Mapping COBIT 5 and ITIL using Semantic Analysis

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Abstract

Enterprise Governance of Information Technology (EGIT) is defined as a means to achieve business/ Information Technology (IT) alignment. Organizations can benefit from this alignment by implementing and assessing new or improved processes defined by EGIT frameworks to become more competitive and produce high-quality services. Researchers agree that Control Objectives for Information and Related Technology (COBIT) and IT Infrastructure Library (ITIL) are among the most valuable and popular practices currently being adopted and adapted by organizations. COBIT and ITIL can be seen as Process Reference Models (PRMs) in which organizations can base their processes. PRMs are always related to Process Assessment Models (PAMs) which holds all details to determine the capability of the processes of the reference model. COBIT supports the alignment of IT with Enterprise Governance while ITIL provides detailed guidance on the management of IT processes, functions, roles, and responsibilities related to IT service management. However, organizations are still struggling with their assessment, and so, they cannot get full advantage of their use. In multi-framework environments, this situation is even higher since each framework defines its scope, structure, definitions, and terminology. To overcome this issue, this research intends to shed some light in this area by proposing an ontological approach for describing TIPA for ITIL PAM and COBIT PAM, using semantic similarity techniques to compare COBIT and ITIL process assessment core concepts. The primary goal of this research is to facilitate a simultaneous assessment of COBIT and ITIL.

Keywords

AgreementMakerLight; COBIT 5 PAM; METHONTOLOGY; Ontologies; Semantic Analysis; TIPA for ITIL;

ITIL;

Resumo

A *Enterprise Governance of IT* (EGIT) é definida como um meio para alinhar o negócio e as Tecnologias de Informação (TI). As organizações podem beneficiar deste alinhamento ao implementar e avaliar novos processos ou melhorar os existentes definidos pelas frameworks de EGIT de forma a tornarem-se mais competitivos e produzir serviços de alta qualidade. Investigadores concordam que o COBIT e o ITIL estão entre as mais importantes e populares frameworks actualmente adoptadas e adaptadas pelas organizações. COBIT e ITIL podem ser vistos como *Process Reference Models* (PRMs) nos quais as organizações podem basear os seus próprios processos. PRMs são sempre relacionados com *Process Assessment Models* (PAMs) que contém todos os detalhes para determinar a capacidade dos processos do modelo de referência. O COBIT suporta o alinhamento das TI com EGIT enquanto o ITIL fornece orientação detalhada sobre a gestão de processos, funções e responsabilidades relacionados a gestão de serviços de TI. No entanto, as organizações têm ainda dificuldades com a sua avaliação e não conseguem obter as vantagens totais do seu uso. Em ambientes multi-framework, esta situação é ainda mais problemática, pois cada framework define o seu âmbito, a sua estrutura, as suas definições e a sua terminologia. Para superar esta questão, esta pesquisa pretende trazer alguma luz a esta área, através de uma abordagem ontológica ao TIPA para ITIL PAM e ao COBIT PAM, usando técnicas de similaridade semântica para comparar conceitos básicos de avaliação de processos COBIT e ITIL. O principal objetivo desta pesquisa é facilitar a avaliação simultânea do COBIT e do ITIL.

Palavras Chave

AgreementMakerLight; COBIT 5 PAM; METHONTOLOGY; Ontologias; Análise Semântica; TIPA for ITIL;

Contents

List of Figures

List of Tables

Acronyms

IT Information Technology

EGIT Enterprise Governance of Information Technology

COBIT Control Objectives for Information and Related Technology

ITIL IT Infrastructure Library

DSRM Design Science Research Methodology

OWL Web Ontology Language

QUDT Quantity, Unit, Dimension and Type

CI Configuration Items

KB Knowledge Base

ITSM IT Service Management

EA Enterprise Architecture

IT Information Technology

PRM Process Reference Model

PAM Process Assessment Model

DSS Deliver, Service and Support

SO Service Operation

AML AgreementMakerLight

ISMS Information Security Management System

ROA Return on Assets

1

Introduction

Contents

1.1 Motivation

In today's complex and competitive business environment, organizations need to react quickly and with the required flexibility to ensure the achievement of business goals and objectives [5] and so, they are heavily dependent on IT. To fully benefit from the advantages of IT processes, a variety of standards and frameworks are used as a reference to improve and to provide effective support for business/IT alignment. Studies prove that organizations with a proper EGIT have 20 percent higher Return on Assets (ROA) than organizations with weaker governance [6].

EGIT can be defined as ”an integral part of corporate governance that addresses the definition and implementation of processes, structures and relational mechanisms in the organization that enable both business and IT people to execute their responsibilities in support of business/IT alignment and the creation of business value from IT-enabled business investments” [7].

EGIT [8] that can be deployed using a mixture processes, structures and relational mechanisms that enable both business and IT people to execute their responsibilities, through the alignment of business with IT with the ambition of creating value from IT-enabled business investments. Some of these mechanisms are available to provide guidelines in multiple dimensions of IT organizations, e.g., Information Security Management System (ISMS) and Information Technology Governance Processes. Others are widely used in the industry to improve the competitiveness of organizations or are required as mandatory standards, becoming a regulatory framework in specific market niches [9].

COBIT and ITIL are currently some of the most valuable and popular EGIT frameworks adopted and adapted by organizations [10] [11] [12]. They are intended to facilitate effective EGIT [13] by providing a set of best practices that are often implemented according to the organization's needs. These frameworks, often classified as complementary [14], attempt to give a holistic representation of all the processes and tasks of an organization. COBIT seeks to provide a holistic approach to the alignment of IT with Enterprise Governance to create value and generate benefits with optimal risk and resources [15]. In turn, ITIL, can be seen as a PRM that provides descriptive guidance on the management of IT processes, functions, roles, and responsibilities related to IT Service Management (ITSM) [16].

For COBIT and ITIL, as PRMs, process management requires each process to be controlled to remain compliant with the objectives of both IT and business [17]. Therefore, PRMs are always related to a PAM which holds all details to determine the capability of the processes of the reference model.

A process assessment is conducted to get a clear view of the current practices in an organization in a particular domain. The goal is to compare these practices to a renowned reference so that the current status of the processes can be measured and appropriate suggestions for process improvement can be made.

COBIT 5 PAM is a model that aims at assessing the capability of a COBIT 5 process. It scales six process capability levels defined on an ordinal scale, which starts from incomplete to optimizing processes. In turn, TIPA for ITIL is a standards-based approach to ITIL (v2, v3 and v3 2011) assessment that can address challenges (posed by improving the quality of product manufacture or IT processes) in several important ways by providing a repeatable, consistent method for conducting process assessment [1].

TIPA for ITIL PAM and COBIT PAM are based on ISO/IEC 15504 (ISO/IEC 15504-1, 2004; ISO/IEC 15504-2, 2003). It means that they both rely on the same foundation (ISO/IEC 15504) , which is a global reference for conducting process capability assessments. From an assessment perspective, both TIPA for ITIL and COBIT 5 PAM break down each process into Base Practices specific to each process and take into account generic practices, which are not restricted to any particular process.

From an assessment perspective, both TIPA for ITIL and COBIT 5 PAM break down each process into Base Practices specific to each process and take into account generic practices, which are not restricted to any particular process. Process assessment is also based on the fact that the rating is not binary, i.e., either OK or not OK. Instead, each item is rated using a 4-point rating scale: "Not", "Partially", "Largely" and "Fully" [1] as shown on Fig. 1.1.

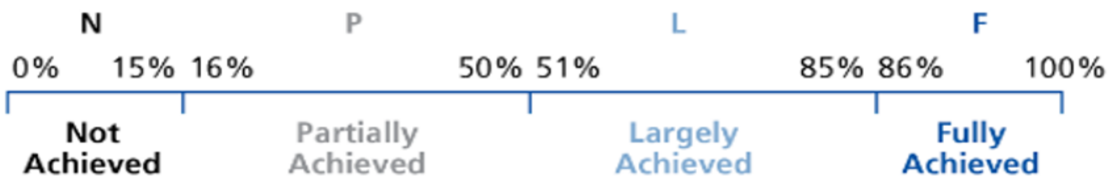

Figure 1.1: Process Assessment rating scale. [1]

The increasing demands of the different industries coupled with compliance requirements, have forced organizations to adopt multiple EGIT Frameworks [18] which add even more complexity to the field, since organizations struggle with the perceived complexity and difficulty of understanding and adopting several frameworks at the same time [19] because each practice defines its own scope, definitions, and terminologies. At a time when organizations strive to be efficient and effective, it seems counterintuitive to be wasting resources by having different organizational departments handling both approaches independently [20].

There is a need to integrate EGIT frameworks to align and support the enterprise in a balanced way [21]. Each framework has its limitations and since frameworks often overlap it is important to use them as a whole to assert full IT management and governance [22]. There is a set of challenges allied to the integration of frameworks [18], but through this mechanism, it is possible to achieve a greater understanding on EGIT and to foster the development of features that would not be possible when using frameworks individually [22] [23] [24].

There is still a gap in literature regarding semantic systems that support EGIT practices [25]. An ontological approach to the integration of COBIT and ITIL would allow the establishment of a Knowledge

Base (KB) and the validation of the already proposed mapping by ISACA [26] and Glenfis [27].

The unification of terms and concepts into an ontology to allow knowledge sharing and clarifying the structure of knowledge through ontological analysis is defended by Chandrasekaran [28].

Ontologies are disseminating in Computer Science [29] [30], and its importance is being recognized specially in information modeling [31] [32] and information integration [33] [34].

Gruber [35] defines an ontology as a ”specification of a conceptualization”, in which vocabulary can only be created to represent knowledge if ontologies or conceptualizations provide a formal representation [36].

According to Textor et al. [37], ontology-based models satisfy the requirements of the need for formal meta-models flexible and expressive enough to allow both technical and non-technical domains to be modeled separately and connect the concepts of different models. In short, it is possible to say that an ontology describes a hierarchy of concepts related by subsumption relationships [29] and are meant to clarify the structure of knowledge of a domain [28], and formally represent all the knowledge of that domain [36].

Therefore, the primary objective of this research is to perform an integration, based on a semantic evaluation, of COBIT and ITIL process assessment core concepts (base practices, inputs/outputs, outcomes and expected results) in order to evidence the overlapping between them and facilitate in this way the simultaneous assessment of these frameworks.

To achieve this goal, this research proposes an ontological approach for describing the PAMs of the TIPA for ITIL and COBIT PAM and also use semantic similarity techniques to compare COBIT and ITIL process assessment core concepts.

1.2 Research Methodology

This research follows the Design Science Research Methodology (DSRM) that aims to produce an artifact relevant to the solution of a problem to address [38]. This artifact must be evaluated regarding its utility, quality and efficacy and should be developed through a search process that is based on already existing knowledge and theories [38]. In Fig. 1.2 is represented the Process Model for DSRM, that shows the series of activities performed during the various process iterations.

This methodology starts by defining the problem and justify the value of a solution to motivate the researcher and the researcher's audience and determine the state of the knowledge about the problem [2].

Once the problem is defined, it is necessary to deduce the desirable solution's objectives through inference.

To create an artifact, whether it is a model, a construction, a method or an instance [38], there is an

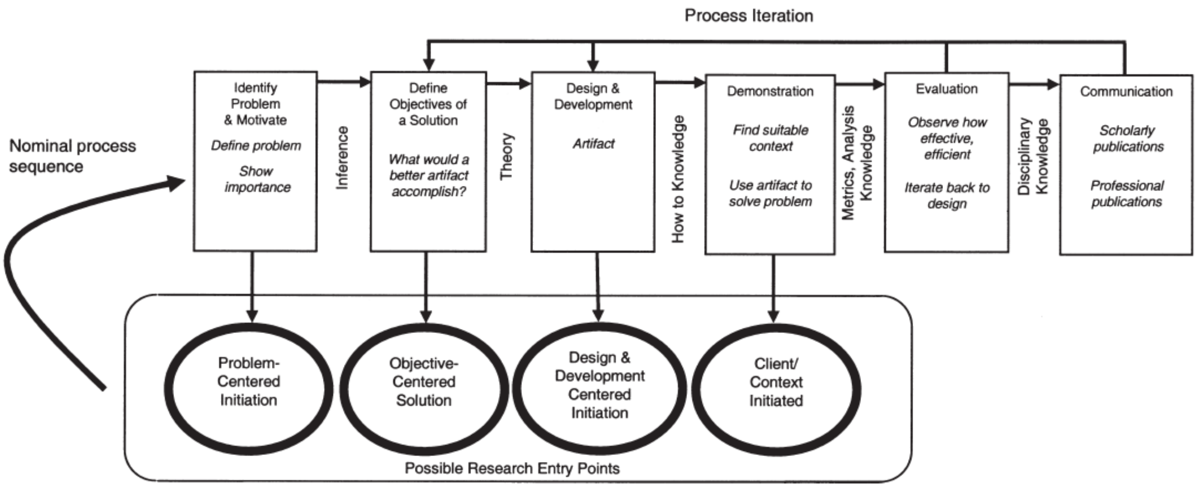

Figure 1.2: DSRM Process Model [2]

assumption that the designed object is a representation of the research.

On the final activity of DSRM the use of the artifact is demonstrated, to show how it solves the problem, is evaluated, to assess the backing of the problem by the solution and is communicated, so relevant audiences can discuss it and review it [2].

The following items represent our research according to the six phases in the DSRM [2] and are developed throughout the Chapters of this document.

1. **Problem identification and motivation**

   Many organizations use multiple EGIT frameworks to achieve balance in the enterprise, but face difficulties in relation to complexity and how to properly implement them.

2. **Define the objectives for a solution**

   Remove the terminology conflicts between COBIT 5 PAM and TIPA for ITIL in order to facilitate the integration and show the degree of overlap between these EGIT frameworks.

3. **Design and development**

   The main artifact developed by this research is a quantitative analysis of the overlap between COBIT 5 and ITIL by measuring the similarity values of their main concepts in order to map them.

