Integrating New Representation Perspectives at the Operational Level of BPM+

by

Ahmad ALOMARI

THESIS PRESENTED TO ÉCOLE DE TECHNOLOGIE SUPÉRIEURE
IN PARTIAL FULFILLMENT FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
Ph.D.

MONTREAL, MAY 11, 2021

ÉCOLE DE TECHNOLOGIE SUPÉRIEURE
UNIVERSITÉ DU QUÉBEC

BOARD OF EXAMINERS

THIS THESIS HAS BEEN EVALUATED

BY THE FOLLOWING BOARD OF EXAMINERS

Mr. Alain April, Thesis Supervisor
Department of Software Engineering and Information Technology, École de technologie supérieure

Mr. Carlos Monsalve, Thesis Co-supervisor
Department of Electrical and Computer Science, Escuela Superior Politécnica del Litoral

Mr. Amin Chaabane, Chair, Board of Examiners
Department of Systems Engineering, École de technologie supérieure

Mr. Alain Abran, Member of the jury
Department of Software Engineering and Information Technology, École de technologie supérieure

Mrs. Monica Villavicencio, External jury
Department of Electrical and Computer Engineering, Escuela Superior Politécnica del Litoral

THIS THESIS WAS PRESENTED AND DEFENDED

IN THE PRESENCE OF A BOARD OF EXAMINERS AND THE PUBLIC

ON APRIL 19, 2021

AT ÉCOLE DE TECHNOLOGIE SUPÉRIEURE

ACKNOWLEDGMENTS

First and foremost, I would like to express my sincere gratitude to my thesis supervisor Prof. Alain April for his dedicated help, advice, inspiration, encouragement, and continuous support throughout this Ph.D. journey. His guidance helped me research and write this thesis. Special thanks also go to my research co-supervisor Prof. Carlos Monsalve for his continuous support, guidance, cooperation, and insightful comments.

My sincere thanks also go to Prof. Amjad Gawanmeh who provided me an opportunity to discuss my research and to receive his guidance. I am grateful to Mr. Edouard Kodsi, from Pyx4, who facilitated the process of conducting my experiment with his company. My special gratitude goes to Prof. Amjad Al Nasser who supported me during the analysis of my experiment results and provided robust feedback to deliver the results as they are presented in this thesis.

Lastly, I would like to thank my family for all their love and encouragement: my parents, who raised me with a love of science and supported me in all my pursuits; my brother Amer, who supported me during this long journey; and, most of all, my loving and patient wife, whose faithful support during this Ph.D. is very much appreciated. Thank you.

Ajout d’une nouvelle perspective de représentation au niveau opérationnel de BPM+

Ahmad ALOMARI

RÉSUMÉ

La gestion des processus d’affaires a attiré beaucoup d’attention au cours des dernières décennies en raison des avantages majeurs qu’elle peut apporter aux organisations. Elle est devenue une discipline essentielle pour la gestion saine d’une organisation. Un concept essentiel de la gestion des processus d’affaires consiste à représenter les processus organisationnels à l’aide de représentations graphiques des processus. La représentation graphique des processus d’affaires a récemment gagné en importance, et l’utilisation des normes et notations de modélisation appropriées est un facteur important de succès pour la réussite des projets de modélisation de processus d’affaires en entreprise. L’un des principaux défis de la représentation des processus d’affaires est le choix d’une notation graphique efficace en l’absence de directives claires provenant des normes de l’industrie. Les utilisateurs préfèrent actuellement utiliser une représentation graphique populaire des processus d’affaires en se basant sur les normes de modélisation établies. Conséquemment, le marché offre plusieurs notations graphiques et la plupart des utilisateurs ont encore de la difficulté à créer un référentiel de processus intégré, d’une manière homogène, qui représente fidèlement leurs processus et ce permettant de répondre à toutes sortes de perspectives de leurs métiers spécifiques.

BPM+ est une approche novatrice de modélisation des processus d’affaires qui permet de représenter les processus d’affaires de manière cohérente et structurée afin de répondre aux besoins des différents acteurs en matière de représentation des processus. BPM+ est basée sur une hiérarchie d’abstraction des processus d’affaires en trois niveaux: stratégique, tactique et opérationnel. Cette hiérarchie d’abstraction, un peu comme des poupées russes, permet aux différents modélisateurs de représenter les processus d’affaires de l’organisation entière selon différents niveaux d’abstraction (c.-à-d. de détails et de spécialisation). L'objectif principal de cette thèse est d'intégrer de nouvelles perspectives au niveau d'abstraction opérationnel BPM + et d'évaluer comment une perspective BPM-partie prenante spécialisée / opérationnelle peut être utilisée pour améliorer le référentiel de modèles de processus organisationnels existants.

Afin d’atteindre cet objectif, cette thèse propose une méthode pour valider des représentations graphiques diverses nécessaires pour la représentation d’un processus au niveau opérationnel. Une version initiale de la nouvelle perspective opérationnelle de représentation d’un processus a été conçue en se basant sur les résultats de la revue de littérature. Cette version initiale a été affinée de manière itérative à travers une série d’analyses ontologiques suivie d’un sondage auprès de modélisateurs de processus. Une version validée d’une perspective opérationnelle d’un processus utilisant une représentation d’arbre de décision est ainsi proposée pour démontrer la faisabilité de la proposition.

Les résultats de cette recherche démontrent que:

1. Le niveau opérationnel de BPM+ permet d'inclure des modèles de processus d'affaires représentant bien les besoins spécifiques et différents de différentes parties prenantes qui désirent représenter leurs processus d'affaires au niveau opérationnel d'une organisation;
2. Une nouvelle perspective de représentation opérationnelle d'un processus, d'un arbre décisionnel, ou ses unités syntaxiques de base sont validés ontologiquement pour présenter un exemple de processus opérationnel spécifique;
3. Une extension à la notation BPMN est proposée afin de démontrer comment il est possible d'utiliser ce nouveau concept dans le langage de modélisation le plus utilisé par les utilisateurs expérimentés en BPM.

Mots-clés: niveau d'abstraction opérationnel, processus d'affaires, gestion des processus d'affaires, modélisation des processus d'affaires (BPM), notation de modélisation des processus d'affaires (BPMN), langages de modélisation.

Integrating New Representation Perspectives at the Operational Level of BPM+

Ahmad ALOMARI

ABSTRACT

Business process management has received lots of attention over the past few decades due to the significant benefits for organizations, and it became a primary discipline for operations management. An essential concept of business process management is representing organizational processes using business process models. The representation of organizational business processes in the form of business process models keeps growing in importance and appropriate modeling standards are a critical success element for successful business process modeling projects. One of the main challenges of representing business processes is that there is no definitive best way to represent them. Users prefer a common business process representation and established modeling standards. In the emerging market of business modeling standards, most users are still trying to identify which standards meet their needs.

BPM+ is a novel business process modeling approach that helps represent process models in a consistent and structured way to meet the process representation needs of different stakeholders. BPM+ is based on an abstraction hierarchy that includes three levels: strategic, tactical, and operational. This abstraction enables the business process modeling user to represent the business process at different levels of abstraction. The main goal of this thesis is to integrate new perspectives at the BPM+ operational level of abstraction and evaluate how a specialized/operational BPM-stakeholder perspective can be used to improve the existing organizational business process model repository.

In order to achieve this goal, this thesis proposes a method to define and validate the many graphical representations perspectives needed at the operational level. An a priori version of the representation perspective was designed based on the findings from the literature review. The a priori version was iteratively refined through a series of ontological analyses and a survey. As a result, an ontologically validated decision tree perspective was proposed to demonstrate the feasibility of the proposal.

The research results show that:

1. The operational BPM+ level allows for generating business process models that represent the needs of various stakeholders involved in operational business processes;
2. A new operational process perspective representation, in the shape of a decision tree and its modeling constructs, are ontologically validated then demonstrated to show an example of how an operational process can be represented; and
3. A BPMN extension is presented to show how this new perspective can be used in the modeling language most used by users with BPM experience.

X

Keywords: Operational level of abstraction, business process, business process management, business process modeling (BPM), business process modeling notations (BPMN), modeling languages.

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF ABREVIATIONS

AD	Activity Diagram
BPEL	Business process execution language
BPM	Business process modeling
BPMI	Business process management initiative
BPML	Business process modeling language
BPMN	Business process model and notation
BPMS	Business process management system
BPM+	Business process modeling approach
BWW	Bunge-Wand-Weber
EPC	Event-driven process chain
ERP	Enterprise resource planning
IDEF	Integrated DEFinition methods
IDEF3	Integrated DEFinition method 3
MLA	Multiple levels of abstraction
OMG	Object Management Group
UML	Unified modeling language
UML-AD	UML-activity diagram
WFM	Workflow management

INTRODUCTION

Most organizations look for ways to improve their productivity and operational output. To achieve this goal, some organizations focus on methods for improving how their business processes function (Elzinga, Horak, Lee and Bruner, 1995). Business process management is the domain of interest for organizations interested in improving their processes and identifying and quantifying their performance (Harmon and Wolfe, 2016). Zur Muehlem and Recker (2008) define *business process management* as “an approach for describing how businesses conduct their operations and typically includes graphical depictions of at least the activities, events/states, and control flow logic that constitute a business process.”

Harmon and Wolfe (2016) present the results of a global survey; they observe that 28% of the time organizations consider business process management initiatives as departmental initiatives and that; consequently, those companies’ business processes are not always properly documented. These survey results also show that only 2% of surveyed organizations document their business processes consistently and that their business process models are synchronized with the information-technology (IT) systems designed to support them only 3% of the time. In addition, the survey results show that 21% of organizational initiatives are led by IT stakeholders, 19% by management stakeholders, and only 15% involve top leadership.

Many organizations have invested in business process modeling (BPM) as a means to document and represent their business processes. BPM is key to documenting business operations as it improves communication between stakeholders and process automation (Becker, Rosemann and von Uthmann, 2000). An important component of successful business process management initiatives is the choice of the graphical notation to represent and communicate an organization’s business processes. Business process models represent daily business activities, events, flow controls, stakeholders, and the relationships between these elements (Bandara and Rosemann, 2005). Furthermore, these official and shared-process models improve process understanding and enable change that allows organizations to reduce costs and improve compliance and efficiency (Nasery, 2014). In addition, business process models improve awareness and knowledge concerning daily business processes and, according to Bandara et al., they reduce organizational complexity (Bandara, Indulska, Chong and Sadiq, 2007). Allowing staff to visualize business processes as business process models has become more common, leading to an increasing number of modeling tools. Appropriate modeling tools have become critical to successful process modeling initiatives (Bandara et al., 2007).

