliver value while managing better the risks associated with the IT processes. On the other side, the Axiomatic Design (AD) theory involves a continuous interplay between the design objectives (the needs / what we want to achieve) and the means capable of reaching those objectives (how we want to achieve) to determine the best configuration capable of satisfying the design intend. The AD theory requires a description of the design's objectives in terms of specific requirements, called Functional Requirements (FR). The development of a complete solution to a given problem starts by mapping the FRs to Design Parameters (DPs) in the solution domain. ISACA Design Guide proposes ten (10) Design Factors and forty (40) Governance Objectives; each objective (a set of Functional Requirements) can be achieved through several combinations of Design Parameters. From the Axiomatic Design theory perspective, this determines a coupled matrix. To decouple the matrix, the profile of each design factor is drawn, and the sub-factors will be taken only once within the factor where the sub-factor has the highest weight. A case study is presented.

1. Introduction
Information and related information technologies (IT) are ubiquitous and play critical roles in most organizations. IT has become a business facilitator, playing a major role in the efficient delivery of products and services, bringing more value to stakeholders.

Governance of IT enterprises (GEIT), adding value while mitigating risks, has become necessary for meeting strategic objectives and is becoming a fundamental concern of corporate governance.

ISACA (Information Systems Audit and Control Association) has developed COBIT (Control Objectives for Information Technology) as a framework to "help companies implement healthy governance factors," providing a way for organizations to align their business strategy with IT objectives. [1,2]
Over time, the COBIT framework has evolved (several versions are known), and IT specialists have combined this framework with other methods to address specific IT problems.

Research on the use of the COBIT framework is identified from the perspective of axial methodologies combined with other research methods, such as Design Science Research Methodology (DSRM) [3].

There are studies on the integration of the COBIT framework with project management methodologies [4, 5, 6].

The use of the COBIT framework in connection with Sarbanes-Oxley legislation on the security of IT systems in companies is also known [7].

There are approaches to implement sets of good IT management, control, and security practices by unifying the incorporation of ISO 17799, ISO / IEC 38500, Information Technology Infrastructure Library (ITIL), and Capability Maturity Model Integration (CMMI) [8].

The relative importance of different COBIT IT processes in the context of the reliability of corporate financial information has been investigated, which has led to more efficient audits [9].

Based on a literature review on data quality and information integrity, a framework has been created that is considered broader than that provided by COBIT on information integrity [10].

Based on the results obtained in the audit of different systems using the COBIT framework, there are intentions to develop a general theory on internal control applicable to information technology [11].

We have identified studies on the auditing of information systems and regulatory behavior in the field of electricity suppliers [12].

Our research is based on an investigation of a complex IT landscape deployed by a European utilities supplier (electricity and gas) at a time when the company had to undergo an unbundling process [13]. The approach methodology deployed for our investigation used a combination of ISACA and Axiomatic Design [14,15,16] instruments to determine the final state of an IT landscape that would guarantee the most efficient segregation of the IT resources between the unbundled entities.

2. Context of unbundling in the European electricity and gas sector

In the regulation of network industries - such as utilities, e.g., electricity or gas - unbundling refers to the process of separating competitive activities (e.g., energy production and supply) from those in which competition is not feasible or permitted (e.g., transmission and distribution). In the EU, the transport and distribution activities for electricity and gas are delivered by regulated monopolies. To protect the interests of consumers, the EU policies do not permit companies (economic actors) to be engaged simultaneously in both competitive and monopolistic activities.

A company that controls the network and is also involved in the competitive segments of the supply chain has an obvious interest in limiting or denying access to other companies active upstream or downstream. Therefore, EU policies aim to guarantee fair, transparent, and non-discriminatory access to the market for all market players, hence the need for unbundling.

Different degrees of unbundling are possible with varying levels of effectiveness; Figure 1 below is a representation of the various possible degree of activity unbundling.

**Figure 1.** Summary of the different degrees of unbundling [13]
A brief description of each type of unbundling is presented below:

- **Account unbundling** - the firm is required to separate the bookkeeping of its various activities, separating the costs and revenues that derive from each of them.
- **Functional unbundling** - the firm is obliged to reorganize its internal structure and split responsibility for the network and competitive activities into different units with independent decision-making structures.
- **Legal unbundling** - separate legal entities are established, each permitted to operate in only one part of the supply chain.
- **Independent System Operator (ISO)**, not owned by the vertically integrated firm that is tasked with the operation and planning of the infrastructure; however, the ownership of network assets can still remain in the hands of the integrated firm.
- **Ownership unbundling** - a firm owning and operating a network cannot be active in the competitive segment of the supply chain or have interest in any of the companies involved in those activities.