   To achieve this artifact it is necessary to firstly produce two other artifacts: A ITIL Ontology and a COBIT Ontology. This will clarify the structure of knowledge between these frameworks and underpin how the semantic analysis is going to be performed.

   Therefore it will be necessary to do two DSRM iterations during this research.

4. **Demonstration**

   On the first DSRM iteration the proposed TIPA for ITIL Ontology is demonstrated by assessing the ITIL Incident Management process in a Portuguese hospital. Since COBIT 5 PAM ontology shares the same ontological structure and concepts, we can by inference say that by demonstrating the suitability of the TIPA for ITIL Ontology we are demonstrating the suitability of both.

   For the second iteration of DSRM we present demonstrate the similarity values by presenting the top of comparisons between the ITIL Service Operation (SO) Life cycle Stage and COBIT 5 Deliver, Service and Support (DSS) Domain Processes main concepts.

5. **Evaluation**

   For the first DSRM iteration the proposed ontologies are evaluated through a technical and a user judgment. The evaluation of the artifacts developed in the second iteration of DSRM are done with an analysis of the similarity values.

   Lastly, an evaluation using the Österle Principles [39] will cover both iterations.

6. **Communication**

   This research published a paper entitled *"Towards Conceptual Metamodeling of ITIL and COBIT"*, to the 14th European Mediterranean & Middle Eastern Conference on Information Systems (EMCIS 2017) and submitted two papers, one entitled "An Ontology-based model for ITIL Process Assessment using TIPA for ITIL" to the 27th International Conference on Information Systems Development (ISD2018) and the other entitled "Integrating COBIT 5 PAM and TIPA for ITIL Using an Ontology Matching System" to the 10th International Conference on Formal Ontology in Information Systems (FOIS2018).

1.3 Outline

This document outline is shaped by the methodology used to carry out this research, DSRM, dedicating a chapter for each of its iterations.

The problem that this research addresses is presented on Chapter 2. On Chapter 3 is given a theoretical background of the topics to approach during this research and overviews the state of the art regarding on how COBIT and ITIL are being integrated in literature.

In Chapters 4 and 5 each of the DSRM iterations are presented with the description of the proposed artifacts, their design and development, its demonstration and evaluation.

Finally, in Chapter 6 the main conclusions, limitations, communication and future directions are presented.

2

Research Problem

Currently, different frameworks, industry-specific standards, and methodologies of quality can be taken as references for the improvement of an organization's processes [9].

This situation allows organizations to select and complement their processes from the frameworks that better fits their context [9]. However, independently of the EGIT Framework to be used, its implementation requires specific experience, knowledge and a high degree of effort and investment, as key factors for the implementation to be successful. Therefore, the task is not easy, and there is a significant risk of failure [40].

Moreover, considering the overlaps that exist between these EGIT frameworks, their independent adoption prevents organizations from asserting full IT management and governance because each one has limitations in its application to the management of specific IT areas [22].

According to Othman et al. [13] and Othman and Chan [41], the adoption of EGIT Frameworks includes different inhibitors such as: the lack of top management support, communication, slack resources, formalization and regulatory environment; the compatibility with existing practices; and the complexity of understanding and using these frameworks and politics. Goeken and Alter [42] also pointed out that this kind of EGIT Frameworks lacks a theoretical foundation from a scientific viewpoint.

Furthermore, the increasing demands of the different industries coupled with compliance requirements, have forced organizations to adopt multiple EGIT Frameworks [18] which add even more complexity to the field, since organizations struggle with the perceived complexity and difficulty of understanding and adopting several frameworks at the same time [19], because each practice defines its scope, definitions, and terminologies [43].

Wasting resources by having different departments handling different EGIT practices independently is counterintuitive since organizations seek efficiency and effectiveness [44]. Choosing how to integrate practices is a major challenge when integrating EGIT in organizations [18], Gehrmann [22] defends that EGIT must comprise a combination of two sets of frameworks. There are many benefits resulting from the integration of EGIT practices. The primary one is the enabling of features that would be unavailable through the use of practices individually, leading to a more comprehensive and efficient approach on EGIT [23] [22] [24]. Challenges arise when integrating COBIT 5 and ITIL [18]. Othman et al. [13] report the following difficulties on the context of framework integration:

- Different languages
- Semantics of each Framework in same pace are different
- Balance between EGIT framework integration and corresponding expense
- Treated as technical guidance
- Requires much work and experience

- No single guideline because each case is different

Due to the lack of formal consensus on the terminology used, inconsistencies and conflicts arise when an organization decides to adopt and assess multiple frameworks making it difficult to understand the main concepts involved [19] [45].

Humans do not judge text relatedness merely at the level of text words. Words trigger reasoning at a much deeper level that manipulates concepts—the basic units of meaning that serve humans to organize and share their knowledge. Thus, humans interpret the specific wording of a document in the much larger context of their background knowledge and experience [46].

A fundamental operation performed while handling ontologies is the ”Mapping” operation which interprets a set of correspondences between similar concepts through two (or more) ontologies of the same application domain or similar domains. Alignment process takes two input ontologies and produces a set of relationships between concepts that match semantically with each other. Ontologically speaking, there are three main forms of linguistic mismatches between ontologies, namely the syntactic, semantic and lexical mismatches [47].

To sum up, the problem that this paper intends to help solve is:

- The terminological disparities between ITIL V3 2011 and COBIT 5 makes best professional judgment the only approach currently available to integrate these EGIT practices;
- The measureless degree of overlapping prevents organizations to assess COBIT 5 and ITIL simultaneously.

Consequently, it is important for organizations to have a proposal that assists them in integrating multiple models, identifying and resolving their differences and similarities. When this occurs, an integrated solution is obtained, which takes advantage of the qualities of each model and maximizes them. This situation should make a positive impact on the entire organization, mainly on the interoperability of the process assessments defined from multiple models, and on the cost and effort used to assess similar frameworks.

3

Related Work

Contents

This chapter presents the literature related to this proposal. In Section 3.1 an overview of the concepts related to EGIT are presented with focus on the frameworks addressed in this research and their integration. Section is focused on the engineering behind the creation of ontologies through an analysis of the various methodologies, languages and tools used during this process.

We have also identified some efforts to define formal ontologies for ITIL and COBIT 5, which are also analyzed in this chapter.

3.1 Enterprise Governance of IT

EGIT as defined by Van Grembergen et al. [48] addresses the definition and implementation of processes, structures and relational mechanisms that enable both business and IT people to execute their responsibilities, enabling the alignment of business with IT with the ambition of creating value from IT-enabled business investments.

A series of practices like, frameworks as COBIT and ITIL are promoted as practice-oriented guidance for implementing EGIT but there is a lack of empirical support of academic research that EGIT practices improve business performance [49].

Measurement models have been proposed to measure the alignment between IT and business, but there is no universal way to clearly assess [50] the fit and integration between business strategy [51].

3.1.1 COBIT 5

According to ISACA [15], COBIT 5 provides a comprehensive practice that assists enterprises in achieving their objectives for the governance and management of enterprise IT. Simply stated, it helps enterprises create optimal value from IT by maintaining a balance between realizing benefits and optimizing risk levels and resource use.

COBIT 5 advocates that enterprises exist to create value for their stakeholders and such value creation should be attained through benefits realization at an optimal resource cost while optimizing risk. Stakeholder needs have to be transformed into an enterprise's actionable strategy. The COBIT 5 Goals Cascade is the mechanism to translate stakeholder needs into specific, actionable and customized enterprise goals, IT-related goals and enabler goals [15]. This translation allows practitioners to set specific goals at every level and area of the enterprise in support of the overall goals and stakeholder requirements, and thus effectively supports alignment between enterprise needs and IT solutions. COBIT 5 defines 17 generic goals and IT-related goals. The mapping between IT-related goals and enterprise goals shows how IT-related goals support enterprise goals.

Achieving IT-related goals requires the successful application and use of some enablers that include processes, organizational structures, and information - and then, for each enabler, a set of specific relevant goals can be defined in support of the IT-related goals. Processes are one of the enablers, and ISACA [15] provides a mapping between IT-related goals and the relevant COBIT 5 processes, which then contain related process goals.

Different meta-models for COBIT have already been proposed by [42] [37] [52]. Textor and Gheis [37] proposed an ontological meta-model, represented using Web Ontology Language (OWL), for the calculation of metric values at runtime using data from existing systems with the goal of making better informed dynamic management decisions based on the estimated values. To formalize the metrics is used the Quantity, Unit, Dimension and Type (QUDT) ontology that further details each metric. This ontology contains approximately 30 classes, 40 object properties, 2500 individuals and 21,400 axioms.

Goeken and Alter [42] and Souza Neto et al. [52] formalized COBIT 4.1 through a conceptual meta-model provided solely in human-readable format, an entity-relationship model.

3.1.2 ITIL

ITIL is a set of comprehensive publications providing detailed guidance on the management of IT processes, functions, roles, and responsibilities related to IT service management [16].

ITIL has evolved since its first version based on the recommendations from experienced IT professionals and academic researchers who are always thriving to improve and standardize the IT processes worldwide [53]. Now, instead of focusing on the service itself, the focus lay on this cycle of life, renewal and decommissioning of services, with a higher business-focused perspective [54].

ITIL benefits have been addressed from a few relevant academic researchers, that frequently evidenced the following benefits: improvement of Service Quality, improvement of Customer Satisfaction, improvement of Return on Investment [55], [56].

However, according to Strahonja [57], ITIL has also some weaknesses such as the lack of holistic visibility and traceability from the theory (specifications, glossary, guidelines, manuals, amongst others) to its implementations and software applications; its focus on the logical level of processes, instructing what should be done but not how; and its poorly definition of the information models corresponding to process description.

In the literature, several ontologies were proposed for describing ITIL. An ontology-based model for ITIL has been proposed by dos Santos et al. [25] with the goal of describing Configuration Items (CI) (software modules, hardware components, or staff members) and the processes dependent on them by creating a KB describing processes, CIs, and their relationship.

Valiente et al. [58] proposed Onto-ITIL, an ontology based on the ITIL V3 Service Management Model that aims to achieve formalization of ITSM domain. Onto-ITIL provides a mechanism for managing interoperability, consistency checking and decision making, and can be used as a knowledge base for ITIL based process implementations, allowing IT service providers to add semantics and constraints to the data associated with the different ITIL-based processes that underpin a business, so that they can share and reuse information in a homogeneous way [58]. This ontology is defined in OWL DL, and its architecture is based on ITIL service lifecycle.

3.1.3 Use of Multi-Frameworks

Organizations are implementing several frameworks simultaneously, this adoption is for IT Managers a matter of legal compliance and for others a risk management strategy, a cost saving measure or a mean to satisfy customers more effectively [23]. Frameworks often overlap because they share the same application area [22] and cannot be perceived as mutually exclusive, when combined provide powerful IT governance [23].

When using multiple frameworks, an organization faces a number of challenges because the scope of different frameworks is likely to differ, interpreting the framework with the broader scope from the perspective of the framework with the narrow scope is usually appropriate [59].

Users need more guidance on how to integrate the leading global frameworks and other practices and standards to realize value from IT investments and services [60].

3.1.4 Integrating COBIT 5 and ITIL

A COBIT-ITIL Mapping ontology based on the mapping proposed by Glenfis [27] was referenced by Textor et al. [37] to explicit services on the proposal for a COBIT meta-model.

Cater-Steel and Toleman [23] promote this integration by stating that although ITIL provides good documentation of IT process flows and interactions, it is not a complete approach because of its absence of a measurement system for process improvement. With this in mind, organizations are urged to use COBIT to put their ITIL program in the context of a wider governance and control framework [23].

The research carried out by Sahibudin et al. [61] states that ITIL corresponds to COBIT in a high degree when ITIL is benchmarked.

Most of the proposals found in literature refer to the integration of COBIT 4 with ITIL, it is important to realize that since there was a version upgrade to COBIT this integration is out of date because new artifacts were introduced in COBIT 5.

3.1.5 Process Assessment Models

A process assessment is conducted to get a clear view of the current practices in an organization in a particular domain. The goal is to compare these practices to a renowned reference so that the current status of the processes can be measured and appropriate suggestions for process improvement can be made.

COBIT 5 PAM is a model that aims at assessing the capability of a COBIT 5 process. It scales six process capability levels defined on an ordinal scale, which starts from incomplete to optimizing processes. Process maturity has been a core component of COBIT for more than a decade.

Determining the level of process capability for a given set of IT-related processes allows organizations to determine which processes are essentially under control and which represent potential "pain points". The concept of process maturity in earlier versions of COBIT was adopted and adapted from the Software Engineering Institute's Capability Maturity Model. In COBIT 5, process maturity has been replaced by the concept of process capability.

TIPA is the result of more than ten years of research work, including experimentation on how to combine ITIL with the ISO/IEC 15504 [62]. TIPA uses the generic approach for process assessment published by the ISO in ISO/IEC 15504-2 – Process Assessment (now ISO/IEC 33000) (ISO/IEC 15504-1/2, ISO/IEC 33000). TIPA is a standards-based approach to ITIL (v2, v3 and v3 2011) assessment that can address challenges (posed by improving the quality of product manufacture or IT processes) in several important ways by providing a repeatable, consistent method for conducting process assessment [1].

TIPA for ITIL PAM and COBIT PAM are based on ISO/IEC 15504 (ISO/IEC 15504-1, 2004; ISO/IEC 15504-2, 2003). It means that they both rely on the same foundation (ISO/IEC 15504), which is a global reference for conducting process capability assessments.

From an assessment perspective, both TIPA for ITIL and COBIT 5 PAM break down each process into Base Practices specific to each process and take into account generic practices, which are not restricted to any particular process. Process assessment is also based on the fact that the rating is not binary, i.e., either OK or not OK. Instead, each item is rated using uses a 4-point rating scale: "Not", "Partially", "Largely" and "Fully" [1].

COBIT 5 PAM Base Practices are specific to COBIT processes and ensure proper governance and management of Enterprise IT while TIPA for ITIL Base Practices are specific to ITIL and guarantee the proper execution of the process to support the service delivery in line with customer needs.