A significant issue for business process documentation is the lack of available common modeling languages to represent business processes within an organization. As a result, many initiatives produce disconnected and contradictory instructions. Management should ensure each participant uses the same modeling language and is trained on what is important and how best to represent processes before starting corporate modeling initiatives. While modeling language users prefer common data representation, organizations struggle to determine their own preferred modeling languages and how to model their organizations (Harmon and Wolfe, 2016).

According to an industrial study (Harmon and Wolfe, 2016), numerous process notation standardization efforts exist to define process related criteria. Different graphical notations are currently available, including business process models and notations (BPMN), unified modeling languages (UML), integrated DEFinition methods (IDEFs), event-driven process chains (EPCs), and Qualigram, with some of them having emerged as industry leaders. Harmon and Wolfe (2016) point to the growing importance of the Object Management Group (OMG), which has dominated process notation standards since 2010, especially in the IT domain. The Business Process Management Initiative (BPMI) developed BPMN as an easily read and comprehensible notation for business users who design, implement, or monitor business processes (Korherr and List, 2007).

BPM researchers Roker, Indulska, Rosemann and Green (2006), zur Muehlen and Recker (2008), zur Muehlen, Recker and Indulska (2007), Indulska, zur Muehlen and Recker (2009) and Wand and Weber (2002) have observed that to satisfy different modeling perspectives required by different stakeholders, current BPM languages are becoming more complex, which is a key reason why modeling languages might not be capable of producing effective models. This reduces modeling-language efficiency and the possibility of producing a common understanding of resultant models.

To assess if a modeling-language adequately represents what it intends to convey, Wand and Weber's developed a representation theory known as the Bunge-Wand-Weber (BWW) representation model (Green, Rosemann, Indulska and Recker, 2006). This representation model might be used for the evaluation of a modeling language's representational capabilities, and to determine the completeness and clarity of any modeling notation. According to Wand and Weber (1993), for a modeling notation to be ontologically complete, it should be mapped and integrated with each of the representation model's concepts. If the mapping is one to one, then the notation is ontologically clear. Any ontological deficiency is caused by a deviation from this one-to-one mapping. According to Wand and Weber, ontological deficiencies include construct overload, construct redundancy, and construct excess.

Also, despite the growing complexity of BPM notations, they still cannot satisfy all the modeling needs of the different stakeholders. Furthermore, some researchers report that various businesses are looking for single modeling notations that allow effective communication and participation for all of their stakeholders (Indulska et al., 2009; and Curtis, Kellner and Over, 1992).

Previous research by Monsalve, April and Abran (2011), Monsalve, April and Abran (2013) and Monsalve (2012) reported that the proposed process modeling approach (BPM+) helps provide modeling concepts for representing modeling needs and constraints of different stakeholders, especially since BPM+ includes multiple levels of abstraction (MLA) for the purpose of representing process information that addresses concerns of different types of stakeholders. BPM+ was originally designed to include three levels of abstraction: strategic, tactical, and operational. Many publications have already focused on the first two levels (Monsalve, April and Abran, 2011, and Monsalve, 2015). This research focuses on the third level, i.e., the operational level of abstraction. This abstraction level is meant to represent process models according to operational stakeholder perspectives. So, this research is interested in what type of business process models might better suit the stakeholder needs at operational levels.

Purpose and research questions of this thesis

The purpose of this thesis is to improve the representation of business processes by proposing new representation perspectives for the operational level of abstraction. The primary research question concerns how multiple representation perspectives for the operational level of abstraction can effectively improve the existing organizational business process model repository. This research question includes the following sub-questions:

- What do specialized/operational BPM stakeholders think about BPM+'s third level of abstraction (the operational level) proposals?
- How well do current business process modeling notations represent the operational level of abstraction and its modeling constructs?
- What could be useful operational level representations of business processes?

Research goal, objectives, and scope

The overall research goals are to:

1. List some possible specialized operational representations that have potential for use;
2. Evaluate/validate one representation using the Bunge-Wand-Weber (BWW) representation model;
3. Ask BPM users what they think of the usefulness of the proposed concept of a specialized representation at the operational level;
4. Extend the existing BPMN notation to add this new validated representation to show how BPMN extension can be easily used in future BPM projects to validate and add any specialized representation needed.

To achieve these goals, the thesis objective is to study possible business process operational representation perspectives and choose one specialized operational level representation to be added at the operational level of BPM+ as a new representational perspective. To achieve this research objective, the following specific research sub-objectives are defined:

- Identify potential specialized representation perspective that could be integrated at the operational level of process models;
- Identify one and define its modeling concepts to represent a new specialized perspective at the operational level;
- Evaluate the new representation perspective proposal with BPM practitioners and determine what they think about process models generated using the new operational perspective concept;
- Evaluate how well current BPM notations could include and represent this new operational perspective.

Because BPM languages and notations have been increasingly introduced for BPM, Ko, Lee and Wah (2009) have classified BPM notations and languages into four categories: graphical languages (e.g., BPMN), execution languages (e.g., business process modeling language (BPML), interchange languages (e.g., business process definition model (BPDM), and diagnosis languages (e.g., business process query language (BPQL)).

This research is interested in using graphical notations because this BPM category typically allows specialized stakeholders to express their business processes in a diagrammatic way (Ko et al., 2009), and enables users to communicate business information flows, decisions, and roles. Also, among the four aforementioned modeling-notation categories, graphical notations are the easiest to understand and read without prior or in-depth technical training (Ko et al., 2009).

Thesis organization

The rest of the thesis is outlined as follows: Chapter 1 is the literature review and presents an overview of the state of the art and related work. It also discusses the background and theoretical foundations of this research. It introduces the reader to the terminology of the BPM domain, then, describes existing studies pertinent in solving this thesis's research questions. It also presents current problems unsolved by industry or academic research initiatives, as well as accepted BPM techniques and approaches that can be used in this research.

Chapter 2 addresses the planning and research methodology, as well as its activities and expected results. It introduces the research problems, and the proposed experimental design used to contribute to their solution. Then it presents a description of the research plan, the details of the evaluation and experimental activities, and their execution. It also presents the interpretation of the results observed from the execution of the research activities. This chapter discusses each of the main research methods/techniques used during the execution of the research activities. It presents the complete research design and validity concerns for each research method/technique.

Chapter 3 presents the development lifecycle of a decision tree as the chosen example to operational perspective and its integration process at the BPM+ operational level. It discusses the proposed modeling-perspective version that has been built based on this thesis's literature review results. We study and improve this initial version through research methods/techniques, including representational analyses and a survey, and propose a final version.

Chapter 4 covers the test of the set of propositions defined to evaluate the operational level of BPM+ according to the findings from a survey conducted with BPM practitioners.

Chapter 5 presents the development steps of a BPMN extension to incorporate the decision tree perspective into Business Process Diagrams and demonstrate its possible use in the most popular graphical notation.

Finally, the thesis conclusion summarizes this research's main contributions, and it presents the expected impacts of this research work, it's limitations and proposes recommendations for future research work.

CHAPTER 1

LITERATURE REVIEW

This chapter introduces the terminology of the BPM domain to the reader. It presents definitions (i.e., business process model, business process, etc.). Section 1.1 defines and discusses the notion of business process. Section 1.2 introduces the topic of business process management. Then, section 1.3 explains what a business process model (BPM) is.

Increased interest in business process management has resulted in a growing number of modeling notations for modeling business processes. Sections 1.3.2 and 1.3.3 introduce the most popular modeling notations currently available.

Because business processes involve many types of elements (e.g., activities, roles, events, etc.), modeling a business process is vital to creating robust processes. Modeling is meant to impose the types of elements that should be modeled, with each stakeholder presenting specific needs for a type of element that should be modeled in a business process model (Luo and Tung, 1999) and (Rosemann and Green, 2000). A business process model for documenting a business process might look different from a business process model that aims to automate the same business process. Selecting the right types of elements that will be represented by a business process model depends on the needs of a specific stakeholder when performing a specific task. The literature has reported the difficulty of representing all possible needed types of elements with one single BPM notation (Dreiling, Michael, van der Aalst and Sadiq, 2008; Van Nuffel and De Backer, 2012), and it has proposed multiple approaches to solving this problem. Section 1.4 aims at presenting the work of some authors where some of these approaches introduce the notion of representation of several BPM perspectives, while other authors suggest that it is best to use the notion of multiple levels of abstractions (MLA) that will be discussed in section 1.5.

This literature review then presents a framework for assessing BPM notations, focusing on the representational capabilities of BPM notations to represent specific modeling needs and constraints. This notation assessment framework follows an assessment technique based on a well-established ontology of this field of research. Section 1.6 reviews this ontology-based assessment technique and how it is used.

Finally, in section 1.7, the literature review presents the proposed enhancement to the BPM+ process architecture at the third level of abstraction. BPM+ was initially proposed by our research lab and already provides modeling concepts that help BPM participants select the correct modeling elements to better structure and represent their business processes for levels 1 and 2 of abstraction. This thesis contribution is aimed at the level 3 of abstraction. The reader must understand that BPM+ includes the notion of multiple levels of abstractions; it is well suited to help different types of stakeholder concerns.

1.1 Business process

Many definitions of the business process can be found in the literature. Each definition is different based on the author's viewpoint and publication context. The following are some of the most popular interpretations of a business process.

Ljungberg (2002) defines a business process as "a repetitively used network of orderly-linked activities using resources for transforming inputs into outputs, extending from the point of identification to that of the satisfaction of the customer's needs." This definition highlights the business process objectives, the key to which is the provision of an overview of organization activities and helping the organization achieve customer satisfaction via available resources. Hammer and Champ (1993) extend the reach of this definition by making it more inclusive: "A business process is a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer. A business process has a goal and is affected by the events that occur in the external world or other processes."