3. Research background

Our research is based on several concepts and tools that are referred to throughout this paper; for the sake of clarity, these concepts are introduced briefly below.

3.1. **COBIT Process Assessment Model (PAM)**

The COBIT Process Assessment Model (PAM) provides a number of governance and management objectives should be achieved to contribute to enterprise goals [1].

The governance and management objectives in COBIT are grouped into five domains. The domains have names with verbs that express the key purpose and areas of activity of the objectives contained in them:

- **Governance objectives** are grouped in one domain: Evaluate, Direct and Monitor (EDM). These governance processes deal with the stakeholder governance objectives - value delivery, risk optimization, and resource optimization - and include practices and activities aimed at evaluating strategic options, providing direction to IT, and monitoring the outcome.
- **Management objectives** grouped in four (4) domains that are in line with the responsibility areas of plan, build, run and monitor (PBRM), and they provide end-to-end coverage of IT. Each domain contains a number of processes.

The domains for management objectives are:

- **Align, Plan and Organize (APO)** - Provides direction to solution delivery (BAI) and service delivery and support (DSS). This domain covers strategy and tactics and concerns identifying the best way IT can contribute to the achievement of the business objectives. The realization of the strategic vision needs to be planned, communicated, and managed from different perspectives. A proper organization, as well as technological infrastructure, should be put in place.
- **Build, Acquire and Implement (BAI)**—Provides the solutions and passes them on to be turned into services. To realize the IT strategy, IT solutions need to be identified, developed, or acquired, as well as implemented and integrated into the business process. Changes in and maintenance of existing systems are also covered by this domain to ensure that the solutions continue to meet business objectives.
- **Deliver, Service, and Support (DSS)**—Receives the solutions and makes them usable for end-users. This domain is concerned with the actual delivery and support of required services, which include service delivery, management of security and continuity, service support for users, and management of data and operational facilities.
- **Monitor, Evaluate and Assess (MEA)**—Monitors all processes to ensure that the direction provided is followed. All IT processes need to be regularly assessed over time for their
quality and compliance with control requirements. This domain addresses performance management, monitoring of internal control, regulatory compliance, and governance.

An image depicting how the five (5) domains are organized in the framework is presented in figure 2 below.

![Figure 2. COBIT PAM Overview [1]](image-url)

Across the five domains (one domain assigned to governance objectives and four domains assigned to management objectives), there are 40 defined IT processes, organized as depicted in figure 2 above. The process assessment model is a two-dimensional model of process capability; the capability dimension provides a measure of a process's capability to meet an enterprise's current or projected business goals for the process. The process capability is expressed in terms of capability levels. The rating scale involves six capability levels:

- **Level 0** Incomplete process - The process is not implemented or fails to achieve its process purpose.
- **Level 1** Performed process - The implemented process achieves its process purpose.
- **Level 2** Managed process - The previously described performed process is now implemented in a managed fashion (planned, monitored, and adjusted), and its work products are appropriately established, controlled, and maintained.
- **Level 3** Established process - The previously described managed process is now implemented using a defined process that is capable of achieving its process outcomes.
- **Level 4** Predictable process - The previously described established process now operates within defined limits to achieve its process outcomes.
- **Level 5** Optimizing process - The previously described predictable process is continuously improved to meet relevant current and projected business goals.
3.2. **COBIT 2019 Design Guide and Toolkit. Design Methodology Foundation**

To satisfy governance and management objectives, each enterprise needs to establish and maintain a governance system built from a number of components.

- Components are factors that, individually and collectively, contribute to the good operations of the enterprise's governance system over Information and Technology (I&T).
- Components interact with each other, resulting in a holistic governance system for I&T.
- Components can be of different types. The most familiar are processes. However, components of a governance system also include organizational structures; policies and procedures; information items; culture and behavior; skills and competencies; and services, infrastructure, and applications.

Design factors are factors that can influence the design of an enterprise's governance system and position it for success in the use of I&T.

The design factors are presented in figure 3 below.

![Figure 3. COBIT Design Factors [2]](image)

The different stages and steps in the design process, as illustrated in figure 4, will result in recommendations for prioritizing governance and management objectives or related governance system components, for target capability levels, or for adopting specific variants of a governance system component.