3.1.6 ArchiMate

ArchiMate [63] is a graphical modeling language used to describe enterprise architectures that aims to provide well-defined relationships between concepts in different architectures [64]. ArchiMate provides a set of concepts and relationships to model its three main layers of "Service orientation", the Business Layer, the Application Layer and the Technology Layer. These layers expose functionality in the form of a service to the above layer [64] [63].

The Business Layer is typically used to model the business architecture of an enterprise, as a description of the structure and interaction between the business strategy, organization, functions, business processes, and information needs [65]. The Application Layer models information systems architectures of the enterprise, including the application architecture, that describes the structure and interaction of the applications [65]. The Technology Layer is used to model the technology architecture of the enterprise, defined as the structure and interaction of the platform services, and logical and physical technology components by The Open Group [66].

Stakeholders can address more specific domains using the motivation extension and the Implementation and Migration Extension. Motivation elements are used to model motivations, or reasons, that guide the design or change of an Enterprise Architecture (EA) [65]. The Implementation and Migration Extension adds concepts to support activities like project management.

3.2 Ontology Engineering

Ontologies are disseminating in Computer Science [29] [30], and its importance is being recognized specially in information modeling [31] [32] and information integration [33] [34] [67].

An ontology denotes a system of categories accounted for a particular vision of the world if it is perceived in a philosophical sense [29], and so, it defines a common vocabulary for researchers who need to share information in a domain [28]. It includes machine-interpretable definitions of basic concepts in a specific domain and the relations among them [35] [58]. Additionally, they can provide semantic context by adding semantic information to models [58].

In that way, Gruber [35] defines an ontology as a ”specification of a conceptualization”, in which vocabulary can only be created to represent knowledge if ontologies or conceptualizations provide a formal representation [36].

A conceptualization is an abstract model of the objects, concepts and entities that exist in an area of interest and the relationships that hold among them. A vocabulary can only be created to represent knowledge if ontologies or conceptualizations provide a formal representation [36].

According to Textor et al. [37], ontology-based models satisfy the requirements of the need for formal meta-models flexible and expressive enough to allow both technical and non-technical domains to be modeled separately and connect the concepts of different models. In short, it is possible to say that an ontology describes a hierarchy of concepts related by subsumption relationships [29] and ontologies are meant to clarify the structure of knowledge of a domain [28], and formally represent all the knowledge of that domain [36].

Ontologies are evaluated through verification and validation, where the correct process of ontology building and the representation of the domain of disclosure are assessed [68] [69].

3.2.1 Methodologies and Methods for Ontology Building

For the development of ontologies from scratch, several authors provide a set of methods and methodologies which aim to facilitate this development. In this section, several approaches are presented according to the information collected from Goméz-Péres et al. [3]. The methods and methodologies are listed in the same way they are presented in [3]. According to IEEE [70] a methodology is a "comprehensive, integrated series of techniques and methods creating a general systems theory of how a class of thought-intensive work ought be performed" and a method is part of a methodology being also defined by IEEE [70] as a set of "orderly process or procedure used in the engineering of a product or performing a service".

Cyc Method

The Cyc method developed by Lenat and Guha [71] aims to form a knowledge base based on common sense knowledge using the CycL language. Cyc can be employed as a substrate for building different communicative and interacting intelligent systems and therefore it can be considered an ontology. Based on three processes, Cyc starts by extracting common sense knowledge manually (Process I), then coding the previously gathered knowledge with the help of computational tools (Process II) and lastly the extraction of common sense knowledge only performed by tools (Process III). Through all this process a top-level ontology and a knowledge representation of the most abstract concepts are developed. Also, a representation of the knowledge from different domains is developed in this method.

Uschold and King's method [72]

This was the first proposed method for ontology development and consists of four primary processes: Identifying the ontology purpose; Building the ontology; Evaluating the ontology and Document the ontology.

Building the ontology comprises ontology capturing, where the key concepts and the domain of interest are identified and described through textual definitions as well as the terms referring to them. The terms are identified by one of three strategies: bottom-up, top-down and middle-out.

The bottom-up strategy results in a higher level of detail once the most specific concepts are first identified and then generalized to more abstract concepts. This approach bears some disadvantages such as the increase of the overall effort, the difficulty of recognizing commonalities between related concepts, the increase of the risk of inconsistencies and the probability of the need of re-working leading to more effort.

The top-down approach starts by identifying the more abstract concepts and then specialize them into more specific concepts allowing the control of the level of detail, but this approach can result in high-level categories that are not needed, giving the model less stability and causing rework.

The middle-out strategy goes through the identification firstly of the core basic terms and then specifying and generalizing them as required, allowing balance in the level of detail. The second activity of ontology building is coding, where the terms used to define the ontology and the code are written. Finally, when building the ontology alongside with the previous activities, the ontology being built can be integrated with existing ontologies.

The evaluation process of the Uschold and King's method is based on technical judgment, requirement specification, competency questions and the real world. The final process, to document the ontology, is based on established guidelines.

This methodology presents a primary disadvantage, the lack of conceptualization process before implementing the ontology. This drawback inhibits the domain model from being less formal than the implementation model and more formal than the definition of the model in natural language, causes difficulties understanding ontologies implemented in ontology languages and prevents domain experts from building ontologies on their domain of expertise [73].

Grüninger and Fox's methodology [74]

This methodology for building and evaluating ontologies is inspired by the development of knowledge-based systems with the use of first-order logic. It comprises six processes.

On the first process, the motivation and scenario for the ontology development are defined, this also provides requirements to be satisfied to be hereafter fulfilled. The second process consists in the elaboration of a set of competency questions written in the natural language to be answered by the developed ontology, and thereby evaluate the ontology.

To build the ontology in first-order logic is the third process of this methodology. For this, it is necessary to specify the terminology that it is going be used. This terminology can be extracted from the informal competency questions developed in the previous process, in the shape of concepts, attributes, and relations. In the fourth process, the competency questions defined in process two are re-written in precise terminology.

The fifth process specifies axioms using first-order logic to establish definitions for the terms in the ontology. Finally, the last process is about specifying theorems for completeness of the ontology where the competency questions should be thoroughly answered.

KACTUS approach [75]

The KACTUS approach focuses on the construction of ontologies that represent the knowledge required for an application. This method comprises three processes: The first, specification of the application tries to describe a context and the components of the application to be modeled, providing a list of terms and tasks.

On the second process, preliminary design based on top-level ontological categories, views of the model composed of top-level ontological categories, such as concept, relation, attributes are obtained concerning the terms and tasks gathered in the previous process. Involved in this process is the search of already developed ontologies for extension or reuse in the development of the new ontology.

Finally, the last process, Ontology Refinement and Structuring, aspires to achieve a specific design.

METHONTOLOGY

This methodology, developed by Férnandéz-Lopez et al. [76], aspires to produce ontologies at the knowledge level. The ontology building process respects an ontology life cycle based on evolving prototypes. For each ontology's prototype developed, the first activity executed is the schedule activity where all the tasks to be performed are identified, arranged and a survey of the needed resources is done. During the ontology's life cycle three different types of activities are performed in parallel carrying an intra-dependency relationship, as portrayed in Fig. 3.1: the management activities, the development activities, and the support activities.

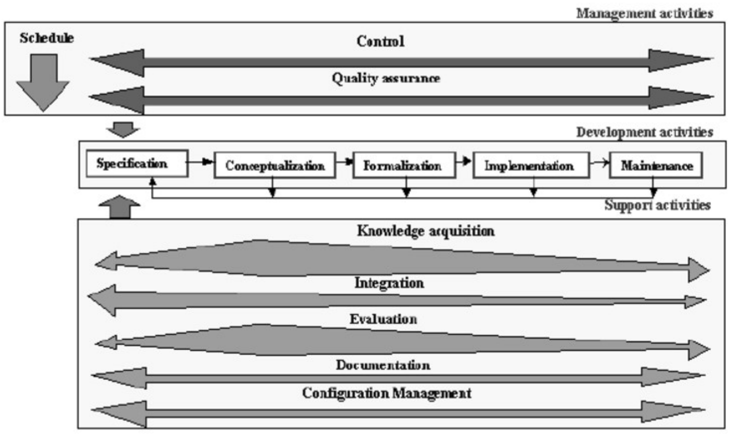

Figure 3.1: METHONTOLOGY Lifecycle

In the management activities, the control activity guarantees that the tasks to be performed meet the performance requirements and the quality assurance activity ensures the quality of every output of the ontology development process.

The support activities fluctuate during the ontology's lifecycle and include knowledge acquisition, integration, evaluation, documentation and configuration management.

Regarding the development activities, in the first activity, namely Specification, one should establish a prototype and state the ontology significance by defining its intended uses and the presumed end users. The Conceptualization activity is crucial for the ontology development. During the Conceptualization activity, all the knowledge gathered will be structured and organized. METHONTOLOGY highlights that a conceptual model should be developed and then formalized to be later implemented in an ontology implementation language.

In this methodology, the Conceptualization activity includes a set of tasks that aim to structure knowledge.

In Task 1, a glossary of terms is built, and the terms to be included in the ontology are identified, as well as their natural language definition. Task 2 is where the concept taxonomies are built to define the concept hierarchy. Task 3 proposes to build ad-hoc binary relation diagrams to establish ad hoc relationships. In Task 4 a concept dictionary is built to specify the properties and relations that describe each concept of the taxonomy, containing all the domain concepts, relations, their instances, their class and the instance attributes. Task 5 takes the previous ad-hoc binary relations and details them in a relation table. Task 6 complements Task 5 by describing in detail each instance attribute on a concept dictionary. Task 7 is about describing the class attributes, and Task 8 is about describing each constant value used as values in data properties producing a constant table.

After describing concepts, the ad-hoc binary relationships, the instance attributes, the classes and the constants, first-order logic is used to define the formal in Task 9 and in Task 10 the rules of the ontology are described in a rule table. Lastly, in Task 11, the instances of the conceptual model of the ontology are defined and presented in an instance table.

Following the Conceptualization, we have the Formalization activity where the conceptual model is transformed into a semi-computable or formal model to be implemented in the next activity, the Implementation activity. The last activity from development stage is the Maintenance activity, in which the ontology should be corrected and updated to be later reused by other ontologies or applications.

SENSUS-based method [77]

The SENSUS approach proposes the construction of a domain ontology with the SENSUS ontology as a base, achieving a skeleton for the new ontology, by linking the domain specific terms with the SENSUS ontology, promoting knowledge shareability. The processes of this methodology are the following. Firstly, the seed terms are identified, and then they are manually linked to the SENSUS ontology as hyponyms after that path from the seed terms to the root of the SENSUS ontology are formed, and all the concepts in the path are included. If relevant terms for the domain are not yet included, they must be manually added, and the previous processes should be repeated to include paths from these new terms to the root of SENSUS. Finally, the nodes with a higher number of paths through them will be analyzed to decide if it is necessary to add nodes to the subtree under them. The biggest advantage of this method is to provide a common terminological foundation for the consolidation of independently developed ontologies [77].

On-to-Knowledge [78]

The On-to-Knowledge methodology comprises five processes for the intelligent access to large volumes of semi-structured and textual information sources in intra-, extra- and Internet-based environments, constructing ontologies with their application in mind. The first process is to conduct a feasibility study to the application of the ontology as a starting point to its construction. The kickoff process follows, by doing a specification document that incorporates all the ontologies requirements, constituted by the domain and goal of the ontology, its design guidelines, the available knowledge sources and the potential users and supported applications. This document identifies the most important concepts and relations and is often labeled as a baseline ontology.

The goal of process 3 is to refine the ontology into the specification given in the previous process to target a specific application. Domain experts are introduced in this process to polish the draft ontology, model and identify axioms. Later the terms and concepts are mapped, and the ontology is formalized by implementing the ontology in an ontology language.

The evaluation process is the fourth process to occur, an ontology-based application is checked for requirement satisfaction and satisfaction of the competency questions, and is tested for the target application environment. To conclude, on process five maintenance is carried out.

Comparison of Ontology methods and methodologies and Conclusions

In this Section we provide, on Table 3.1 a comparison between the Ontology methodologies and methods described previously focusing on their construction strategies.

Table 3.1: Comparison of Ontology methods and methodologies [3]

Feature	Cyc	Uschold & King	Grüninger & Fox	KACTUS	METHONTOLOGY	SENSUS	On-To-Knowledge
Life cycle Proposal	Evolving Prototypes	Non-proposed	Evolving prototypes or incremental	Evolving Prototypes	Evolving Prototypes	Non-proposed	Incremental and cyclic with evolving prototypes
Strategy concerning the application	Application independent	Application independent	Application semi-dependent	Application dependent	Application independent	Application semi-dependent	Application dependent
Strategy to identify concepts	Not Specified	Middle-out	Middle-out	Top-down	Middle-out	Not Specified	Top-down Bottom-up Middle-out
Use of a core ontology	Yes	No	No	No	Depends on the available resources	Yes	Depends on the available resources

3.2.2 Languages for building Ontologies

When developing an ontology, it is necessary to select the language in which the ontology will be developed. Ontologies are usually implemented in ontology implementation languages and knowledge representation languages, selected based on the preferences of the ontologist. Each language has its own expressiveness and its own knowledge representation paradigm, therefore, it is important to meet the requirements imposed by the ontology to construct. There is an important trade-off between expressiveness in ontologies and inference, unraveling what can be said of what can be obtained from the present information.

Corcho and Goméz-Pérez [79] developed an evaluation framework for comparing ontology languages in relation to their expressiveness and reasoning capabilities. Two major ontology language dimensions should be distinguished, knowledge representation and reasoning mechanisms.