Eriksson and Penker (2000) define a business process as a means that "emphasizes how work is performed, rather than describing products or series that are a result of a process." Davenport (1992) supports the Eriksson and Penker (2000) viewpoint when he describes a business process as "simply a structured set of activities designed to produce a specified output for a particular customer or market," emphasizing how work is carried out within an organization rather than focusing on products or services provided. In this perspective, a process is thus a specific ordering of work activities across time and place with a beginning, an end, and identified inputs and outputs. It is, in other words, a structure for action (Aldin and de Cesare, 2011).

For this research, a "business process is a set of one or more linked activities executed following a predefined order which collectively realize a business objective or policy goal, normally within the boundary of an organization defining functional roles and relationships. A business process is typically associated with operational objectives and business relationships" (Nasery, 2014). To be effective, a business process should be directed, using all available information and resources to achieve a goal, which, typically includes a series of structured activities that transform inputs into outputs, providing value to a customer, or adding value to the market in the process. An activity might be triggered by an internal or external event, but it is executed by stakeholders playing specific roles and using organizational resources.

1.2 Business process management

Given growing wants of organizations to remain competitive in local and international marketplaces, business process management has become a critical business priority and research subject (Harmon and Wolfe, 2016). It is the logical continuation of the interest in business processes that started three decades ago, peaking in the mid-90s with Six Sigma, Business Process Reengineering, and Workflow (Harmon and Wolfe, 2016). Business process management is aimed to ensure business processes support businesses and contribute to an organizations' goals.

Business process management has different contextual meanings. For example, Elzinga et al. (1995) state that business process management provides a comprehensive method for evaluating and improving an organization's business processes, defining the term as: "a systematic structured approach to analyze, improve, control, and manage business processes with the goal to improve quality of products and services."

Alternatively, Gao and Jia (2011) define the term as "a field of knowledge at the intersection between business and IT, encompassing methods, techniques and tools to analyze, improve, innovate, design, enact and control business processes involving customer, human, organization, application documents and other sources of information."

Recker et al. (2006) take a more general view but nevertheless support the above concepts, defining business process management as "a structured, coherent and consistent way of understanding, documenting, modeling, analyzing, simulating, executing and continuously changing end-to-end business processes and all involved resources in light of their contribution to business performance."

According to van der Aalst, ter Hofstede and Weske (2003) business process management "support[s] business processes using methods, techniques and software to design, enact, control, and analyze operational processes involving humans, organizations, applications, documents and other sources of information."

Comprehension of business process management includes the study of business process management lifecycles, the most popular view of which is van der Aalst's et al. (2003). Figure 1.1 shows a business process management lifecycle, adapted from Dumas, van der Aalst and ter Hofstede (2005), consisting of four stages: the process design stage, the system-configuration stage, the process enactment stage, and the diagnosis stage.

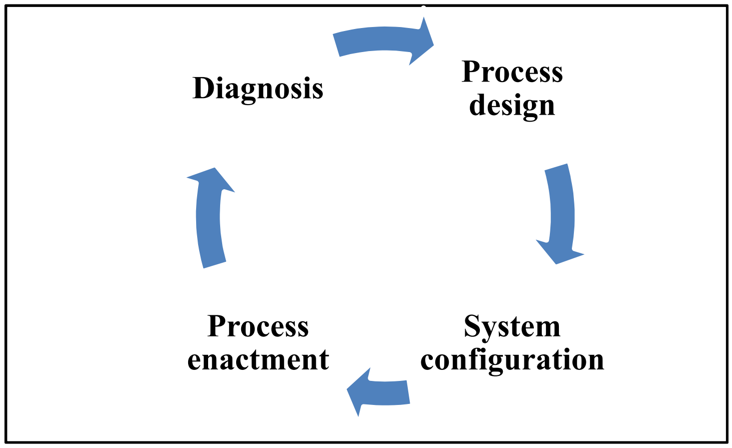


Figure 1.1 The business process management lifecycle
Adapted from Dumas et al. (2005)

A business process management system (BPMS) is a software tool that supports the management of such operational processes. In the process design phase, business processes are modeled into BPMS. This stage often uses graphical notations. The system-configuration phase configures BPMS and related system infrastructure. The enactment phase deploys business process models in BPMS engines. In the fourth phase, diagnosis, business process management analysts analyze business processes to identify problems and improve loopholes. The monitoring tools used for the analysis are already part of the diagnosis standards.

This research favours Monsalve's (2012) definition of *business process management*; a structured management approach can be used to monitor and optimize business processes, allowing all participants to understand them, in order to achieve the organization's goals. This definition supports the research goal: the development of a new business process representation perspective at the BPM+ operational level.

Business process management is not the automation of manual tasks, workflow, or the reengineering of an organization but an approach that supports any of these systems. Of the four business process management lifecycle phases, this thesis focuses on the first one:

Business process design and modeling. Section 1.3 will introduce baseline BPM concepts and review some of the most popular languages and standards.

1.3 Business process modeling

Davenport (2005) and Curtis et al. (1992) define business process modeling as "an approach for describing how businesses conduct their operations and typically includes graphical depictions of at least the activities, events/states, and control flow logic that constitute a business." A study by Indulska, Green, Recker and Rosemann (2009), involving academics, practitioners, and experts, explored benefits related to process modeling use and showed that process improvement, process understanding, and process communication are the most important benefits of using BPM in an organization. Other authors such as Kerasi, Chang and Seddon (2003) and Indulska et al. (2009) agree that BPM use in organizations facilitates and improves internal communication about process execution. Furthermore, Kesari et al. (2003) claim significant benefits when graphically representing business processes through modeling.

1.3.1 What is a business process model?

A model is a representation of the construction and working of a system (Maria, 1997). Curtis et al. (1992) define a model as "an abstract representation of reality that excludes much of the world's infinite detail." They stipulate that the model's main purpose is to minimize complexity, simplify understanding, and eliminate details of a system to enable practitioners to predict the effect of system changes. In this context, BPM is an abstract description of an actual business process that represents proposed process components considered important to the model's purpose and which can be enacted by a human or a machine (Curtis et al., 1992).

In addition, modeling a business process involves workflow specification, which leads to capturing process abstraction. Process abstraction levels fall into two categories: high and low, depending on the workflow specification's actual use. In other words, modeling may describe a process at the highest conceptual level necessary to understand, evaluate, and redesign its methods. On the other hand, another modeling action may describe the same process at a lower level of detail that is designed for performing process implementation. A clarification for this thesis and its scope in relation to BPM is important because business process modeling at the lower level (implementation and enactment phases) might also be required.

An organization's BPM project can be affected by the modeling notation. Choosing the right modeling notation for process modeling is key to a BPM project's success (Bandara and Rosemann, 2005). The following sections review the most popular BPM notations.

1.4 BPM languages

Increasing interest in BPM has resulted in the emergence of various BPM graphical representations and standards (Peixoto, Batista, Atayde, Borges, Resende and Pádua, 2008). Consequently, organizations need to choose an appropriate BPM notation for modeling their business processes. According to Recker, Rosemann, Indulska and Green (2009), existing BPM notations can be categorized into two groups:

1. Graphical modeling notations, such as EPC, mostly concern the capture and understanding of processes for project-scoping tasks and for discussing business requirements and process improvement initiatives; and
2. Other BPM-notation groups, such as Petri nets, are based on rigorous mathematical paradigms and can be used for process analysis, process execution, or experimentation with different process scenarios (Recker et al., 2009).

This research focuses on the graphical notations group since it was established specifically for the BPM-lifecycle design phase (Ko et al., 2009). According to Harmon and Wolfe (2016) and Ko et al. (2009), the graphical notations most frequently used for modeling business processes at the design phase are BPMN, architecture of integrated information systems (ARIS) EPCs, Activity Diagram, and IDEF notations. The next sections summarize these four notations.

1.4.1 Business process model and notation (BPMN)

BPMI released the BPMN notation in 2004. The notation was adopted by OMG in 2006 and is now a popular standard (Prezel, Gasevic and Milanovic, 2010). The main goal for BPMN was to provide a graphical notation comprehensible to all business users (Prezel et al., 2010). In addition, BPMN specifies business processes via a business process diagram based on a flowcharting technique like activity diagrams used by the UML standard (Prezel et al., 2010). BPMN is a rich modeling notation that includes constructs for the representation of various types of control flow and events. Rosemann, Recker, Green and Indulska (2009) presented a study of how various BPM notations become more expressive over time. Their study shows that BPMN, for representing business processes, seems to be the most appropriate notation among all the other BPM graphical notations studied, including ARIS EPC, IDEF, and Activity Diagram notations (Rosemann et al., 2009). Furthermore, a 2016 survey by Harmon and Wolf (2016, p. 29) claims BPMN continues to interest users as a process modeling notation standard.

1.4.2 Integrated definition method 3 (IDEF3)

IDEF is a family of modeling languages that includes IDEF0, IDEF1X, IDEF3, IDEF4, and IDEF5, and is most closely related to the integrated computer-aided manufacturing domain. The IDEF language uses computer technology to improve manufacturing productivity and was initially intended for system engineering. After its implementation, it was also extended to support modeling methods for software-system analysis and design (List and Korherr, 2006).

IDEF3 was also designed to model business processes and system sequences. This is achieved by providing two perspectives: the process schematics (i.e., the process sequence's model) and the object schematics (i.e., the model of objects and their changing states throughout a process) (List and Korherr, 2006).

1.4.3 Unified modeling language (UML)

UML is an object-oriented notation that embodies a set of formalisms for capturing the detailed design aspects of software systems. UML is important for software modeling and design, it can be tailored to several purposes, and its activity diagram (AD) can be used for BPM (Maria, 1997). UML was generated to help with developing software and understanding user requirements needed in the software. The main concepts of the AD are actions and swim lanes (List and Korherr, 2006), which provide a high level means of modeling dynamic system behavior (Kühne, 2005).

1.4.4 Event-driven process chain (EPC)

EPC is a BPM language that provides a comprehensive means for modeling relevant business process aspects (Recker et al., 2006). In addition, EPC provides various links that allow for the alternative and parallel execution of processes (van der Aalst et al., 2003). Many popular companies worldwide have used EPCs, such as SAP, to model their business processes. There are two main elements employed for describing system activities in EPC diagrams: functions and events. Functions model the activities of a business process, while events are created by processing functions or actors outside of the model (Kühne, 2005).