![Figure 4. Governance System Design Workflow [2]](image)

The application of the governance system design workflow explained in figure 4 is supported by a COBIT Design Guide toolkit.

3.3. **Axiomatic Design Principles**

Axiomatic design [14,15,16] is a design theory and methodology based on the Independence Axiom and the Information Axiom. The methodology contains corollaries and theorems which guide/help designers mapping functional space to physical space (see Figure 5).
According to Axiomatic Design theory [14,15], design involves a continuous interplay between what is wanted to achieve and how it is wanted to achieve it. It must determine the design’s objectives by defining it in terms of specific requirements called functional requirements (FRs). To satisfy functional requirements, a physical embodiment characterized in terms of design parameters (DPs) must be created.

The basic assumption of the Axiomatic Design (AD) approach to design is that there exist two axioms that determine good design practice:

Axiom 1: The Independence Axiom (independence of FRs)
Axiom 2: The information Axiom (minimize the information content of the design)

Independence axiom may be mathematically expressed by the design equation (1):

\[
\{FR\} = \{A\} \times \{DP\}
\]  

(1)

Where:

\{FR\} is the functional requirement vector;

\{DP\} is the design parameters vector;

[A] is the design matrix.

In a particular case, equation (1) can be written in the form shown in equation (2)

\[
\begin{bmatrix}
FR_1 \\
FR_2 \\
FR_3
\end{bmatrix} =
\begin{bmatrix}
A_{11} & A_{12} & A_{13} \\
A_{21} & A_{22} & A_{23} \\
A_{31} & A_{32} & A_{33}
\end{bmatrix}
\times
\begin{bmatrix}
DP_1 \\
DP_2 \\
DP_3
\end{bmatrix}
\]  

(2)

If all of the elements of the design matrix are nonzero, Axiom 1 cannot be respected, and the design is classified as coupled design.

In the case when only the diagonal elements from the design matrix are different from zero (equation 3), the design satisfies Axiom 1, and the design is classified as an uncoupled design.

\[
\begin{bmatrix}
FR_1 \\
FR_2 \\
FR_3
\end{bmatrix} =
\begin{bmatrix}
A_{11} & 0 & 0 \\
0 & A_{22} & 0 \\
0 & 0 & A_{33}
\end{bmatrix}
\times
\begin{bmatrix}
DP_1 \\
DP_2 \\
DP_3
\end{bmatrix}
\]  

(3)

A coupled design can be decupled. A case is presented by equation (4), where the design matrix is a triangular matrix. The independence of FRs can be ensured by adjusting the design parameters in a particular order (DP1 first, DP2 second, and third DP3).
This system is called decoupled design.

The theory makes use of many theorems and corollaries, and in-depth knowledge can be obtained from the books written by the founder of the theory [14,15].

4. Methodology

The research is based on a case study done on an IT landscape of a large utility supplier and distributor of gas and electricity, which had to undergo unbundling to comply with the applicable policies.

The objective of the study was to identify a configuration for sharing the existing IT landscape post unbundling.

The perspective from which the study was made is that of a functional unbundling (see description in Chapter 2).

4.1. Data Collection

To collect the data, a set of investigation activities were undertaken to determine the As-Is configuration of the existing IT landscape, both the software and the hardware perspective. However, for the purpose of this paper, only software-related data is considered. As part of the baseline investigation, all existing applications deployed on the IT landscape were investigated and recorded in a table with the following structure (fields): Application, Description, Vendor, Version, Environment, Operating System, Application License, Interfaces, No of users, Cores, RAM [GB], Storage [GB], Company entities using the application.

The survey revealed that 73 applications were installed; an excerpt from the application inventory table, including the Application and Description fields, is presented in Table 1.

| No. | Application          | Description                                 |
|-----|----------------------|---------------------------------------------|
| 1   | NWM Prod APP         | Prod Application mobile workforce management|
| 2   | Assets management    | Software for assets management              |
| 3   | Facility Management application | Software for facility management       |
| 4   | JANTAR               | Buildings control access application        |
| …   |                      |                                             |
| 71  | UCCX                 | Call center & AR                           |
| 72  | CUCM                 | Call manager                               |
| 73  | TSM                  | Backup and Recovery for Power systems       |

4.2. Data Analysis

The COBIT Process Assessment Model (PAM), described in Section 3.1, was used for data analysis. The IT landscape (the software component) has been evaluated (audited) rigorously, in line with the COBIT Process Assessment Model methodology, following all forty (40) evaluation processes, grouped into six (6) levels of evaluation, and using specific tools to aid the evaluation process.