The knowledge representation dimension focuses on the following components:

- **Concept**: The central modeling component, can be abstract or concrete, elementary or composite, real or fictitious.
- **Concept attributes**:
  - Instance attributes: Attributes whose value may be different for each instance of the concept;
  - Class attributes: Attributes whose value must be the same for all instances of the concept;
  - Local attributes: Attributes which belong to a specific concept;
  - Polymorph attributes: Attributes with the same name and different behavior for different concepts;
- **Concept Taxonomies**: Used to organize ontological knowledge in the domain using generalization/specialization relationships through which simple/multiple inheritance could be applied. In framed-based languages are implemented as the subclass-of relationships between concepts and are explicitly represented at design time. In DL-based languages taxonomies are inferred at run time by an inference engine, called classifier.
- **Relations**: Describe the relationships that can be established between concepts, and consequently, between the instances of those concepts.
- **Axioms**: Model sentences that are always true. Represent pieces of knowledge that cannot be implemented in the ontology with the rest of modeling components. Can appear independent or embedded in the ontology. Are included in an ontology for purposes as constraining its information, verifying its correctness or deducting new information.

- **Instances**: Individuals, the basic component of an ontology. Represent elements of a given concept.

Each language has a reasoning mechanism where the previously defined concepts are used. In DL-based languages there is an automatic classifier that computes automatically the concept taxonomies from concept definitions.

Markup languages are the foundations of semantic web with syntax based on HTML and XML. There are several markup languages known (SHOE, XOL, RDF, OIL, OWL, etc), in the next sections only some will be described.

OWL [80]

It is a web-based ontology language whose purpose is data presentation and data exchange with the capacity to perform as a formal language and characterized by formal semantics. Supports inference through an efficient representation of ontologies and is based on the Open World Assumption that what is not known, it is simply unknown resulting in the need for the ontology to have its information, relations and dependencies explicitly.

RDF

The Resource Description Framework (RDF) is a general-purpose language for representing information in the Web [81]. RDF enables the encoding, exchange and reuse of structured meta data through the design of mechanisms that support common conventions of semantics, syntax and structure [82]. RDF uses XML as a common syntax for the exchange and processing of meta-data. RDF provides a model for describing resources which consequently have properties (express the relationships of values associated with resources) [82] and statements (resources with named properties and property values [83]). RDF Schema (RDFS) is a system that allows to define domain-specific properties and resources to be used in RDF descriptions [83]. RDFS is an extension to RDF that supports the expression of structured vocabularies, providing a minimal ontology representation language.

3.2.3 Ontology Tools

Protégé

Protégé[1] was developed by Stanford Medical Informatics at Stanford University and is an open source environment for ontology edition with a library of plug-ins to support a series of functionalities [30]. Protégé fully supports OWL.

[1] http://protege.stanford.edu/

3.2.4 Ontology Integration

The word integration can have multiple meanings in the ontology field, Pinto et al. [84] expresses the difficulty to use this word correctly, especially because of its abusive use. Different authors use different terms to refer to similar concepts, and, vice versa, sometimes different concepts are referred to by the same term [4]. The word integration can be presented with different meanings, which can be summarily in Table 3.2 [4]:

Table 3.2: Different meanings of the term integration [4]

Term	Definition
Matching	The process of finding relationships or correspondences between entities of different ontologies.
Alignment	Set of correspondences between two or more ontologies. The alignment of the output of the matching process.
Correspondence	The relationship holding, according to a particular alignment, between entities of different ontologies.
Mapping	The oriented, or directed, version of an alignment: it maps the entities of one ontology to at most one entity of another ontology.
Merging	The creation of a new ontology from two, possibly overlapping, source ontologies. The initial ontologies remain unaltered and the merged ontology is assumed to contain the knowledge of the initial ontologies.

Pinto et al. [84] recognizes the problem of integration of two ontologies that use the same terminology but different semantics.

Amrouch et al. [47] also identifies the types of mismatches that occur during the process of integration of different ontologies integration.

- **Syntactic mismatches**: Two ontologies are represented through different representation languages, resulting in syntactically heterogeneity.
- **Lexical mismatches**: Heterogeneities between names of entities, instances, properties or relations. Can be synonyms (same entity represented by two different names), homonyms (same name represented by two different entities), same entity with the same name in different languages and same entities named with different syntactic variations of the same name.
- **Semantic mismatches**: Mismatches related to the content of the input ontologies.

3.2.5 Ontology Matching Systems

Ontology matching provides a mean to link concepts from different ontologies. It can be viewed as a process that takes as input two ontologies and outputs a set of correspondences between semantically related ontology concepts. Several matching algorithms, called matchers, are used to assign a numerical value to each mapping. This numerical value reflects the semantic similarity between different terms.

There are different levels upon how those matchers can work, including the element level and the structural level. Element level matchers analyze concepts or their instances in isolation, ignoring their relations with other concepts or instances. These matchers can use internal knowledge only, this means, information that is contained in the ontology itself, or incorporate external knowledge in the form of reusable alignments, upper or domain ontologies, and other linguistic resources. A popular internal-knowledge element-level matching technique is based on the lexical matching of the labels associated with ontology concepts.

Structure level techniques compare ontology concepts or their instances based on their relationships with other concepts or instances. They can also use external knowledge, such as instances that are not part of the ontology or previous alignments.

When selecting the relevant tools for ontology matching, Ganzha et al. [85] proposes pragmatic criteria essential for the application of these tools in real-life use cases. These tool must be approached taking into account the availability of the website and the date of the last update, the number of related publications and date of last publication, the availability of the source code and documentation, the used technology, the I/O data format, if it use is merely academic or is also commercial and its scalability.

This research requires the tool to be able to produce alignments between instances. Taking this into account only some of the tools meet the stipulated criteria, in the next sections they are here presented.

LogMap

LogMap [86] is a tool written in Java that can be used via command-line or web interface, accepting all OWL API format as input. LogMap provides a consistency check method based on Horn-clause satisfiability. LogMap produces alignments between classes, properties and instances and checks the. Ganzha et al. [85] refers that this tool has a major down point for ontologies that are lexically disparate or that lack lexical information because the algorithm used by LogMap to find similarities between concepts only utilizes vocabulary from the input ontologies.

Silk Framework

Silk Framework [87]is a tool for finding relationships between entities within different data sources. Supporting RDF, CSV and XML formats, and uses SPARQL to do user querying. It features a declarative language for specifying which types of RDF links should be discovered between data sources as well as which conditions entities must fulfill in order to be interlinked.

Silk requires manual input of link specifications, to discover links between data values, inhibiting this process to occur automatically.

AgreementMakerLight

AgreementMaker [88] is one of the leading ontology matching systems, combines flexibility and extensibility with a comprehensive user interface that enables alignment, visualization, and manual editing. Its derivative, AML, focused on computational efficiency and designed to handle very large ontologies while preserving most of the flexibility and extensibility of the original AgreementMaker framework. AgreementMakerLight (AML) [89], derived from AgreementMaker, is an automated ontology matching framework based on element-level matching and the use of external resources as background knowledge.

The AML framework includes three key data structures: The Lexicon, the Relationship Map, and the Alignment. The first two data structures are the main components of Ontology Objects, i.e., representations of ontologies used in AML to support the matching process. As their names suggest, the Lexicon stores the lexical information of an ontology (i.e., the labels and synonyms of each term) and the Relationship Map stores the structural information of an ontology (i.e., the relationships between all terms). The Alignment stores the set of mappings between two ontologies produced by one or more matching algorithms. In this paper, we used the AML framework since we were looking for an ontology mapping system that not only is flexible, efficient and reliable but also provides the possibility to map ontologies at different levels (Classes, Attributes, Relations and Individuals). AML is one of the few mapping systems that provide all the mentioned functionalities.

3.2.6 Similarity Measures

Semantic similarity measures allow the assessment of the degree of similarity between words, currently are used in fields like word sense disambiguation [90] [91], ontology alignment [92], clustering [93], information retrieval [94] and synonym extraction [95].

The semantic similarity differs from the lexical similarity between two words because it does not refer to the common sequence of characters, but to use of the words in the same manner, in the same context and if both words share the same type [96].

To determine similarity between words, it is possible to extract information from large collections of text (corpora) - *Corpus-based Similarity Measures* - or to use the information from semantic networks - *Knowledge-based Similarity Measures*.

Corpus-based similarity measures are fundamental to compare units of the language or concepts when there is no expression of knowledge available to drive the comparison [97]. It is important to refer the following Corpus-based similarity measures:

- **LSA** - Latent Semantic Analysis: Extracts a group of terms from various contexts and constructs a term-document matrix to describe the frequency of occurrence of terms in documents. Using singular value decomposition LSA acquires knowledge of the terms expressed [98].

- **HAL** - Hyperspace Analogue to Language: Uses concurrent vocabulary to retrieve the meaning of a term, similar to LSA but uses a paragraph or document as unit of the document to establish the information matrix. Scans the entire corpus shifting a window matrix of a shared term without exceeding the definition of the window matrix [98].

Knowledge-based similarity measures rely on formal expressions of knowledge to understand how to compare concepts and instances. Knowledge-based similarity can be used to compare any formally described piece of knowledge, but its main limitation is the strong dependence on ontology availability [97].

There are several approaches to Knowledge-base similarity, the **Path-based** approach states that the similarity between two concepts is a function of the length of the path linking the concepts and the position of the concepts in the taxonomy [99]. The **Information Content-based** approach is formally defined as the negative log of the probability of a concept [100], it uses the information content of concepts to measure the semantic similarity between two concepts/terms by calculating the content value of a concept based on its frequency on a given document [101]. Several Path-based and Information Content-based measures are presented in Table 3.3.

Table 3.3: Path-based and Information Content-based Semantic Similarity measures.

Name	Metric	Limitations [99]
Path-Based		
Rada et al. [102]	Taxonomic distance of two concepts defined in a taxonomic tree as a function of the shortest path linking them [97].	- Different pairs of concepts at different levels of the hierarchy can have the same minimal distance and the same similarity value; - Taxonomies can have irregular densities of links between concepts.
Wu and Palmer [103]	Takes the position of concepts c1 and c2 in the taxonomy relatively to the position of the most specific common concept lso(c1, c2) into account. It assumes that the similarity between two concepts is the function of path length and depth inpath-based measures. [99]	- Two pairs with the same lso and equal lengths of shortest path will have the same similarity.
Li [104]	Uses both the amount of information needed to state the commonality between the two concepts and the information needed to fully describe these terms. [101]	- Two pairs with the same lso and equal lenghts of shortest path will have the same similarity.
Information Content-Based		
Resnick [105]	For two given concepts, similarity is depended on the information content that subsumes them in the taxonomy. [99]	- Two pairs with the same lso will have the same similarity.
Lin [106]	Uses the amount of information to state the commonalities between two concepts and the information needed to fully describe these terms. [99]	Two pairs with the same summation of IC(c1) and IC(c2) will have the same similarity.

The **Feature-based** measures approach, also called Gloss-based, is based on the assumption that each concept is described by a set of words indicating its properties or features, such as their definitions or “glosses” in WordNet [99]. There are a number of measures that combine both these approaches, creating a **Hybrid** category of semantic similarity measures.Several Feature-based and Hybrid measures are presented in Table 3.4.

Table 3.4: Feature-based and Hybrid Semantic Similarity measures.

Name	Metric	Limitations
	Feature-based	
Tversky [107]	Simmilarity is not symmetric. Features between a subclass and its superclass have a larger contribution to the similarity evaluation than those in the inverse direction. [99]	- High computational complexity; - Do not work well on incomplete feature sets. [99]
Lesk [108]	Function of the overlap between two concept definitions as provided by a dictionary. [91]	- Ignores dimension and size of words.
Gloss Vector	Creates a co–occurrence matrix from a corpus made up of the WordNet glosses. Each content word used in a WordNet gloss has an associated context vector. [91]	- Only biagrams frequencies are considered without taking frequencies of individual terms into account. - Is developed for relatedness measurement rather than similarity estimation. [109]
	Hybrid	
Zhou [110]	Combines Path-based with Information Content-based approaches as a parameter. [99]	- Parameter to be settled, turning is required, may bring deviation. [99]

WordNet

Wordnet is a lexical reference system that aims to model the lexical knowledge of the English language, gathers all nouns, verbs, adjectives and adverbs in an online database and gathers them into sets of synonyms, called synsets, to express distinct concepts (senses) [101]. In the field of Natural Language Processing is the most popular lexical knowledge resource [90].

Wordnet provides the following semantic relations [111] [90]:

- **Synonymy** : the basic relation of WordNet’s. The representation of word senses occurs through sets of synonyms (synsets).
- **Antonymy** : is a symmetric semantic relation between word forms, important on the organization of adjective and adverb’s meaning.
- **Hyponymy** : (expresses concept specialization) and its inverse, hypernymy (expresses concept generalization), are transitive relations between synsets. Allows the organization of noun’s meanings into a hierarchical structure (lexicalized taxonomy).
- **Meronymy** : (part-name) and its inverse, holonymy (whole-name), define a part-of relation expressing the elements of a partition.
- **Troponymy** : (manner-name) is for verbs what hyponymy is for nouns, although the resulting hierarchies are much shallower.

These relations are associated with words to form a hierarchy structure useful for computational linguistics and natural language processing [99]. Wordnet can be used to compute similarity scores and can be seen as an ontology for natural language terms [101]. Most of semantic similarity calculus researches focus on nouns because it argued that a language semantics is mostly captured by nouns or noun phrases [99].

4

Developing the ontologies for TIPA for ITIL and COBIT 5 PAM - First DSRM Iteration

Contents

On this chapter the first iteration of DSRM is presented. On Section 4.1 we present the solution objectives. Then, on section 4.2 the artifact that results from this DSRM iteration is presented in detail as well as its design and development process. An evidence of the utility of the designed artifacts are presented on Section 4.3 as a demonstration and on Section 4.4 an evaluation of the artifacts is performed.

4.1 Objectives

To support the multi-framework adoption and facilitate the assessment of these frameworks in organizations, we propose an ontological integration of ITIL and COBIT 5 process assessment concepts (base practices, inputs/outputs and outcomes).

In order to increase the theoretical foundation of these frameworks, in this DSRM iteration we developed two ontologies: one for TIPA for ITIL and the other for COBIT 5 PAM.

TIPA for ITIL and COBIT 5 PAM are described in natural language. Therefore, they are prone to ambiguity and subjectivity.