Finally, from these four BPM notations, BPMN has been selected as one of the notations to be used by this research because of these reasons: the notation’s growing popularity, it is a recognized standard by the OMG, and it has a high degree of completeness. Evidence shows that organizations often look for simplicity and ease of use in a BPM notation (Monsalve, 2012). BPMN, though, is a complex BPM notation. To consider and address this concern, this thesis has selected the management-oriented notation Qualigram (Berger and Guillard, 2000). Section 1.4.5 reviews Qualigram notation in more detail.

1.4.5 Qualigram notation

The Qualigram notation is a management centric BPM notation that facilitates documentation and communication of business processes (Berger and Guillard, 2000). Qualigram structures business processes by using three modeling levels (see Figure 1.2). The highest level of abstraction (the strategic level) uses notation to describe the high-level business processes of an organization and typically achieves this by representing the organization's context and strategic aspects, including policies to be implemented, objectives to be reached, and interactions between various identified high-level objectives. This level is meant to represent business processes from the point of view of organizational strategy. It is often referred to as the metaprocesses of an organization.

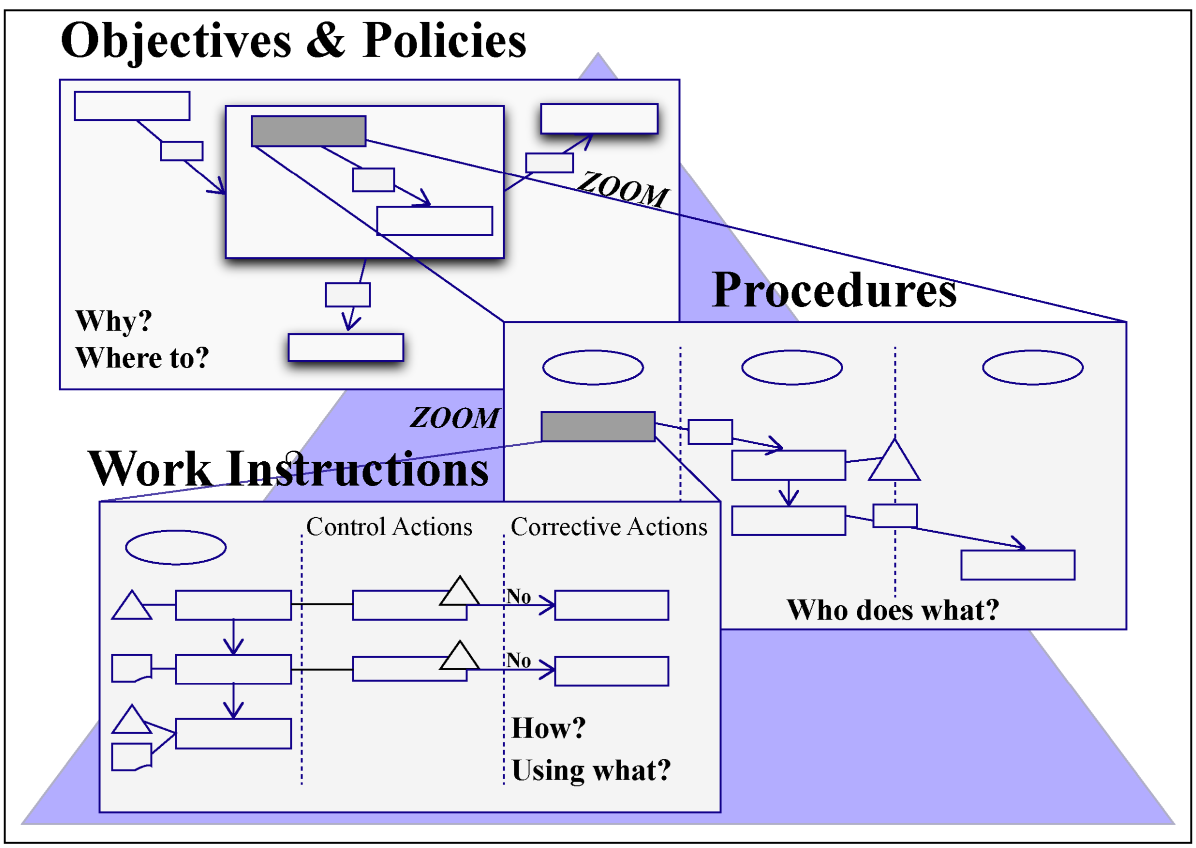


Figure 1.2 Qualigram notation's three levels of abstraction
Adapted from Berger and Guillard (2000)

The intermediate level of abstraction concerns the tactical models of the organizational procedures of the actions to be performed, the roles performing those actions, the information those roles will exchange, and the tools they will use. This level indicates “who does what” tasks in the organization. Finally, the lowest level of abstraction is the operational level, which graphically represents work instructions, aiming to show how an operational stakeholder in the organization performs a specific activity.

A Qualigram diagram is easy to interpret. Each level of abstraction shows process models based on four concepts using the corresponding graphical forms: action, entity, tool, and information. Variants of the action forms illustrate processes, procedures, work instructions, and elementary operations. Variants of the entity form represent roles (internal and external), departmental units, and external entities. The tool form represents any kind of physical equipment or document produced or used by an action. The information form appears for the input and output flows of detail between the various types of elements. Since Qualigram is a simple modeling notation, it is easily understood by most stakeholders in an organization (Berger and Guillard, 2000).

Our main reasons for choosing the Qualigram notation for this work are that: it represents a manager’s perspective, it implements the ISO 9001 recommendation for describing and structuring processes (i.e., a quality-management system) using Anthony’s model recommendation (ISO 9000), and it uses a hierarchy of abstraction levels.

Section 1.5 debates the impact on business processes caused by the presence of various BPM perspectives in a typical BPM project.

1.5 Elements of a business process for representation

A business process mainly includes actors, roles, activities, events, inputs, outputs, resources, objects to be transformed, customers, and goals to be achieved. Medina-Mora, Winograd, Flores and Flores (1993) identify actors as the most important business process element, whereas Curtis et al. (1992) emphasize the representation of the coordination activity, even if manually performed. Eriksson et al. (2000) focus on a holistic representation of business processes that covers its purposes and the activities in achieving those goals. According to Berger and Guillard (2000), a “good” business process model is supposed to add a logical sequence of actions, the responsibilities of individuals accountable for the execution of processes, and the information flow among these different roles. White (2004) identifies activities and flow control as the most important elements. Finally, Wohed, van der Aalst, Dumas, ter Hofstede and Russell (2006) believe the representation of resources related to the business process to be modeled is more important.

This research identifies a number of important elements that should be represented in a business process model. Different authors emphasize different business process elements, which leads to the need for several perspectives of a given business process. The next sections further review and discuss the necessity for different BPM perspectives and identify the most available versions.

1.5.1 The necessity of BPM perspectives

A business process modeller’s point of view greatly influences the representation of a business process model. To represent the business process from different perspectives, different models are often created, resulting in duplication and confusion. Several publications support the need for modeling various perspectives in a typical BPM project (Becker et al., 2000; Georgakopoulos, Hornick and Sheth, 1995; Smith and Fingar, 2007).

Many stakeholders are involved in a typical BPM project (Becker et al., 2000; Georgakopoulos et al., 1995; Smith and Fingar, 2007). Business process models should be understandable to each stakeholder, provide stakeholders a common vision, and allow for easy communication among stakeholders. Usually, management and IT stakeholders will both take part in a project. These stakeholders have different cultures, necessities, and goals. IT stakeholders typically focus on the implementation and enactment phases of the BPM-project lifecycle. Management stakeholders are usually more involved in the design, and diagnosis phases. Employees assigned to these projects by each stakeholder group represent their own needs, which can include different perspectives, sometimes using different notations, while also representing the overall business process. Resulting BPM-project representations demonstrate both few similarities between these different perspectives and characteristics unique to each.

Each stakeholder needs different information from the same business process (Georgakopoulos et al., 1995; Curtis et al., 1992, Becker et al., 2000; Milanovic and Gasevic, 2009; zur Muehlem, 2004). Thus, a BPM project should include different perspectives of the same business process. These perspectives should complement each other and include the most important business process elements and information. Each perspective constitutes one layer of the overall development within which each stakeholder can draw from other layers to help them achieve their goals.

The most common BPM perspectives proposed in academia are presented in the following section.

1.5.2 Business process perspectives

The previous section concluded that different business process perspectives should be included in a BPM project to fulfill various modeling needs required by the two different stakeholders: IT and management. Table 1.1 shows the literature-review results related to these perspectives which have been classified into categories.

Table 1.1 Business process model perspectives
Adapted from (Monsalve, 2012; Monsalve, April and Abran, 2013)

Perspectives					
Curtis et al. (1992)	Functional	Behavioral	Organizational	Informational	
Eriksson and Penker (2000)	Process + Behavioral			Structural	Vision
Dumas et al. (2005)	Operation	Process	Data/information	Organizational	Integration
Engels, Forster, Heckel and Thone (2005)	Action and Control flow + Interaction		Data and Object Flow + System Specific	Organizational Structure	
Scheer, Thomas and Adam (2005)	Output + Function	Control	Information	Organizational	
List and Korherr (2005)	Functional	Behavioral	Organizational	Informational	Contextual

Curtis et al. (1992) categorize four types of perspectives: functional (representing the *what*), behavioral (modeling the *when* and *how*), organizational (abstracting the *where* and *who*), and informational (modeling the information entities). Eriksson and Penker (2000) also categorize four different perspectives: process (e.g., activities, resources, and value added), behavioral (e.g., states and transitions), structural (e.g., organizational structure, products, and service structure), and vision (e.g., vision, goals, and problems). Dumas et al. (2005) present five perspective types: operation (i.e., atomic elements), process (i.e., control flow), data/information, organization (i.e., structure of resources), and integration. Engels et al. (2005) offer five different perspectives: actions and control flow, interaction, data and object flow, system specific, and organizational structure. Scheer et al. (2005) also propose five perspectives: output (e.g., materials, products, and services), function (i.e., activities and their interactions), control (i.e., integration of all the perspectives and control flow), information (e.g., information services, information objects, and data flow), and organizational (i.e., organizational units, their interactions, and their resources). Finally, List and Korherr (2005) append a “business process context” perspective to Curtis’s proposition.