The results are shown in Table 2, Process Capability Level columns (an excerpt from the evaluation table).
Table 2: Process Capability and Concluded Scope Table (Excerpt)

| Process Name/Design Factors | Process Capability Level | Concluded Scope: Governance/Management Objectives Priority Weight |
|-----------------------------|--------------------------|---------------------------------------------------------------|
|                             |                          | 0 1 2 3 4 5                                                  |
| Evaluate, Direct, and Monitor (EDM) |                          |                                                              |
| EDM01 Ensured Governance Framework Setting and Maintenance | x | 40 |
| EDM02 Ensured Benefits Delivery | x | 30 |
| EDM03 Ensured Risk Optimization | x | 65 |
| EDM04 Ensured Resource Optimization | x | 0 |
| EDM05 Ensured Stakeholder Engagement | x | 20 |
| Align, Plan and Organize (APO) |                          |                                                              |
| APO01 Managed I&T Management Framework | x | 55 |
| APO02 Managed Strategy | x | 10 |
| APO03 Managed Enterprise Architecture | x | 55 |
| APO04 Managed Innovation | x | 60 |
| APO05 Managed Portfolio | x | 10 |
| Deliver, Service, and Support (DSS) |                          |                                                              |
| DSS01 Managed Operations | x | -5 |
| DSS02 Managed Service Requests and Incidents | x | 40 |
| DSS03 Managed Problems | x | 45 |
| DSS04 Managed Continuity | x | 65 |
| DSS05 Managed Security Services | x | 60 |
| DSS06 Managed Business Process Controls | x | 35 |
| Monitor, Evaluate and Assess (MEA) |                          |                                                              |
| MEA01 Managed Performance and Conformance Monitoring | x | 60 |
| MEA02 Managed System of Internal Control | x | 10 |
| MEA03 Managed Compliance with External Requirements | x | 25 |
| MEA04 Managed Assurance | x | 35 |

Having the landscape evaluation completed (Process Capability Level established), the problem of improvement is posed by establishing the scope of the governance system.

COBIT 2019 Design Guide [2] explores design factors that can influence governance and includes a workflow for planning a customized governance system for the enterprise (see figure 3 and figure 4).

The application of the methodology described in paragraph 3.2 leads to obtaining Governance and Management Importance scores (for all Design Factors).

The relative importance (of governance and management objectives) is a score that indicates the influence of a certain design factor on the importance of a certain COBIT governance or management objective as compared to the baseline (standard) situation. The number is calculated as a percentage difference between the baseline and the current situation, as determined by the values given to the design factor at hand [2].

The results obtained are presented in Table 2, column titled "Calculated Scope: Governance / Management Objective Priority Weight."

The first conclusion is that priority (importance) scores of the governance objectives are very diverse.

A further review of the data in Table 2, column Calculated Scope: Governance / Management Objective Priority Weight, reveals that Deliver, Service, and Support (DSS) field has the most significant importance. Considering this field, we have assessed further the way in which the processes from this category (field) are satisfied by the portfolio of applications (Table 1) from the perspective of the functional unbundling process.
5. Axiomatic Design Model Development

The Application Inventory (Table 1) revealed an IT landscape consisting of a very heterogeneous and complex set of interdependent applications used non-uniformly at the various operating locations. From the perspective of functional unbundling (as described in Chapter 2), this heterogeneity is a challenge.

In this context, we consider using Axiom 1, The Independence Axiom, from the Axiomatic Design theory to reorganize and redeploy the applications on various existing platforms with the aim to achieve the functional independence objectives. The Independence of Functional Requirements would permit the function segregation of the IT landscape and enable smooth operations of various other organizational groups of the company after unbundling.

5.1. Identification of functional requirements

Deliver, Service and Support (DSS) processes can be identified as Functional Requirement, as follows:
- DSS01 Manage operations;
- DSS02 Manage service requests and incidents;
- DSS03 Manage problems;
- DSS04 Manage continuity;
- DSS05 Manage security services;
- DSS06 Manage business process controls;

5.2. Identification of design parameters

The applications identified during the system landscaping investigation can be considered Design Parameters, therefore:

- Application 1
- Application 2
- Application 3
- Application 72
- Application 73

Note: Because the research was done for a private company, certain information is bound to remain confidential. Accordingly, in this paper, we use generic names for the applications, Application 1, 2,… However, each of the generic names has a correspondence in the Applications Inventory, Table 1; however, this simplification does not invalidate the content or the approach.