By developing an ontology for each of these frameworks, we aim to have a formal representation of COBIT 5 PAM and of TIPA for ITIL that allows us to have a computational resource to clarify the strucuture of knowledge of their domain and, in a subsequent iteration of DSRM, allow the integration of both of them.

4.2 Design and Development

Considering the analysis made by Gomez-Perez et al. [3], it is important to point out that in the scope of this research a method/methodology with a life cycle is beneficial because it can give a scheduled structure to the ontology development, specifying in this way a chronology for the performance of ontology development activities and the stages coupled to them. Evolving prototypes allows alterations in each version of the ontology because they allow ontologists to add, change and remove terms.

The ontologies to be developed should be application dependent because in our opinion it is destined to be used in EGIT field and that context should be taking into account when choosing the terminology to represent the ontologies. Ontology methods that are intended to produce "application independent" ontologies will not pose a problem when used; they will just be more generic and inclusive.

For the construction of our ontologies, preference is given to a middle-out approach. This approach is important not only to miss commonalities between related concepts but also to simultaneously achieve balance in the level of detail of terms and a stable ontology, saving in this way effort and preventing rework.

Knowing that none of these methods and methodologies covers all the processes involved in ontology building, METHONTOLOGY meets the requirements mentioned above and is considered the approach that provides the most accurate descriptions of each activity. Moreover, METHONTOLOGY also distinguishes itself from the other methods and methodologies by paying more attention to aspects related to management, evolution, and evaluation of ontologies and for providing a set of specific tools that give it technological support. Therefore, in this research, we are going use the METHONTOLOGY approach to build the TIPA for ITIL and COBIT 5 PAM Ontologies.

During the construction of both ontologies, on the specification activity, we defined the scope of this proposal as "Process Assessment" that is translated into the use of TIPA for ITIL PAM and COBIT 5 PAM. As it was stated before, both these frameworks arr based on ISO/IEC 15504 and are a method for conducting process assessments. Therefore, these ontology intend to be used by ITIL, COBIT 5 and ITSM assessors and experts to perform process assessment using TIPA for ITIL and COBIT 5 PAM, and therefore improve the management of their IT services, infrastructures, and resources [1].

The first step of the conceptualization activity is to propose a model that aims to represent the structure of the ontology. ArchiMate is typically used for high-level processes and their relations to the enterprise context, but it is not intended for detailed workflow modeling [112]. ArchiMate provides a uniform representation for diagrams that describe EAs. Since the motivational layer is essential to model the PAMs, ArchiMate seemed to be a suitable language for this activity. This research uses latest version of the language - ArchiMate 3.0.

Fig. 4.1 illustrates the conceptual model that serves as a draft to the rest of the ontology construction and that later is formalized into the ontology. This model represents the knowledge acquired that will be translated into an ontology development language and become machine readable.

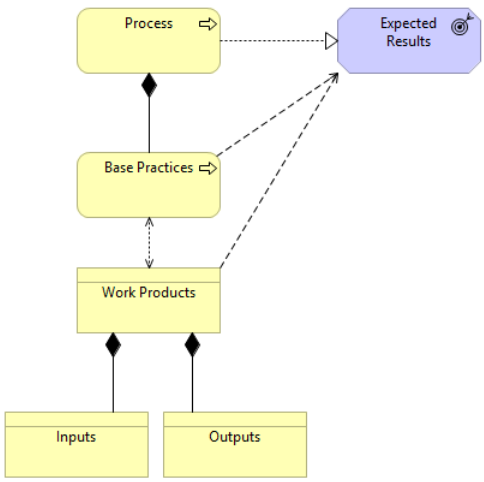

Figure 4.1: A conceptual model for the TIPA for ITIL and COBIT 5 PAM Ontologies using ArchiMate.

Since TIPA for ITIL PAM and COBIT PAM were both designed according to ISO/IEC 15504 requirements, they rely on the same foundation and, therefore, share the same structure of concepts, as presented on Fig. 4.1.

Regarding Fig. 4.1, there is a term that deserves a particular discussion: the option for the term “Expected Result” instead of the term “Outcome” from ISO/IEC 15504 standard was purposely done by the TIPA for ITIL developers [1] to diminish the terminology disparities in the ITSM community and to ensure the understanding of this concept with no loss of significance. On the COBIT 5 PAM Ontology the term ”Outcome” is used instead of ExpectedResult to comply with the terminology used by ISACA.

After a model for the implementation of the Ontologies is created, the conceptualization tasks, proposed in METHONTOLOGY, can take place.

Table 4.1 presents a glossary of the terms presented on the TIPA for ITIL and COBIT 5 PAM Ontologies together with their descriptions, and a concept dictionary with the properties and relations that describe each concept of the taxonomy .

Table 4.1: A Glossary of terms and concept dictionary

Class Name	Description [15] [1]	Class Attributes	Relations
Process	A structured set of activities designed to accomplish a specific structured set of activities designed to accomplish a specific objective. It may include any of the roles, responsibilities, tools and management controls required to deliver the outputs reliably. A process may define policies, standards, guidelines, activities and work instructions if they are needed.	process-name purpose process-description lifecycle stage/domain	hasObjective isComposedBy Uses Produces
Work Product	Structured sets of data that make the process work and that are expected to be produced by the process. Inputs are gradually converted into outputs.	workproduct-name workproduct-description characteristics	isRelatedToAsOutput isRelatedToAsInput supportsAsInput supportsAsOutput isUsed isProduced
Base Practice	A set of actions designed to achieve a particular result. Usually defined as part of processes or plans and are documented in procedures.	basepractice-name basepractice-description	hasOutput hasInput helpAchieve composes
Expected Result/ Outcome	The expected results/Outcomes required from a process, activity or organization to ensure that its purpose will be fulfilled. Expected results are usually expressed as measurable targets.	expectedresult-description/ outcome-description	isSupportedByInput isSupportedByOutput achievedBy

Once the ontology’s terms were defined, we set the concept hierarchies by building a concept taxonomy, defining the disjoint relations between them. In the TIPA for ITIL and COBIT 5 PAM Ontologies, all concepts share a disjoint-decomposition relation because they do not share instances.

In Fig. 4.2. is presented a diagram extracted from VOWL plugin in Protégé that establishes the ad-hoc relationships between concepts of the same concept taxonomy later detailed on Table 4.2.

As we can see in Fig. 4.2 all the ontologies attributes are Strings and they are defined with (0,1) cardinalities, whether they exist or not.

Our TIPA for ITIL Ontology has 107 instances and our COBIT 5 PAM has 160 instances, it would

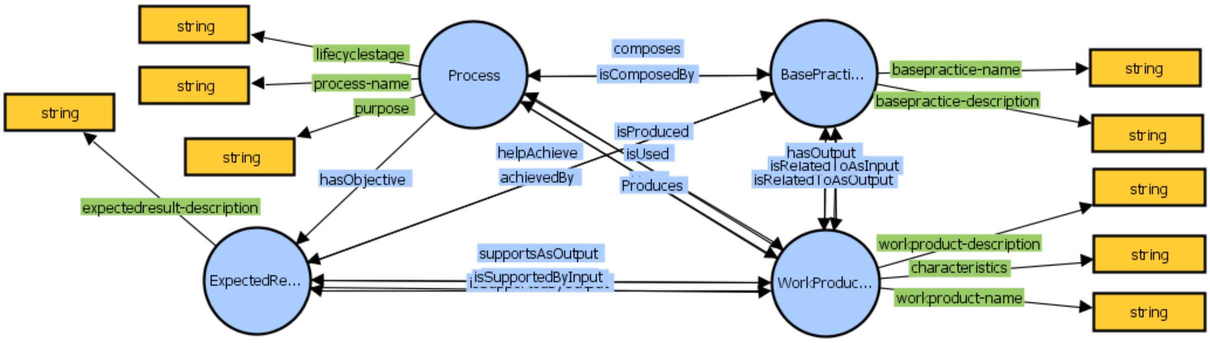

Figure 4.2: Ad Hoc Binary relations diagram for the TIPA for ITIL and COBIT 5 PAM Ontologies.

Table 4.2: Ad hoc Binary Relation Table of TIPA for ITIL and COBIT 5 PAM Ontologies

Relation Name	Source Concept	Source card. (Max)	Target Concept	Mathematical Properties	Inverse Relation
hasObjective	Process	1	ExpectedResult	Asymmetric Irreflexive	-
hasOutput	BasePractice	N	WorkProduct	Asymmetric Irreflexive	isRelatedToAsOutput
hasInput	BasePractice	N	WorkProduct	Asymmetric Irreflexive	isRelatedToAsInput
isComposedBy	Process	1	BasePractice	Asymmetric Irreflexive	Composes
isSupportedByInput	ExpectedResult	N	WorkProduct	Asymmetric Irreflexive	supportsAsInput
isSupportedByOutput	ExpectedResult	N	WorkProduct	Asymmetric Irreflexive	supportsAsOutput
helpAchieve	BasePractice	N	ExpectedResult	Asymmetric Irreflexive	achievedBy
Uses	Process	N	WorkProduct	Asymmetric Irreflexive	isUsed
Produces	Process	N	WorkProduct	Asymmetric Irreflexive	isProduced

be inefficient to illustrate all these instances in this research, and so, we present in the Demonstration Section a practical example of the implementation through the instantiation of the TIPA for ITIL and COBIT 5 PAM ontologies. In Fig. 4.3 is possible to show how the TIPA for ITIL ontology is instantiated on Protégé. Note that there exists a set of relations between concepts that are defined by inference through the use of a reasoner.

4.3 Demonstration

Since both ontologies share the same structure and main concepts, only differing only in their instances we can assume that by inference when demonstrating one of the ontologies we are thus demonstrating both.

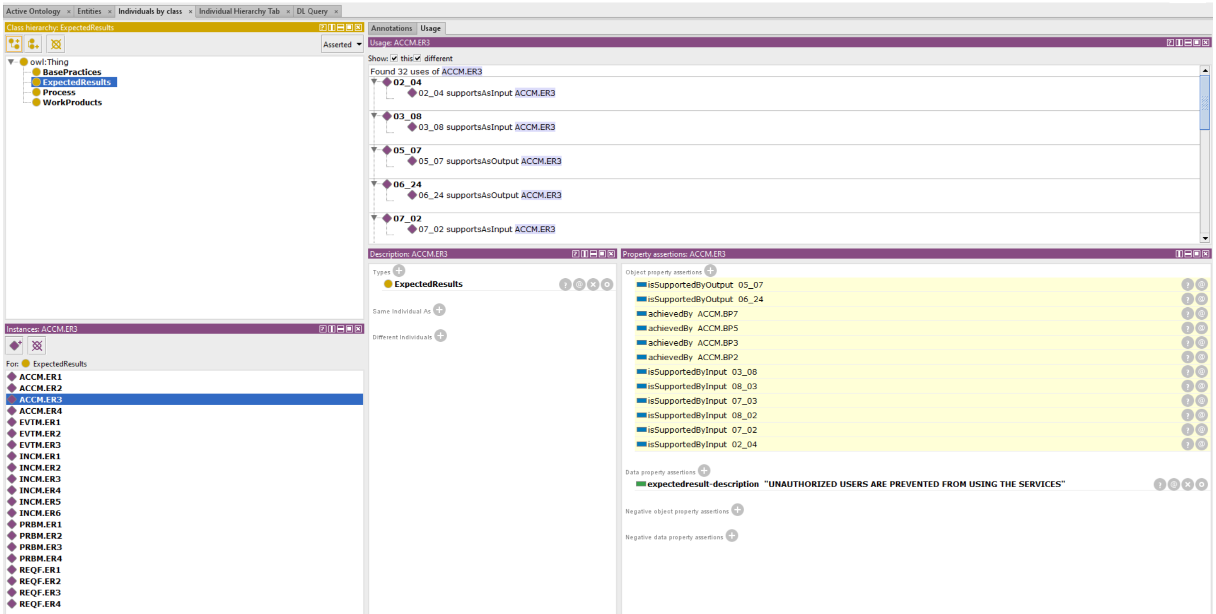

Figure 4.3: A view of the TIPA for ITIL Ontology in Protégé

Therefore, we carried a demonstration of the suitability of this proposal by assessing the ITIL Incident Management process in a Portuguese hospital.

To understand the capability level of the ITIL Incident Management process, semi-structured interviews were performed. Interviews were conducted with two hospitals' IT decision-makers at the top and medium management levels usually responsible for all decisions concerning IT [113]. In this demonstration, the focus of the assessment was the process capability level 1. In this level, the process performance attribute is a measure of the extent to which the process purpose is achieved. The primary goal in this level is to analyze if the process achieves its objectives, expected results, and whether it shows some tangible evidence of process activities. In practice, a process cannot be observed and assessed. A process is assessed through evidence indicators of the way it performs [1].

Two different approaches were used to demonstrate the TIPA for ITIL Ontology.

Firstly, we demonstrate how the ontology can support the process assessment carried out in a Portuguese hospital by instantiating the ontology with examples of the hospital enterprise architecture. In Fig. 4.4, a detailed example of the instantiated ontology is presented, allowing us to better structure, design and formalize the TIPA for ITIL assessment.

Secondly, the ontology was used to answer some questions that are crucial when assessing the enterprise's process capability. Process performance indicators are specific to each process and are used to determine whether a process has achieved the process capability level 1.