Consequently, finding a perspective group that works for every BPM project is difficult. So, too, is using a single BPM notation for the representation of all required perspectives (Curtis et al., 1992; Lankhorst, 2009; Lind and Seigerroth, 2020; van Nuffel and De Backer, 2012). While several conventions, techniques, and multiple BPM notations address this challenge (Curtis et al., 1992; Smith and Fingar, 2007; Lankhorst, 2009; Harmon and Wolfe, 2016, zur Muehlen and Ho, 2008), using too many notations in a BPM initiative might cause other problems, like miscommunication, rework, and delay. Many researchers identify current BPM notations as highly complex, especially because stakeholders use them for different modeling perspectives (Indulska et al., 2009; Curtis el al., 1992; Mendling, Reijers and Cardoso, 2007).

So far, this thesis has summarized the need for different perspectives and the challenges of selecting a BPM notation to represent all perspectives. Studies show that using BPM with MLA helps represent process information that addresses the concerns of different types of stakeholders (Monsalve, 2012). Section 1.6 summarizes the use of MLA in recent BPM contributions.

1.6 Multiple levels of abstraction (MLA) for BPM

Drawing on key BPM research publications, this section explores MLA as applied to BPM. Section 1.6.1 presents the theoretical fundamentals of incorporating MLA into a BPM. Section 1.6.2 delves into the utilization of BPM in process-oriented approaches. The literature agrees that three abstraction levels are adequate to represent all processes of an organization that uses BPM, although authors disagree about what content makes up those levels. Finally, this section summarizes research proposals and case-study experiments aimed at ascertaining what can be learned from both management and IT perspectives.

1.6.1 Theoretical foundations

Development of business process management has focused on making businesses more competitive in their respective markets (Elzinga et al., 1995). Monsalve et al. (2011) present business process management as a management approach rather than as a technology or information system. Smith and Fingar (2007) differently stipulate that business process management is often considered nothing more than an IT initiative a core reason why organizations have not successfully benefitted from business process management and have difficulty recognizing BPM’s proprietary and real benefits. Organizations need to understand that the use of MLA, when representing processes, goes beyond management-oriented and IT-oriented needs when both stakeholder groups are actively participating in a BPM project. Researchers argue that MLA is necessary for effective representation of processes for multiple user types with multiple needs (Curtis et al., 1992; Berger and Guillard, 2000), especially when management and IT are both involved in a BPM project. Burton-Jones and Meso (2006) argue that research within an organization should be conducted through a multilevel approach but on an individual level foundation.

MLA representation of business processes accommodates the need for multiple perspectives of an organization’s managerial and technical activities. MLA use for business process representation originates from theories of organizational management, management-information systems, and decision-support systems. Anthony’s model posits three levels of abstraction (Anthony, 1965): strategic planning, management control, and operational control. Strategic planning includes all activities related to the policies and objectives of an organization; management control focuses on the efficient use of the resources of the organization; and operational control focuses on performance, analyzing how individual tasks are accomplished efficiently and effectively. Researchers report that organizations commonly use these process classifications when studying MLA because this three-tier classification provides users with a common and easy-to-understand approach for business process objectives and purposes.

Actors within organizations often handle activities of different levels that require various levels of information. Authors like Gorry and Scott-Morton (1989) have also observed that problems are becoming more complex given organizations are seeking solutions that are not the responsibility of individuals but teams; organizations should, therefore, establish robust team-member coordination. Courtney (2001) states that information support systems focus has shifted from the individual level to the organizational, having progressed through the group level. Organizational knowledge is a "collective mind" that requires "communications between individuals," "sharing of knowledge," and "coordinating actions" (Courtney, 2001). These collaboration levels require all stakeholder points of view.

Different business process approaches have commonly used MLA, especially within organizations with multiple types of stakeholders requesting detail and information of different levels. The following sections review MLA use in: management- oriented approaches, BPM notations, and BPM research proposals.

1.6.2 MLA within management-oriented approaches

The balanced score card indicates four key process perspectives to adopt: financial, customer, internal process, and innovation/learning (Kaplan and Norton, 2007). These perspectives must be internally applied to an understanding of an organization's core business process elements, each of which, in turn, becomes defined by a triple-layered structure based on mission, objectives, and measures. Drawing upon the ISO 9000 standards, three further levels of documentation are recommended: the quality manual, the descriptions of processes, and the support records (ISO, 2008). The ISO standards reflect the three levels of managerial duties: strategy, tactics, and operations (Berger and Guillard, 2000). Several researchers attest to the affiliation between ISO 9000 and BPM objectives (Berger and Guillard, 2000; Hoyle, 2009; ISO 2008, 2012; List et al., 2005; Zairi, 1997). Elzinga et al. (1995) and Harmon and Wolfe (2016) also detail cases demonstrating that businesses acquainted with ISO 9000 are better positioned to take advantage of BPM.

Introduced in 2008, the supply-chain-operations (SCC, 2008) reference model proposes another three-tiered reference model of the process description: the top level covers processes an organization pursues with its scope of vision; the middle level allows for configuration and strategy, determining organizational direction; and the process element level covers decomposition and the clearest detail possible of each process. Although these are clearly defined, the supply-chain-operations reference model also allows the inclusion of additional abstraction levels for organizations wishing for further decomposition and processes implementation.

1.6.3 MLA within BPM notations and approaches

As discussed earlier, Qualigram represents abstraction in three levels: the top, the intermediate, and the lowest. The top level establishes a model for the process, asks *why* and *where to*, is focused on determining reasons for the current structure in place, and defines goals. The intermediate level models the procedures, asks *who* and *what*, and addresses how organization goals are pursued and achieved. The lowest level models work instructions, it asks *how* and *using what* and focuses on the control of specific tasks. Qualigram is a management-oriented BPM notation designed to suit all fluid elements of management processes and does not aim to establish foundations for information system development.

Put forward by the likes of Scheer et al. (2005), Davis (2008), and Scheer and Schneider (1998), the architecture of integrated information systems (ARIS) consists of five enterprise perspectives (organization, data, flow, output, and control), each of which presents three description levels (strategy, design specification and control, and implementation). This structure provides an abstraction hierarchy and is IT-focused. Also, ARIS suggests a BPM hierarchy consisting of three levels of abstraction: high level processes, functions, and tasks. ARIS is chiefly employed to transform business processes into clear information systems (Davis, 2008).

BPMN is not as clearly layered but focuses on assessing the level of detail management and IT require; thus, it offers a granular approach with a unified representation. BPMN offers two sets of modeling constructs: the basic set of constructs called the BPMN core modeling set and, the extended BPMN modeling set (OMG, 2013). The BPMN core modeling set is meant for documentation and communication purposes, and the extended BPMN modeling set is for developing more detailed models, devoted to BPMS implementations (OMG, 2013; White, 2004). BPMN also outlines three types of models: processes, choreographies; and collaboration (OMG, 2013).

The process model includes: private nonexecutable models, private nonexecutable models, and public models. A private executable model is a process modeled with the objective of being executed; the private nonexecutable model aims to document a process according to a user-defined detail level. The public model represents a private nonexecutable model interacting with another process or participant. The public model includes activities requiring communication with other participants. Internal activities of the other process or participant must not need to be shown. As a result, the public model shows message flows to the outside world and their order, thus demonstrating how interactions occur.

The choreography is self-contained because it does not exist within a pool but between business entities, pools, or participants. Finally, collaboration models depict interactions between two or more business participants and tend to contain two or more pools that represent each participant. A message flow then demonstrates the message exchange between the participants, connecting two of the pools or the objects within them (Figure1.3). The messages associated with the message flows should be shown.

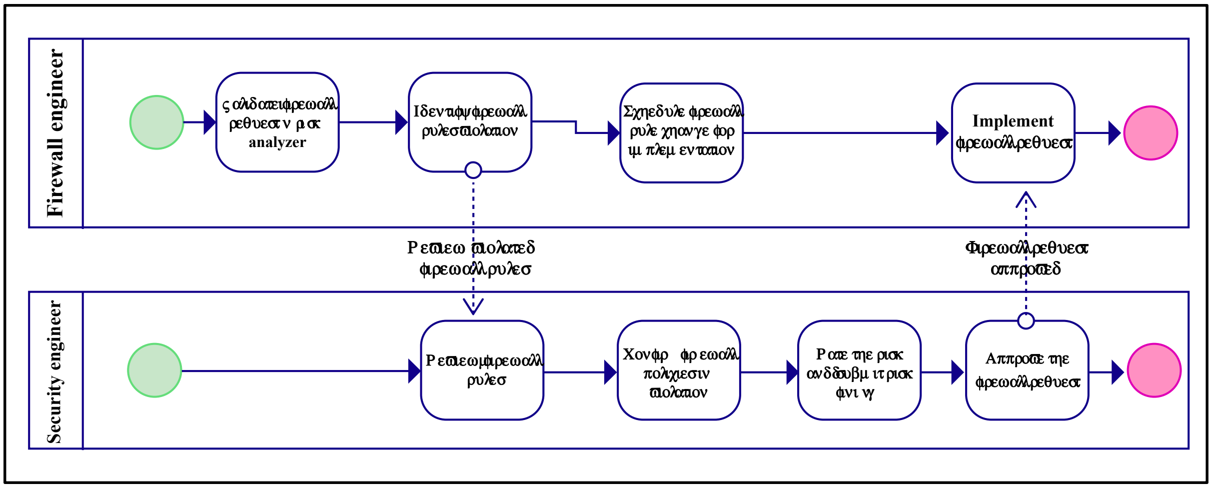


Figure 1.3 An example of a collaborative process

Silver (2009) proposes a style to BPMN modeling by splitting a model into three use levels organized to suit BPMN criteria–descriptive, analytical, and executable. Though the overall structure is simple, each of these levels has a specific methodology that users need to fulfill to meet the BPMN objectives in the semantics-of-modeling constructs used throughout a BPMN initiative. The descriptive level represents the main business process workflow for business and management users using the core elements set of BPMN. The analytical level delves into the detail used to depict all potential operations and activities a business process incorporates to achieve its goals but leaves out anything technical that can be defined as executable. All modeling constructs offered by BPMN can be used at the analytical level. Lastly, the executable level draws on the extensible markup language (XML) that concerns software engineers wanting to build a software system that is compliant with a business process model. The descriptive and analytic levels focus on visible elements and a minimal subset of supporting attributes/elements.