By investigating the way how the applications are assigned to different processes, i.e., the connection between Functional Requirements and Design Parameters, the Design Matrix has been generated – Table 3 below. Each design parameter is a module (application) that is related to a functional requirement (or more) on the corresponding point of hierarchy, so there are more DPs than FRs. It can be noted that the matrix design is coupled.

| Processes / Design Factors | Applications |
|----------------------------|--------------|
| DSS01 Managed Operations   | x            | x |
| DSS02 Managed Service Requests and Incidents | x | x | x |
| DSS03 Managed Problems     | x | x | x |
| DSS04 Managed Continuity   | x | x | x |
| DSS05 Managed Security Services | x | x |
| DSS06 Managed Business Process Controls | x | x | x |
5.3. Identification of design equation

According to Theorem 3 [16], "when there are more DPs than FRs, the design is a redundant design, which can be reduced to an uncoupled design or a decoupled design, or a coupled design."

Theorem 4 [16] states that in an ideal design, the number of DPs is equal to the number of FRs, and the FRs are always maintained independent of each other.

The problem at hand - reconfiguration of the IT landscape to enable an unbundled operation - could be transformed into a model solvable using Axiomatic Design formalism (axioms, corollaries, and theorems).

On the basis of Theorem 4, the first attempt was to decrease the number of design parameters to match the number of Functional Requirements. The result was a deployment of applications portfolio (73 applications) on six (6) platforms; the methodology of assigning the platforms (Design Parameters) to processes (Functional Requirements) is presented in Table 4 below.

**Table 4** Matrix for assigning platforms to processes.

| Processes / Design Factors | Platforms |
|----------------------------|-----------|
| Deliver, Service, and Support (DSS) | A | B | C | D | E | F |
| DSS01 Managed Operations | x |   |   |   |   |   |
| DSS02 Managed Service Requests and Incidents |   | x |   |   |   |   |
| DSS03 Managed Problems |   | x |   |   |   |   |
| DSS04 Managed Continuity |   |   |   |   | x |   |
| DSS05 Managed Security Services |   |   |   | x |   |   |
| DSS06 Managed Business Process Controls | x |   |   |   |   |   |

**Note:** The meaning of the platform here is that of a group of applications and technologies that have been used to meet the functional needs of a process. In the sense of Axiomatic Design, the notion of Platform has the meaning of a Parameter Design.

Considering the configuration presented in Table 4 above, the design equation can be written:

\[
\begin{bmatrix}
DSS01 \\
DSS02 \\
DSS03 \\
DSS04 \\
DSS05 \\
DSS06
\end{bmatrix}=egin{bmatrix}
A_{11} & 0 & 0 & 0 & 0 & 0 \\
0 & A_{22} & 0 & 0 & 0 & 0 \\
0 & 0 & A_{33} & 0 & 0 & 0 \\
0 & 0 & 0 & A_{44} & 0 & 0 \\
0 & 0 & 0 & 0 & A_{55} & 0 \\
0 & 0 & 0 & 0 & 0 & A_{66}
\end{bmatrix}
\begin{bmatrix}
\text{PlatformA} \\
\text{PlatformB} \\
\text{PlatformC} \\
\text{PlatformD} \\
\text{PlatformE} \\
\text{PlatformF}
\end{bmatrix}\]

(5)

Under these conditions, the independence of Functional Requirements (Axiom 1) is respected, and consequently, it can be concluded that a configuration solution for the IT landscape to support company's operation in an unbundled (Chapter 2) state can be achieved through reconfiguration of existing assets (software and hardware).

6. Conclusions

ISACA (Information Systems Audit and Control Association) has developed COBIT (Control Objectives for Information Technology) as a framework to "help companies implement healthy governance factors," providing a way for organizations to align their business strategy with IT objectives.

Often, however, problems in IT landscapes require extensive approaches using complementary tools, and the literature presents such situations.

This paper, too, demonstrates that the formalism (principles and tools) developed under COBIT Design Framework and Axiomatic Design theory could be deployed complementarily to arrive at a practical solution for a real-life project. After performing the system audit and redesigning it considering the Governance of IT enterprises (GEIT) perspective, Axiomatic Design principles have been applied to
derive an acceptable configuration of the IT landscape (software component) of a utility firm, helping it to comply with the applicable market's regulations.

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