To simplify this demonstration, we selected the following expected result on the TIPA for ITIL Ontology: INCM.ER3 - "Incidents are resolved within agreed service levels to restore the normal service

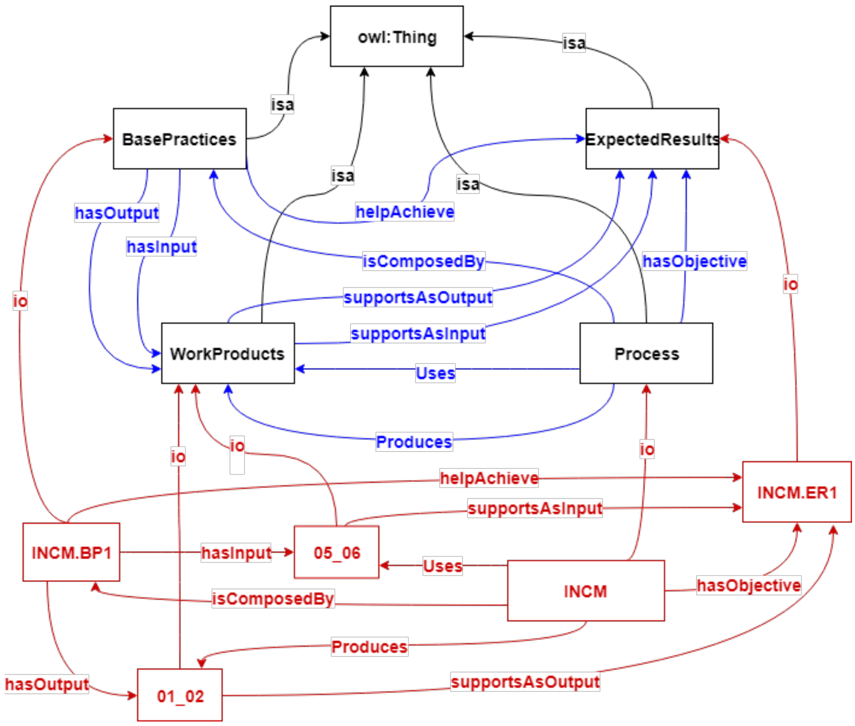

Figure 4.4: Instantiated TIPA for ITIL Ontology

operation" to demonstrate the suitability of this proposal. To determine if this expected result is achieved we firstly inquired our ontology about which are the base practices that support this expected result. One can conclude through the relation achievedBy that the following base practices directly influence the achievement of INCM.ER3: INCM-BP2, INCM-BP3, INCM-BP4, INCMBP5, INCM-BP6, INCM-BP7, INCM-BP9 as shown on Fig. 4.5.

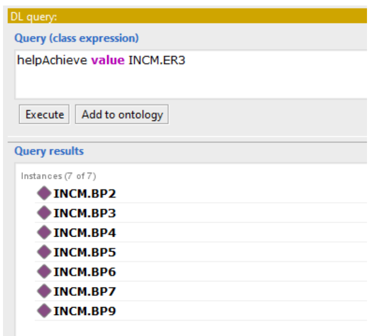

Figure 4.5: DL Query to assess the achievement of INCM.ER3

After that, one should use the TIPA for ITIL questionnaire to determine if these base practices are being correctly performed. Some questions that were used are: "Are there time limits to diagnose (and resolve) the incident in each specialized support line?"; "Is there a link to the SLAs?"; "When is an incident escalated to your manager or a higher authority level?". Then, one should resort again to the ontology to examine which are the work products related to this specific expected result, by checking the isSupportedByInput and isSupportedByOutput relations. Fig. 4.6 shows that regarding the process outputs, only the following outputs 05-04, 05-07, 02-07 and 07-02 influence the INCM.ER3. Regarding the inputs, only the 05-04, 05-05, 05-06, 02-07, 08- 01, 02-06, 01-02, 05-02, 05-03 influence INCM.ER3.

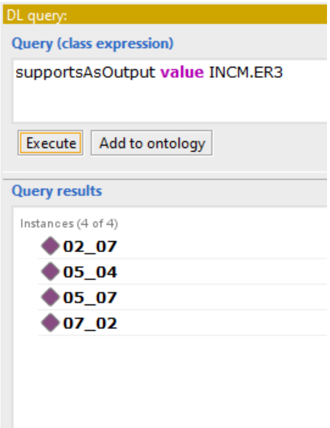

Figure 4.6: DLQuery for the supporting outputs of INCM.ER3

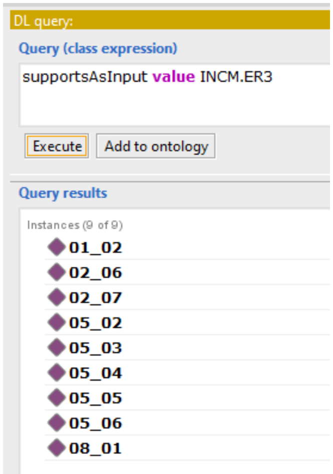

Figure 4.7: DLQuery for the supporting inputs of INCM.ER3

By using this information, one can assess the process capability of the chosen process. In this particular case, we examined the Portuguese hospital work products and base practices and concluded that the hospital achieved the process capability level 1, since as one can see on Table 4.3 not all the process work products are used. However, one cannot conduct a process capability level 2 assessment since the following expected result INCM.ER3 “Incidents are resolved within agreed service levels to restore the normal service operation” is largely (and not fully) achieved.

4.4 Evaluation

The ontologies’ evaluation comprises two different kinds of judgments, a technical judgment, and a user judgment, from now on referred to as an ontology assessment [76].

The technical evaluation of the taxonomy presented in the ontology developed is processed with judgment of the content of the ontology with respect to a frame of reference, in this case we resort to competency questions, a set of questions in natural language to determine the scope of the ontology and to extract the main concepts of the ontology, their properties, relations and formal axioms.

The competency questions are firstly identified informally in natural language as requirement specifications for the ontology to answer once it is expressed in a formal language. These questions are not merely queries; they must be stratified so that they can be composed or decomposed into other

Table 4.3: Evaluation of the Incident Management Process Work Products on the Portuguese Hospital

Process Input Work Products		
ID	workproduct-name	Used (X)
05_06	Event record	
05_05	Configuration Management System (CMS)	
08_01	Service Level Agreement (SLA)	X
05_03	Known Error Base Database (KEBD)	
05_04	Incident knowledge base	
05_02	Problem knowledge base	
01_02	Incident management tool	X
02_06	Incident model	
02_07	Incident categories	X
Process Output Work Products		
ID	workproduct-name	Used (X)
05_07	Incident record	
05_04	Incident knowledge base	
01_02	Incident management tool	
02_07	Incident categories	
06_05	Customer Satisfaction Survey	X
07_02	Request for Change	

competency questions. Therefore, it is essential to explore how the solution to the competency question can be used and what is the relevant information to answer the question.

For the evaluation of the TIPA for ITIL Ontology the following competency questions were defined:

1. If there is a problem with the Configuration Management System (CMS) what are the expected results that are not achieved?

2. Which Base Practices influence the Expected Result INCM.ER4 – "The incident impact on the business is minimized"?

3. Which Process uses Known Error Databases (KEDB) and produces a Request for Change (RFC)?

During the various stages of the development lifecycle, the ontology was subjected to a technical verification to ensure that the ontology was being built correctly and to a technical validation, to ensure that it represented a reliable model of the real world to be formally defined. The previously defined competency questions were implemented in OWL DL and Fig. 4.8 presents the ontology answers to these questions.

A similar evaluation process with identical competency questions was performed for the COBIT 5 PAM Ontology to ensure that the ontology was correctly instantiated and that chosen the structure, concepts and relations also make sense when applied to the COBIT 5 domain.

The ontology assessment is focused on the user evaluation of the ontology's correct definition and performance based on consistency, completeness, and conciseness.

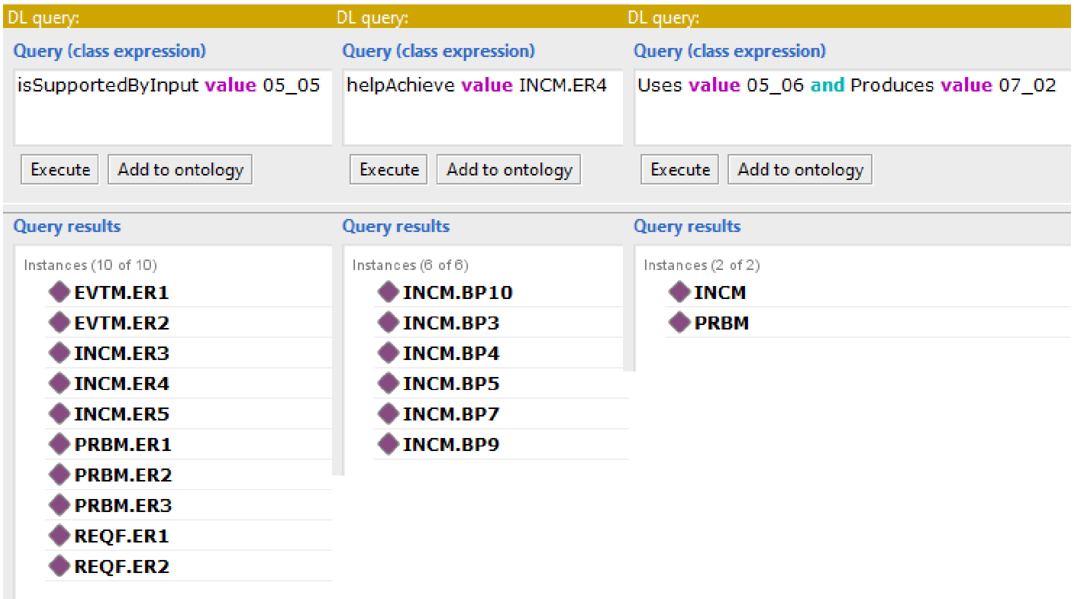

Figure 4.8: DL Query answers for the defined competency questions.

- The consistency assesses if contradictory knowledge can be inferred from the ontology.
- Completeness can only be assessed by proving the nonexistence of incompleteness, by determining if the individual definitions are well established and if all that is supposed to be stated in the ontology is present or can be inferred.
- If the ontology does not present redundancies and useless definitions, then the ontology can be assessed as concise.

For the assessment of the TIPA for ITIL and COBIT 5 PAM Ontology, 10 interviews with ITIL and TIPA for ITIL and COBIT 5 practitioners and specialists from Portugal, Brazil, and Luxembourg were performed. The ontology was, regarding the present definitions, consensually assessed as complete, consistent and concise for the scope of process assessment. It is important to emphasize that during the evaluation some important statements emerged. The practitioners stated that "having an Ontology to represent these EGIT frameworks can be valuable to identify inconsistencies" and that an ontology is "a useful resource to give a better vision and identification of the process architecture". Through an incremental process, it was possible to homogenize the concepts, the concept attributes and the relations established that are presented in our ontology.

5

Integrating TIPA for ITIL and COBIT 5 PAM - Second DSRM Iteration

Contents

The second iteration of DSRM is here presented. The solution objectives are presented in Section 5.1. In section 5.2 the artifact that results from this DSRM iteration is presented in detail as well as its design and development process. In Section 5.3 occurs a demonstration of the achieved results complemented with an evaluation of the artifacts in Section 5.4.

5.1 Objectives

The primary objective of this research is to perform an integration, COBIT and ITIL process assessment core concepts (base practices, inputs/outputs, outcomes and expected results) to evidence the overlap between these frameworks and facilitate in this way the simultaneous assessment of these frameworks. Since we already have available two formal representations for each of these frameworks it is now possible to use tools that allow the automatic mapping of concepts using semantic similarity measures.

5.2 Design and Development

Since we developed an ontology to each of these frameworks, it is now possible to use knowledge-based measures to semantically to evaluate the relationship between their concepts. The system used to perform the ontological alignment needs to be flexible and reliable enough to provide us the possibility to map not only classes but also instances.

AML [89] meets our requirements and is one of the leading ontology matching system currently being used. It is derived from the original mapping system AgreementMaker [88]. There are others matching systems with similar characteristics, as presented by Ganzha et al. [85], but the majority are not apparently in active use neither support the ontology language used in this research.

AML implements six matchers that range from simple (label similarity) to complex (so-called, structural matcher), as well as three filters (e.g., cardinality filter). Each matcher is configurable, e.g., the string matcher has a choice of four similarity measures [85]. AML can calculate similarity scores resorting to external knowledge source, like WordNet [85].

Fig. 5.1 is a visual representation of the results gathered from the evaluation of Base Practices in AML. This analysis focused on SO life cycle stage of ITIL and the DSS domain of COBIT 5.

The matchers used to achieve the values here presented function at the element level, by analyzing concepts and instances in isolation, ignoring the relationships with other concepts or instances, and using only internal knowledge contained in the ontologies, in an all-against-all strategy, where all concepts are matched with each other. Using the threshold functionality of AML, it is possible to discard irrelevant values of similarity.

Figure 5.1: Matching results between TIPA for ITIL and COBIT 5 PAM Base Practices.

In our proposal we use the *HybridStringMatcher*, AML default matcher for instance matching) that combines a Lexical Matcher (that finds literal full-name matches from the Lexicon, including labels, names, and synonyms), a String Matcher (that finds matches from Lexicon based on the ISub string similarity metric) and a Word Matcher (that finds matches from the Lexicon based on shared words - weighted Jaccard index); a *ValueStringMatcher* that is similar to the *HybridStringMatcher* but is based on the ValueMap instead of on the Lexicon (i.e. Property values) and also uses the ISub string similary metric; and a *Value2LexiconMatcher* that is similar to the previous two but compares the Lexicon to the *ValueMap*, to catch cases where one ontology has a property that goes to the Lexicon, but the other does not despite having a correspondence and uses WordNet.

The AML, as well as AgreementMaker, allows for serial and parallel composition where, respectively, the output of one or more methods can be used as input to another one, or several methods can be used on the same input and then combined. A set of mappings may therefore be the result of a sequence of steps, called layers, to obtain a final matching or alignment [114].

5.3 Demonstration

In this section, the authors present and discuss the results achieved in this research.

Humans have an innate ability to judge semantic relatedness of texts. Human judgments on a reference set of text pairs can thus be considered correct by definition, a kind of “gold standard” against which computer algorithms are evaluated [46]. Semantic measures are widely used today to compare units of language, concepts, instances or even resources indexed by them (e.g., documents, genes).

Therefore, in this research, the authors just semantically compared the instances from processes that according to ISACA [15] are related.

This analysis only deals with a subset of processes, namely the processes that belong to the SO lifecycle in ITIL and its related domain in COBIT 5 – the DSS domain. These processes were chosen because, according to ISACA [15], the initial focus on any process assessment would be the core (sometimes called primary) processes, which are primarily part of the Build, Acquire and Implement (BAI) and DSS domains.