1.6.4 Research proposals for MLA in BPM

According to Bhat and Deshmukh (2005), a robust and versatile business process needs to be effectively modeled at MLA. Doing so best ensures all involved stakeholders share goals and vision. This can be achieved by top-level modeling of an organization's main processes with a low level of detail. The hierarchy offers two further levels of abstraction: the workflow and task levels (or, respectively, intermediate and lowest). The intermediate level represents the workflow for each business process and is vital for covering sub-processes. The lowest level represents sub-process details, handling individual responsibility within the process and required technical guidance.

Haque, Pawar and Barson (2003) claim organizational aspects are just as important as technical ones. Their research shows how overreliance on technological expertise can allow organizational aspects to be overlooked, negatively impacting results. Collaboration is essential to handling complex issues requiring skills and expertise. Key failures include “lack of communication and collaboration between internal functions and external partners” and a “weak process understanding across functions” (pp. 148–149), which affects integration of all roles and talent. A vision that transcends departmental divides crucially allows needed information to be imparted and facilitates cooperation and communication, providing a clear business process representation. Haque et al. (2003), advise three abstraction levels: the operational-team-and-detailed-operational-process level, the functional and process phase level, and the company-strategy level (levels 1, 2 and 3, respectively).

Lin, Meng-Chyn and Yu-Hua (2002) also focused on effective integration of business-model components to get to the “essence” of what makes up a business’s key “modeling perspectives,” suggesting their own generic BPM method, also based on a three-tiered framework that includes the: gross-grained (a “supply chain network”), medium-grained (focused on core business processes), and fine-grained levels (defined by functionality).

Collaboration and coordination are key to success, according to Gulla and Brasethvik (2000), who point to a lack of these factors as the most common trait of various and inconsistent models for the same business process within an organization. To guard against this possibility, an organization needs to ensure every stakeholder can understand systematic communication flow. They define their three levels of abstraction as the: functional, workflow, and business tiers. They conclude that “in practice, the process models are usually combinations of all these three tiers." Availability of MLA, through which business processes can be effectively modeled, is crucial to this setup's efficacy, especially on larger projects.

Dreiling et al. (2008) state that business process models created for one purpose are hard to apply to other purposes; they, therefore, don't advise reusing models. They advise that stakeholders use modeling systems that are fully integrated and that existing business process models need to be reassessed so they can be amended to suit a new project's requirements. Their three abstraction levels are management-oriented, business analyst oriented, and technical oriented, respectively. Like Bhat and Deshmukh, they stress simplicity for their management-oriented level as key to allowing a concise flow between the other two levels. The business analyst level must handle complex processes as it is used to meet multiple needs and for detailed models. The technical level requires a high degree of thoroughness, consistency, and accuracy. Dreiling et al. (2008) propose a mapping strategy that allows users to align abstract or ambiguous concepts. Doing so may require intermediate layers be put in place between any of the three levels in a bespoke fashion and are dependent on the demands of the individual project.

Although similarities exist between the methodologies, results demonstrate significant differentiation in the definitions of abstraction levels. Key objectives vary greatly in terms of vision, resources, roles, activities, and execution, perhaps demonstrating that comparing different projects can produce a plethora of core goals and processes. Different abstraction methods also show variation in the simplicity or complexity of approach, with some approaches allowing users to delve into detailed descriptions and others advising against making anything complicated. In summary, managing all the business processes of a large organization involves multiple challenges for which achieving unity is not easy.

Sections 1.5 and 1.6 presented researchers' numerous attempts to define modeling requirements and constrictions required by BPM stakeholders, either by exploring the range of BPM perspectives or by exploring modeling at MLA. Where the business process model is applied, problems arise because of varying stakeholder needs and priorities. To answer this problem, a range of perspectives need to be explored and understood.

1.7 Bunge-Wand-Weber ontology for representational analysis

The BWW representation model is a "benchmark for the evaluation of the representational capabilities of modeling standards from the core of the research method of representational analysis" (zur Muehlen et al., 2007). The BWW representational model was developed based on Bunge's proposed ontology (Wand and Weber, 1995). The representation model defines a set of constructs that describe real-world structure and behavior modeling languages they are intended to portray (Wand and Weber, 1995). As Wand and Weber state, two main situations may be studied when a modeling language is evaluated and analyzed: ontological completeness and ontological clarity (Wand and Weber, 1995). A modeling language is considered complete when all the ontological constructs are represented in the modeling-language constructs (Rosemann et al., 2009) (see [a] in Figure1.4). Construct deficit occurs when one or more ontological constructs do not map to any modeling-language construct (Rosemann et al., 2009) (see [b] in Figure1.4). Construct overload occurs in a modeling language if one modeling-language construct represents two or more ontological constructs (Rosemann et al., 2009) (see [c] in Figure1.4). Redundancy exists if two or more modeling-language constructs represent the same ontological construct (Rosemann et al., 2009) (see [d] in Figure1.4). Construct excess exists when a modeling language construct does not map into any ontological construct (Rosemann et al., 2009) (see [e] in Figure1.4). A modeling language is considered ontologically clear when it includes no construct overload, construct redundancy, construct excess, or construct deficit.

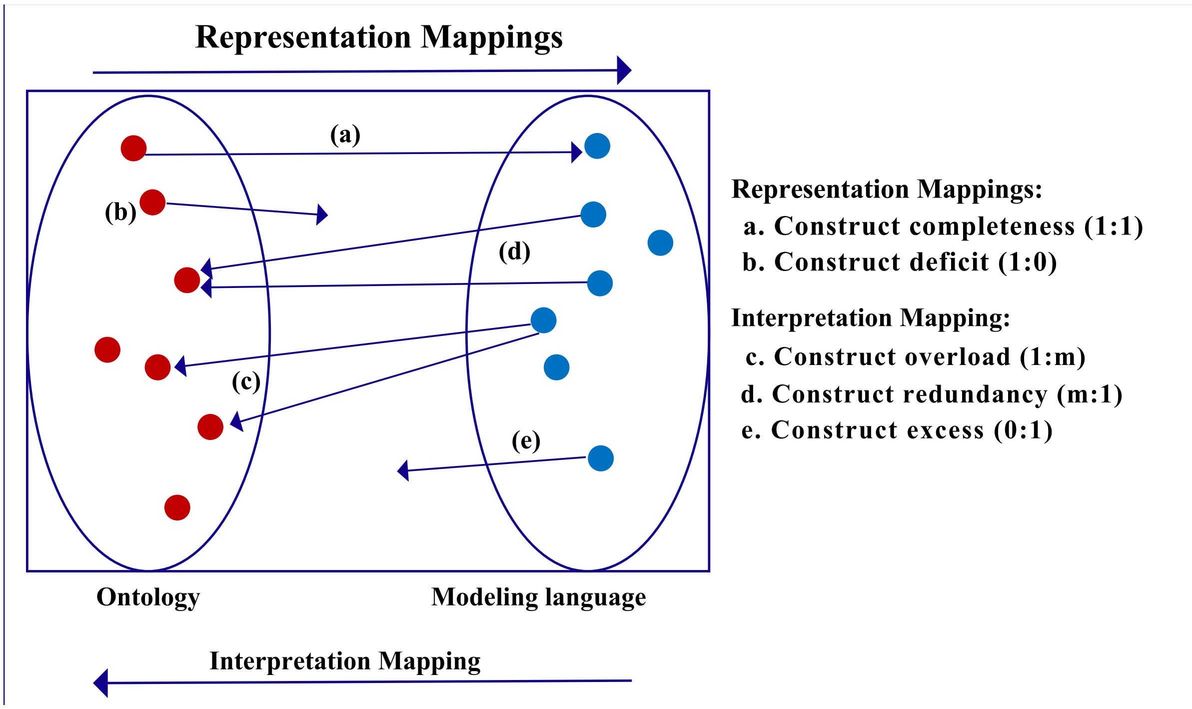


Figure 1.4 Rules of representational analysis
Adapted from Wand and Weber (Monsalve, 2012)

The BWW representational model has been used to evaluate and compare modeling notations, including BPMN (Recker et al. 2005), Qualigram (Monsalve, 2012), UML (Opdahl and Henderson-Sellers, 2002) and many others. The key constructs of the BWW model can be classified into four clusters: things including properties and types of things, states assumed by things, events and transformations occurring on things, and systems structured around things (Rosemann et al., 2009). This thesis uses the BWW representation model to assess the capabilities of modeling notations for representing decision trees. It does so to define possible constructs that will allow the design and integration of a new perspective at the BPM+ operational level.

1.8 BPM+ and its levels of abstraction

BPM+ was originally designed to provide a process representation architecture allowing for differently presented process models to better suit various stakeholder perspectives. BPM+

adopts MLA concepts inspired by Anthony's process categories for organizational planning and control (Anthony, 1965). This is useful because:

1. Previous BPM notations, such as Qualigram, have successfully implemented layered processes using Anthony's model (Ho, 2015) (i.e., also named Anthony's triangle);
2. The ISO 9001 recommendation for documenting business processes proposes, as Anthony's model does, that organizations should document their quality-management system using a process architecture comprised of three levels structured like Russian dolls (i.e., where each process level includes more detail than that of the previous process level); and
3. Anthony's model has successfully provided the classification-of-process basis in many organizations (Monsalve et al., 2011; Monsalve, April and Abran, 2010).

This layered business process modeling architecture, at MLA, could contribute to a consistent representation of business processes that can be used, shared, and easily understood by various groups of stakeholders (Monsalve et al., 2011).

BPM+ recommends organizational-process architecture that reuses Anthony's MLA concepts (see Figure 1.5). Each abstraction level represents a detail set of interest to an audience. The strategic level, the interest of which is primarily upper management's, describes an organization's core processes, goals, and policies. The tactical level, the interest of which is primarily both middle management and the operational staff that execute a process under consideration, describes who does what, clarifying the roles, activities, and resources of each process. This level describes how activities pass between roles by transitioning across the organizational silos of an organization.

As Figure 1.5 demonstrates, the operational abstraction level typically represents the execution of atomic tasks, describing an organization's specific activities as could be documented in a detailed work-instruction set. This perspective is meant to detail the work instructions for a specific operational role.

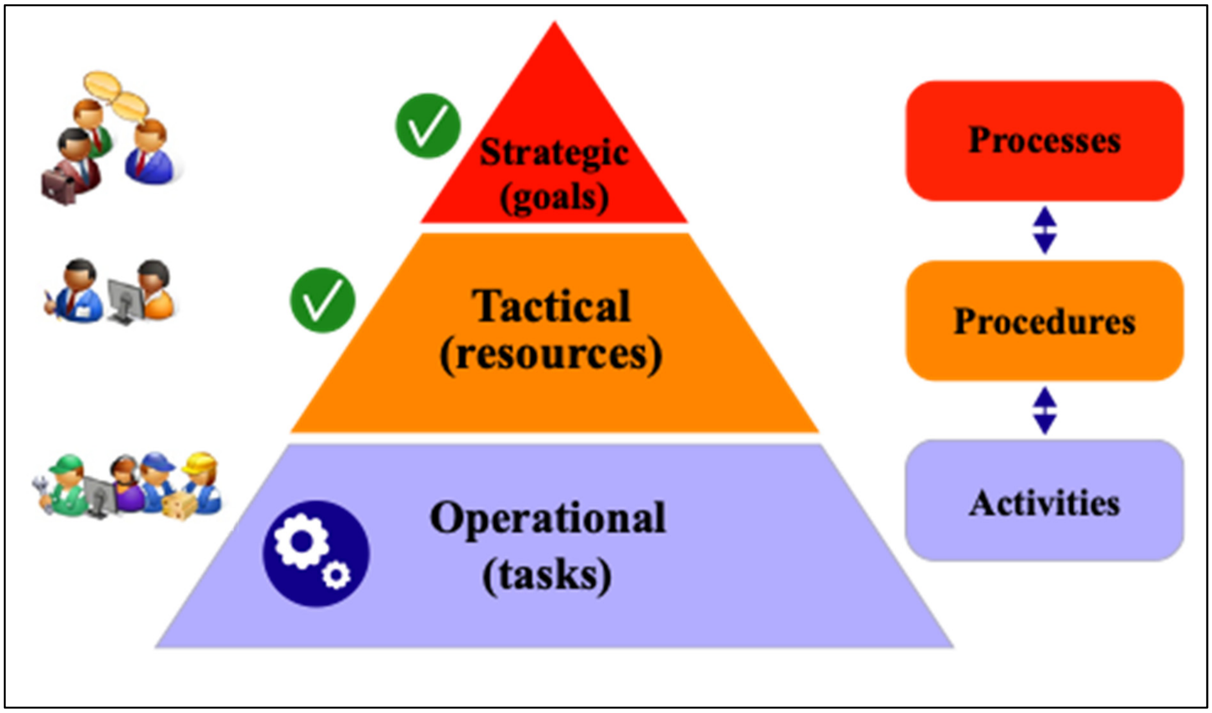


Figure 1.5 BPM+ levels of abstraction
Adapted from Anthony's triangle Monsalve et al. (2011)

1.8.1 Operational level of abstraction

This research focuses only on the operational abstraction level. At the lowest abstraction level, all detailed activities to be executed by an individual can be modeled. This means that many different operational perspectives should be represented to fit whatever a specialist executes in his daily work.

Monsalve et al. (2011) note that challenges to representing processes at the operational level and to meeting different user needs are resultant of the multiple operational representations of processes possibly needed to fulfill operational-stakeholder needs. An organization's operational level includes many types of specialists who are active in executing a procedure's various steps, including, among others, software engineers, nurses, machine operators, security specialists, and chemists. These operational stakeholders have numerous and often preferred ways of representing their operational processes. For example, process representation used by a software engineer may need to represent formal requirements and methods (e.g., using software-class diagrams and data-model representations). On the other hand, the process representation of a detailed security procedure might require compliance with external regulations and the demonstration of auto control activities and corrective actions needed when a problem occurs (Monsalve et al., 2011) (see "Incident-handling instructions" in Figure 1.6). As we can see in Figure 1.6 this operational level work instruction details every activity that has to be taken in this procedure as well as actions that have to be taken if a special event occurs.

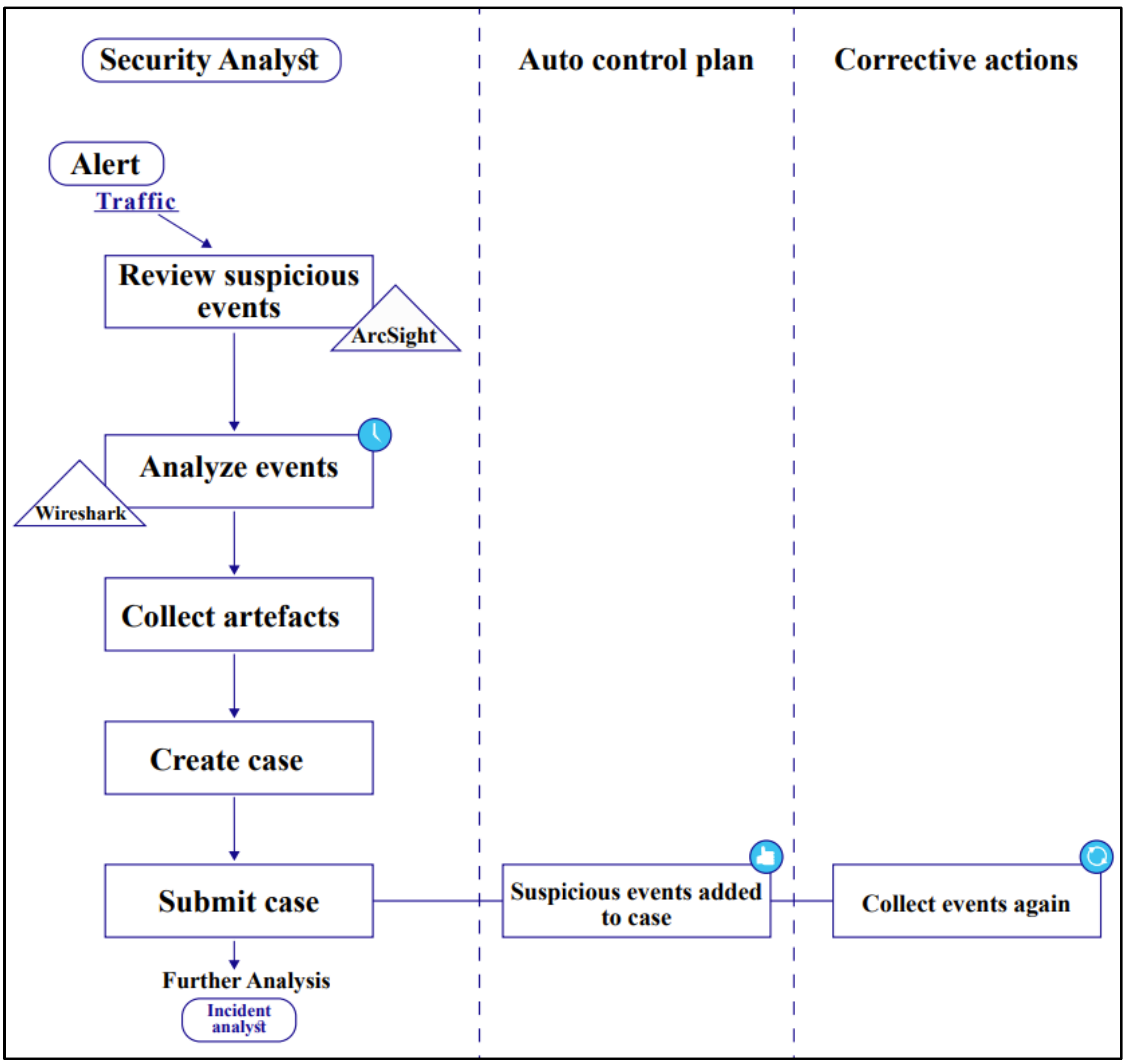


Figure 1.6 Example of Qualigram notation of detailed work instructions for an incident-handling process

Operational activities' graphical representations result in specialized and sometimes detailed graphical representations suited to each stakeholder's needs. Modeling concepts at the operational level need to fulfill these different specialized needs. These different process models can have common modeling concepts, such as actions (i.e., tasks), entities (i.e., roles or internal actors), information (i.e., relationships, dependencies, or relationships between tasks), tools (i.e., physical tools such as computers, software tools, and machinery), and documents (i.e., documents used or produced by the activity), which is what this research project explores.

Furthermore, the BPMN modeling constructs included at the analytical BPMN level, as proposed by Silver (2009), could also be utilized at the BPM+ operational level of abstraction.

1.8.2 Operational level representation perspectives

As mentioned in section 1.8.1, given that the operational level is the lowest abstraction level, all detailed activities to be executed by a specialist in his daily operations will be modeled here. The various steps of work instruction can be documented at this level of abstraction. As there are an infinite number of specialized models used by specialists all over the world, there are many different modeling representation perspectives that can be potential candidates to be represented at the operational level. In the next sections, we present a limited number of such modeling candidates to provide an example of the many types of models that could be represented. In addition to the model presented previously (i.e., detailed work instruction), the next section provides examples of the decision tree, threat and risk model and data modeling to show types of specialized modeling representation perspectives that can be integrated at the operational level of BPM+.

1.8.2.1 Decision tree perspective

One of the prominent decision-making techniques is the decision tree; it can be used for its natural ease in visually representing choices, along with their associated properties and outcomes. The decision tree's simple structure enables its use in a broad range of domains. "A decision tree can be represented to help quickly illustrate and communicate the critical elements in a decision". Also, a decision tree's simple diagram can be used to address complex decision scenarios and problems (https://www.decision-making-solutions.com/decision-making-tree.html).

Organizations and individuals benefit from decision tree representation in the decision-making process. Before making a decision, the organizations and individuals already foresee ideas and solutions. By using a decision tree, the possible choices and solutions can be represented as an outcome and it becomes simpler to choose the right potential choice (Mittal, Khanduja and Tewari, 2017). Figure 1.7 presents a process represented using a decision tree perspective for data encryption.