The results comprise a total of 5749 values that represent the similarity mappings between 167 instances that belong to the DSS domain of COBIT 5 and the Service Operation life cycle stage of ITIL.

Also, in this proposal, we performed a direct evaluation, this means that the obtained measures are evaluated regarding their capacity to mimic human ratings of semantic similarity/relatedness.

Detailed results are presented in Fig. 5.2. This figure presents the top 5 Base Practices with higher similarity. As one can see, the COBIT 5 DSS02-BP4 base practice and ITIL INCM-BP6 base practice achieved the highest degree of similarity with a score of 94%. In Appendix A are presented the top alignments for the other core concepts of the TIPA for ITIL and COBIT 5 PAM Ontologies.

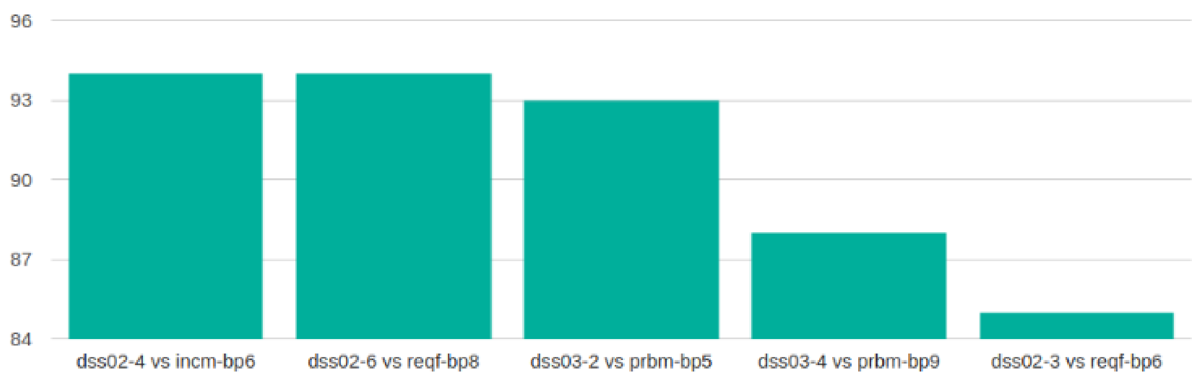

Figure 5.2: Top 5 alignments between TIPA for ITIL and COBIT 5 PAM Base Practices.

In Appendix B are presented all the resulting alignments between the TIPA for ITIL and the COBIT 5 PAM Ontologies core concepts (base practices, expected results and work products).

5.4 Evaluation

For the evaluation of the demonstrated results is important to clarify how these results can be interpreted and whats their significance.

Since the similarity between instances is calculated taking into account all the attributes that compose the base practices (namely, the name and description), the results are not unexpected. As presented in Table 5.1, the name of both base practices is rather similar, and their description has a higher level of coverage.

Table 5.1: Comparison of ITIL and COBIT correspondent instances

Instance Name	basepractice-name	basepractice-description
DSS02-BP4	Investigate, diagnose and allocate incidents.	Identify and record incident symptoms, determine possible causes, and allocate for resolution.
INCM-BP6	Investigate and diagnose the incidents.	Analyze and investigate incidents by the appropriated support line(s) if first line support failed to restore service.

However, it seems obvious that the description is a far more important attribute than the base practices name. Therefore, these results are likely to be biased. In order to avoid such a situation, the authors also semantically compare the base practices using the attributes separately.

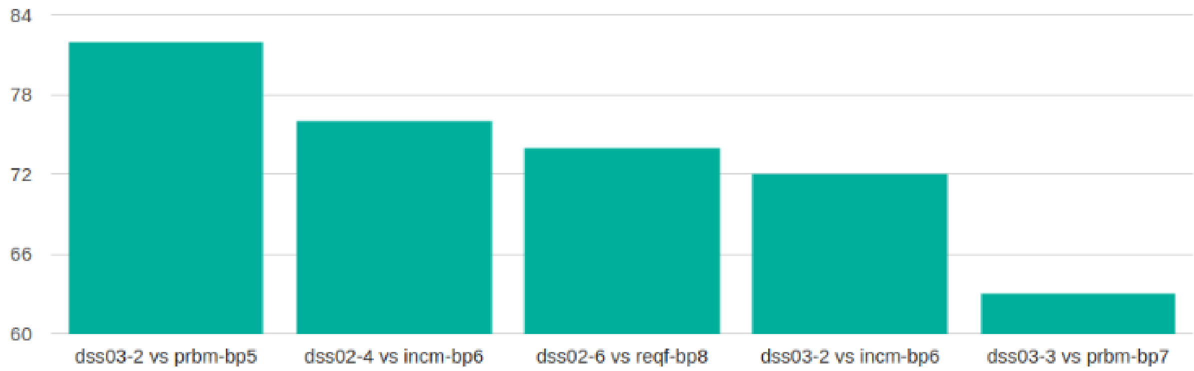

Figure 5.3: Top 5 comparisons between TIPA for ITIL and COBIT 5 PAM Base Practices with only the *basepractice-description* being evaluated.

As one can see, the results are generically lower. In this specific scenario, the practices with the highest similarity are not the same. Taking into account the COBIT 5 DSS02-BP4 base practice and ITIL INCM-BP6 base practice, in Fig. 5.3, the previous value of 94% decreases to 75.58%.

This research focuses mainly on showing the overlap between TIPA for ITIL and COBIT 5 PAM core concepts, but recognizes that giving an example of a possible process-level assessment by cross-checking the available data, gives a perspective on how these values can be translated and interpreted.

5.4.1 Österle Principles

A scientific research is characterized by abstraction, originality, justification, and publication in order to distinguish itself from the way solutions are developed in the practitioners' community (e.g. in user organizations) or by commercial providers (e.g. software vendors, consulting companies) according to Österle et al. [39].

- **Abstraction**: *Each artifact must be applicable to a class of problems* - This research proposes an ontological approach for describing the PAMs of the TIPA for ITIL and COBIT PAM and also use semantic similarity techniques to compare COBIT and ITIL process assessment core concepts.

- **Originality**: *Each artifact must substantially contribute to the advancement of the body of knowledge* - The proposal is not present in the Book of Knowledge of the domain, as fare as the author is aware.
- **Justification**: *Each artifact must be justified in a comprehensible manner and must allow for its validation* - The proposed artifacts and the solution objectives are justified with the literature reviewed in Section 3 and the problem exposed in Section 2.
- **Benefit**: *Each artifact must yield benefit, either immediately or in the future, for the respective stakeholder groups* - The proposal helps to reduce the terminology conflicts that arise in the Integration of COBIT 5 and ITIL and map these frameworks in a deeper level than the mapping proposed by ISACA [26].

6

Conclusion

Contents

At present, there is a wide range of solutions which can be applied as PRMs to improve organizations' processes, some of the most applied solutions in organizations are COBIT 5 and ITIL.

This gives the opportunity to support different needs through the benefits that each of them provides, but these frameworks are heterogeneous and present many differences in their scope, approach, processes structure, definitions and terminology, granularity or level of detail, amongst others. Therefore, organizations struggle with the complexity and difficulty of understanding and interpreting several models at the same time.

Taking into account the above, some solutions and proposals have been defined to support the work within how to conduct and get a clear view of the current practices in an organization in a particular domain. These solutions have been known as process assessment models such as COBIT 5 PAM and TIPA, which are models that aim at assessing the process of COBIT 5 and ITIL, respectively. Likewise, other proposals have been developed in this research subject, e.g., Ontology-based models for the ITIL Process Reference Model, ontological meta-models based on COBIT and mapping ontologies of COBIT-ITIL. However, most of the proposals found referred to the outdated versions of mappings between COBIT and ITIL, and it is important to realize that since there was a version upgrade to COBIT this integration is out of date because new artifacts were introduced in COBIT 5.

Despite the above, however, the efforts have been performed without taking into account the definition of a common and consistent terminology which allows us to have an integrated point of view which allows to decrease the efforts during the assessment processes both in COBIT and ITIL when they are being installed, or they are instantiated at the same time in the same organization. Hence, a consistent terminology for assessment process based on COBIT and ITIL frameworks can provide an important instrument for understanding and support the right implementation of them in an organization, as well as for strengthening this research domain.

In consequence, in this research the main objective was to present an ontological mapping approach of TIPA for ITIL and COBIT 5 PAM through the semantic similarity evaluation of their core concepts, facilitating in this way the assessment of these frameworks in an integrated way. As a support to our objective, we have carried out the mapping between processes of ITIL and COBIT.

6.1 Contributions

During this research two major contributions can be highlighted:

- The **TIPA for ITIL and COBIT 5 PAM Ontologies** - these artifacts are computable resources able to represent the structure of knowledge of the Process Assessment domain using ITIL and COBIT 5. As far as we are aware no similar artifacts

- The **Alignments between TIPA for ITIL and COBIT 5 PAM Core Concepts** - the similarity values resulting from the evaluation of the semantic relatedness between TIPA for ITIL and COBIT 5 PAM Ontologies allows us to not only show how both these frameworks overlap but to have a starting point to the automation of process assessment.

6.2 Limitations

Firstly, to simplify this research and the analysis, demonstration and evaluation of the proposed artifacts only the DSS Domain from COBIT 5 and the SO life cycle stage from ITIL are instantiated on the respective ontologies. Instantiating the ontologies with the remaining processes will represent a similar effort.

The similarity values achieved from the use of AML as the chosen ontology matching system could be improved by allowing the calculation of the similarity values using a structure-level technique that compares the ontology concepts and instances based on their relationships with other concepts or instances.

By limiting ourselves to the use of AML as the chosen ontology matching system we are also limiting the results to the AML functionalities. Therefore, in order to make a more complete and reliable analysis, this research would benefit from the use of other matching systems to compare the results obtained against the AML obtained values.

6.3 Communication

According to the DSRM activity 'Communication' we presented to relevant audiences throughout the course of this research our contributions. On Table 6.1 is a summary of the published and submitted papers.

6.4 Future Work

From the proposal presented here, have emerged some additional research ideas that can be addressed in future works, these are presented as follow:

1. First, although the ontology proposed here has been applied in COBIT 5 PAM and TIPA for ITIL, in the quest to cover a broader range of needs, we hope to extend it and include more terms and relationships of practices that can be related to other models/frameworks such us: ISO 20000 or ISO 33052. This will allow researchers, professionals, and organizations to have an extended ontology

Table 6.1: Submitted and published Papers

Towards Conceptual Meta-Modeling of ITIL and COBIT 5	
Authors	Inês Percheiro, Rafael Almeida, Pedro Linares Pinto, Miguel Mira da Silva
Conference	14th European Mediterranean & Middle Eastern Conference on Information Systems (EMCIS2017) Coimbra, Portugal, September 2017
State	Published on Lecture Notes in Business Information Processing, vol 299. Springer, Cham
An Ontology-based model for ITIL Process Assessment using TIPA for ITIL	
Authors	Inês Percheiro, Rafael Almeida, César Pardo, Miguel Mira da Silva
Conference	27th International Conference on Information Systems Development (ISD2018) Lund, Sweden, August 2018
State	Submitted
Integrating COBIT 5 PAM and TIPA for ITIL Using an Ontology Matching System	
Authors	Inês Percheiro, Bruno Borges, Rafael Almeida, César Pardo, Miguel Mira da Silva
Conference	10th International Conference on Formal Ontology in Information Systems (FOIS2018) Cape Town, South Africa, September 2018
State	Submitted

to support the assessment and improve of processes from multi-frameworks. Even, contribute in the research topic related to the harmonization of multiple models.

2. Second, it should be said that our ontology has been used to instance the terms related to TIPA for ITIL and COBIT 5 PAM, which allowed us to identify relationships between them to support an assessment process in an integrated way. Therefore, it has shown that it can also be used as a basis for supporting the design and improvement of the organization's processes of both models in an aligned way through a software tool which can systematize the assessment of organizations' processes through our ontology. The information stored will be able to be used as a benchmark of processes for other organizations, as well as to help them while defining their processes.

3. Finally, we will focus on the automation of the assessment stage, since the assessment process is currently a manual task. Therefore, as future work, the next step in this research project will focus on the development of algorithms which let us improve and extend the capability of the assessment process through the automation. However, is important to mention that our intention is not to automatize all tasks and activities involved in an assessment, but it will help to evaluators to automatize some steps to assess an organization's processes when multi-frameworks are present.

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A

Top Alignments between TIPA for ITIL and COBIT 5 PAM Ontologies Core Concepts

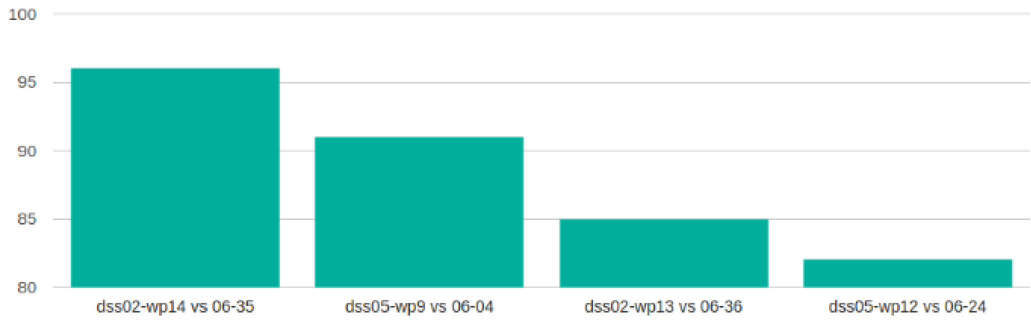

Figure A.1: Top alignments between the TIPA for ITIL and the COBIT 5 PAM work products

Figure A.2: Top alignments between the TIPA for ITIL and the COBIT 5 PAM outcomes/expected results

B

Resulting Alignments between the TIPA for ITIL and the COBIT 5 PAM Ontologies Core Concepts

Table B.1: Alignment of the individuals from the class ”Outcome” with the COBIT 5 PAM Ontology as the source Ontology and the TIPA for ITIL Ontology as the target Ontology

Outcomes		
COBIT 5 PAM as Source	TIPA fo ITIL as Target	Similarity
DSS01-01	REQF-ER1	0.1692
DSS01-02	INCM-ER3	0.2
DSS02-01	ACCM-ER3	0.3525
DSS02-02	INCM-ER3	0.8103
DSS02-03	REQF-ER4	0.5845
DSS03-01	PRBM-ER1	0.2293
DSS04-01	INCM-ER3	0.3715
DSS04-02	ACCM-ER3	0.2429
DSS04-03	REQF-ER4	0.2
DSS04-04	INCM-ER4/INCM-ER2	0.25
DSS04-05	INCM-ER6	0.1299
DSS05-01	INCM-ER4/INCM-ER2	0.2353
DSS05-02	REQF-ER2	0.1784
DSS05-03	REQF-ER1	0.253
DSS05-04	ACCM-ER2	0.259
DSS05-05	-	0
DSS06-01	INCM-ER2	0.191
DSS06-02	REQF-ER3	0.4792
DSS06-03	INCM-ER2	0.34

Table B.3: Alignment of the individuals from the class ”Work Products” with the COBIT 5 PAM Ontology as the source Ontology and the TIPA for ITIL Ontology as the target Ontology

Work Products		
COBIT 5 PAM as Source	TIPA for ITIL as Target	Similarity
APO01-WP14	02-16	0.1
APO01-WP16	04-01	0.1795
APO01-WP8	02-04	0.2025
APO03-WP6	03-08	0.3396
APO09-WP3	04-01	0.5
APO09-WP6	08-01	0.0262
APO09-WP7	01-07	0.0541
APO11-WP1	02-08	0.09
APO12-WP14	06-24	0.1645
APO12-WP15	-	0
APO12-WP16	02-05	0.0462
APO13-WP2	05-05	0.0588
BAI05-WP10	06-09	0.1389
BAI07-WP3	06-09	0.0216
BAI09-WP2	06-05	0.1435
BAI10-WP3	05-05	0.4219
BAI10-WP5	06-36	0.1188
BAI10-WP7	06-35	0.375
DSS01-WP1	08-03	0.4229
DSS01-WP10	06-09	0.019
DSS01-WP2	06-04	0.2787

Table B.3 continued from previous page

DSS01-WP3	04-02	0.2897
DSS01-WP4	05-06	0.5535
DSS01-WP5	06-36	0.6312
DSS01-WP6	03-08	0.2025
DSS01-WP7	06-35	0.3158
DSS01-WP8	06-35	0.2667
DSS01-WP9	02-08	0.1157
DSS02-WP1	02-06	0.4923
DSS02-WP10	05-02	0.5556
DSS02-WP11	07-03	0.3971
DSS02-WP12	05-02	0.3846
DSS02-WP13	06-36	0.7258
DSS02-WP14	06-35	0.8355
DSS02-WP2	04-02	0.2444
DSS02-WP3	07-02	0.1157
DSS02-WP4	07-03	0.5143
DSS02-WP5	04-01	0.2909
DSS02-WP6	07-03	0.537
DSS02-WP7	07-03	0.522
DSS02-WP8	02-06	0.584
DSS02-WP9	02-33/05-01	0.635
DSS03-WP1	02-33/05-01	0.3858
DSS03-WP2	02-33/05-01	0.4343
DSS03-WP3	05-01	0.6496
DSS03-WP4	02-16	0.201
DSS03-WP5	05-01	0.5179
DSS03-WP6	05-03	0.2733
DSS03-WP7	01-02	0.0818
DSS03-WP8	05-01	0.5547
DSS03-WP9	05-02	0.2
DSS03-WP10	05-01	0.4339
DSS03-WP11	05-02	0.1389
DSS04-WP1	08-02	0.2524
DSS04-WP2	06-24	0.162
DSS04-WP3	06-35	0.12
DSS04-WP4	08-02	0.1356
DSS04-WP5	08-02	0.0737
DSS04-WP6	01-05	0.027
DSS04-WP7	02-06	0.3321
DSS04-WP8	08-02	0.1569
DSS04-WP9	08-02	0.0734
DSS04-WP10	05-03	0.0435
DSS04-WP11	05-21	0.3353
DSS04-WP12	02-04	0.1157
DSS04-WP13	01-02	0.09
DSS04-WP14	05-20	0.0843
DSS04-WP15	02-05	0.1509
DSS04-WP17	02-05	0.1081
DSS04-WP18	06-06	0.4892
DSS04-WP19	04-01	0.1125

Table B.3 continued from previous page

DSS05-WP1	04-01	0.0545
DSS05-WP2	06-02	0.2214
DSS05-WP3	03-08	0.3441
DSS05-WP4	02-05	0.1356
DSS05-WP5	06-24	0.4252
DSS05-WP6	07-03	0.1519
DSS05-WP7	02-04	0.18
DSS05-WP8	07-03	0.1667
DSS05-WP9	06-04	0.8208
DSS05-WP10	06-24	0.6915
DSS05-WP11	06-24	0.558
DSS05-WP12	06-24	0.6274
DSS05-WP13	05-21	0.1272
DSS05-WP14	06-04	0.5601
DSS06-WP1	02-04	0.1013
DSS06-WP2	05-21	0.1343
DSS06-WP3	06-35	0.1644
DSS06-WP4	02-04	0.141
DSS06-WP5	02-04	0.1157
DSS06-WP6	05-21	0.125
DSS06-WP7	06-01	0.1059
DSS06-WP8	06-24	0.1505
DSS06-WP9	01-05	0.1236
DSS06-WP10	01-02	0.2273
DSS06-WP11	06-35	0.25
EDM04-WP5	01-01	0.1157

Table B.2: Alignment of the individuals from the class ”Base Practice” with the COBIT 5 PAM Ontology as the source Ontology and the TIPA for ITIL Ontology as the target Ontology

Base Practices		
COBIT 5 PAM as Source	TIPA for ITIL as Target	Similarity
DSS01-BP1	PRBM-BP8	0.3428
DSS01-BP2	REQF-BP3/REQF-BP2	0.5333
DSS01-BP3	EVTM-BP1	0.319
DSS01-BP4	EVTM-BP8	0.3981
DSS01-BP5	EVTM-BP2	0.2682
DSS02-BP1	REQF-BP3/REQF-BP2	0.4651
DSS02-BP2	INCM-BP3	0.5201
DSS02-BP3	REQF-BP6	0.8522
DSS02-BP4	INCM-BP6	0.9446
DSS02-BP5	INCM-BP11	0.4176
DSS02-BP6	REQF-BP8	0.935
DSS02-BP7	INCM-BP8	0.4121
DSS03-BP1	PRBM-BP2	0.5714
DSS03-BP2	PRBM-BP5	0.9275
DSS03-BP3	PRBM-BP7	0.7585
DSS03-BP4	PRBM-BP9	0.88
DSS03-BP5	PRBM-BP8	0.686
DSS04-BP1	ACCM-BP4	0.3173
DSS04-BP2	INCM-BP7	0.2788
DSS04-BP3	INCM-BP9	0.434
DSS04-BP4	EVTM-BP6	0.365
DSS04-BP5	EVTM-BP6	0.4253
DSS04-BP6	EVTM-BP4	0.1937
DSS04-BP7	INCM-BP9	0.2105
DSS04-BP8	EVTM-BP6	0.3601
DSS05-BP1	PRBM-BP8	0.3576
DSS05-BP2	ACCM-BP2	0.1895
DSS05-BP3	REQF-BP1	0.2981
DSS05-BP4	ACCM-BP6	0.4584
DSS05-BP5	ACCM-BP4	0.3504
DSS05-BP6	EVTM-BP4	0.1857
DSS05-BP7	EVTM-BP1	0.454
DSS06-BP1	INCM-BP7	0.3023
DSS06-BP2	PRBM-BP5	0.395
DSS06-BP3	REQF-BP1	0.2392
DSS06-BP4	ACCM-BP7	0.3464
DSS06-BP5	EVTM-BP1	0.2926
DSS06-BP6	EVTM-BP2	0.2683

Table B.4: Alignment of the individuals from the class "Outcome" with the TIPA for ITIL Ontology as the source Ontology and the COBIT 5 PAM Ontology as the target Ontology

Outcomes		
TIPA for ITIL as Source	COBIT 5 PAM as Target	Similarity
ACCM-ER1	DSS02-02	0.1494
ACCM-ER2	DSS05-04	0.259
ACCM-ER3	DSS02-01	0.3525
ACCM-ER4	DSS02-01	0.1827
EVTM-ER1	DSS05-03	0.2339
EVTM-ER2	DSS06-02	0.2147
EVTM-ER3	DSS06-01	0.1618
INCM-ER1	DSS02-02	0.5373
INCM-ER2	DSS06-02	0.4731
INCM-ER3	DSS02-02	0.8103
INCM-ER4	DSS06-03	0.3137
INCM-ER5	DSS02-02	0.2077
INCM-ER6	DSS02-02	0.6598
PRBM-ER1	DSS02-02	0.3382
PRBM-ER2	DSS02-02	0.2469
PRBM-ER3	DSS02-02	0.2515
PRBM-ER4	DSS03-01	0.1033
REQF-ER1	DSS02-03	0.3225
REQF-ER2	DSS02-03	0.1938
REQF-ER3	DSS06-02	0.4792
REQF-ER4	DSS02-03	0.5845

Table B.6: Alignment of the individuals from the class "Work Products" with the TIPA for ITIL Ontology as the source Ontology and the COBIT 5 PAM Ontology as the target Ontology

Work Products		
TIPA for ITIL as Source	COBIT 5 PAM as Target	Similarity
01-01	DSS01-WP4	0.4068
01-02	DSS01-WP5	0.4356
01-05	DSS02-WP14	0.468
01-07	APO09-WP3	0.2909
02-01	DSS02-WP14	0.2875
02-04	APO09-WP3	0.2388
02-05	DSS01-WP4	0.498
02-06	DSS01-WP5	0.5973
02-07	DSS01-WP5	0.5256
02-08	APO09-WP3	0.2807
02-16	DSS02-WP9	0.5858
02-33	DSS02-WP9	0.635
03-08	DSS05-WP5	0.376
04-01	APO09-WP3	0.5
04-02	DSS01-WP4	0.4068
05_01	DSS03-WP3	0.6496
05_02	DSS02-WP10	0.5556
05_03	DSS03-WP6	0.2733
05_04	DSS01-WP5	0.4441

Table B.6 continued from previous page

05_05	BAI10-WP3	0.4219
05-06	DSS01-WP4	0.5535
05-07	DSS01-WP5	0.5796
05-20	DSS02-WP14	0.2598
05-21	DSS04-WP11	0.3353
06-01	DSS02-WP13	0.5667
06-02	DSS01-WP4	0.4783
06-04	DSS05-WP9	0.8208
06-05	BAI09-WP2	0.1435
06-06	DSS04-WP18	0.4892
06-09	DSS04-WP18	0.162
06-24	DSS05-WP10	0.6915
06-35	DSS02-WP14	0.8355
06-36	DSS02-WP13	0.7258
07-02	DSS03-WP6	0.1333
07-03	DSS02-WP6	0.537
08-01	APO09-WP3	0.2685
08-02	DSS04-WP1	0.2524
08-03	DSS01-WP1	0.4229

Table B.5: Alignment of the individuals from the class ”Base Practice” with the TIPA for ITIL Ontology as the source Ontology and the COBIT 5 PAM Ontology as the target Ontology

Base Practices		
TIPA for ITIL as Source	COBIT 5 PAM as Target	Similarity
ACCM-BP1	DSS03-BP5	0.2306
ACCM-BP2	DSS02-BP3	0.6744
ACCM-BP3	DSS05-BP5	0.2105
ACCM-BP4	DSS02-BP1	0.3628
ACCM-BP5	DSS05-BP3	0.1639
ACCM-BP6	DSS05-BP4	0.4584
ACCM-BP7	DSS03-BP4	0.5637
EVTM-BP1	DSS05-BP7	0.454
EVTM-BP2	DSS05-BP3	0.2898
EVTM-BP3	DSS04-BP4	0.2668
EVTM-BP4	DSS06-BP5	0.2455
EVTM-BP5	DSS02-BP3	0.4431
EVTM-BP6	DSS04-BP5	0.4253
EVTM-BP7	DSS05-BP7	0.3213
EVTM-BP8	DSS02-BP6	0.5821
INCM-BP1	DSS02-BP5	0.3626
INCM-BP2	DSS02-BP4	0.3725
INCM-BP3	DSS02-BP2	0.5201
INCM-BP4	DSS02-BP4	0.3246
INCM-BP5	DSS04-BP3	0.2826
INCM-BP6	DSS02-BP4	0.9446
INCM-BP7	DSS03-BP4	0.5126
INCM-BP8	DSS02-BP7	0.4121
INCM-BP9	DSS02-BP6	0.4992
INCM-BP10	DSS02-BP5	0.2909
INCM-BP11	DSS02-BP6	0.8376
PRBM-BP1	DSS03-BP5	0.5122
PRBM-BP2	DSS03-BP2/BP01	0.5714
PRBM-BP3	DSS03-BP2/BP01	0.5
PRBM-BP4	DSS03-BP2/BP01	0.5
PRBM-BP5	DSS03-BP2	0.9275
PRBM-BP6	DSS02-BP5	0.3584
PRBM-BP7	DSS03-BP3	0.7585
PRBM-BP8	DSS03-BP5	0.686
PRBM-BP9	DSS03-BP4	0.88
REQF-BP1	DSS02-BP6	0.6351
REQF-BP2	DSS02-BP3	0.7241
REQF-BP3	DSS02-BP3	0.7241
REQF-BP4	DSS02-BP3	0.6563
REQF-BP5	DSS02-BP3	0.5004
REQF-BP6	DSS02-BP3	0.8522
REQF-BP7	DSS02-BP1	0.4102
REQF-BP8	DSS02-BP6	0.935