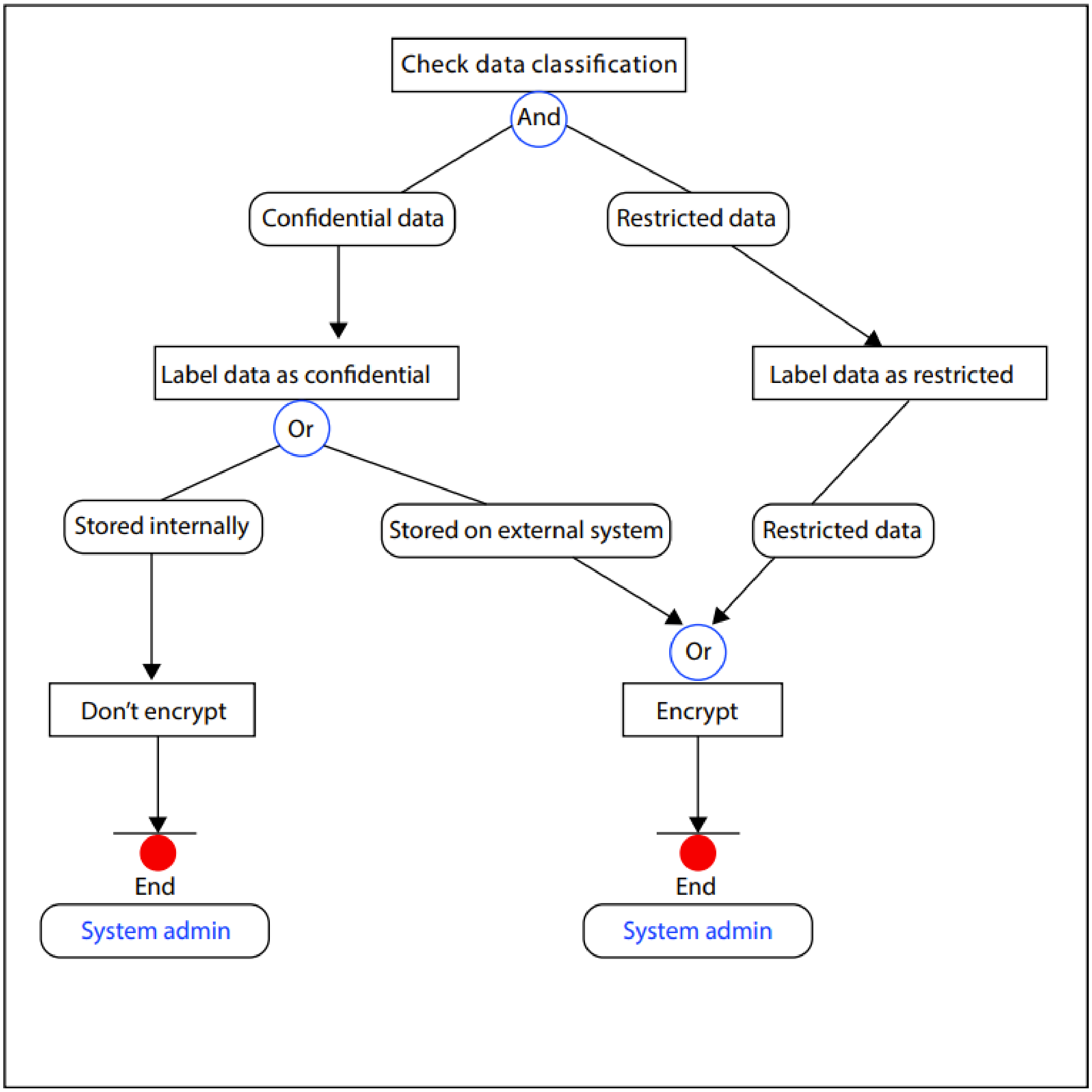


Figure 1.7 Business process represented using decision tree perspective for data encryption

Decision tree is one of most systematic techniques for decision-making theory and application. Decision tree diagrams have been used in complex decision problems due to the help providing a unified visual of choices and their attributes. Furthermore, decision trees are an important technique because of their simplicity of use and understanding, and are visually easy to review https://www.decision-making-solutions.com/decision-making-tree.html.

Due to the aforementioned advantages of using a decision tree for decision-making, the decision tree can be a good perspective candidate to be represented at the operational level of BPM+.

1.8.2.2 Threat and risk model perspective

Threat and risk model is another example of an operational model that could be represented at the operational level. Threats and risks of operational processes can harm an organization because of unpredictability related to possible issues that can affect a system or its environment, which can result in an operations disruption.

Threat and risk modeling is a process to identify, enumerate, and prioritize potential threats such as structural vulnerabilities, from a hypothetical attacker's perspective, within the context of protecting something of value (Figure 1.8). Threat and risk modeling provides scope owners with a systematic analysis of the potential attacker's profile, attack vectors, and a list of the most desired assets by an attacker (Myagmar, Lee and Yurcik, 2005).

Threat and risk modeling can be leveraged to a wide range of domains, including digital information and communication systems, embedded and manufacturing systems, and telecommunication systems (Myagmar et al., 2005).

Generally, organizations manage threats and risks in order to systematically handle uncertainties and improve the level of awareness in case of an incident. Communities can share information about threats, risks, and incidents using different approaches. While each of these risk approaches provides value for a specific community, it is not very easy to map these multiple representations to provide a general assessment and to then conduct the appropriate set of actions. Increasingly, cyber-attacks are becoming a concern that current assessment and mitigation strategies are unable to control. Therefore, the conceptual representation of threats and risks that unifies the semantics can enable threats and risks to be better communicated between different communities, understood and effectively handled (OMG, 2017).

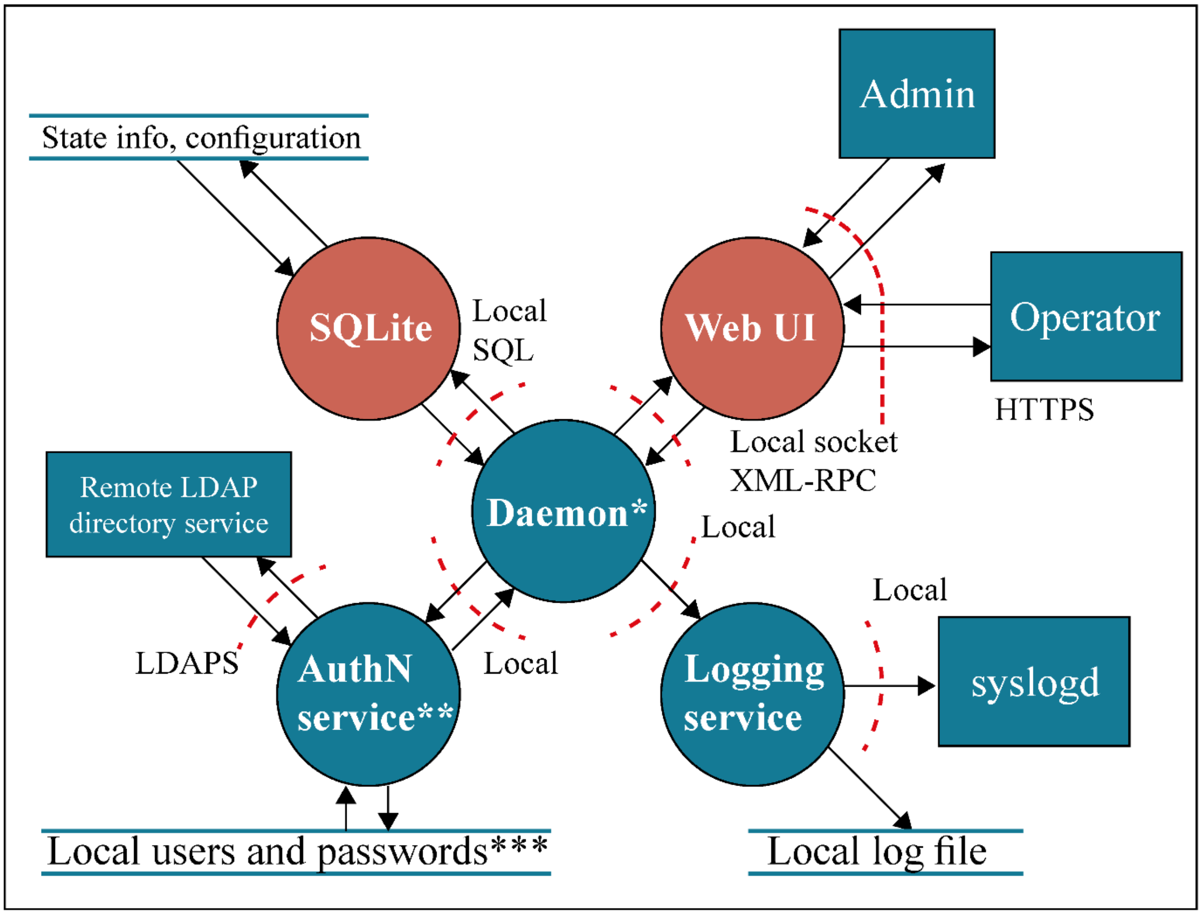


Figure 1.8 Dataflow diagram of system, which helps identify additional interaction points that attackers can leverage

Taken from (Dhillon, 2011)

1.8.2.3 Data modeling perspective

Data modeling is another popular model representation used by specialists that could be represented at the operational level. Data modeling is known as a process for defining and analyzing data required to support the business processes within the domain of information systems in organizations. Therefore, the data modeling process requires data modelers to work closely with business stakeholders and future users of the information system. There are three data model types generated during the process of collecting requirements for the database (http://www.agiledata.org/ essays/dataModeling101.html): conceptual data model, which is a set of specifications about the data and is used to detail and review initial requirements with the business stakeholders; logical data model, which is translated from the conceptual model and documents the data structures that can be implemented in databases; physical data model, which is translated from the logical, organizes the data into tables, and accounts for access, performance and storage details. Data modeling defines data elements and how they are structured and communicated (https://www.guru99.com/data-modelling-conceptual-logical.html). Data modeling techniques support the process to model data in a standardized, consistent, and predictable way, which helps to manage it as a resource. Data modeling standards support IT professionals, related organizations, and clients to understand and use created concept models to handle data as a resource within the scope of information systems integration for designing databases and data repositories. Data models are gradual and considered a working document that may change according to business requirements. The data models can ideally be hosted in a repository where they can be created, edited, and updated over time. Finally, data modeling is a technique used for defining and detailing business requirements for databases. It is from time to time called database modeling as a data model can be eventually be translated into a database (https://www.guru99.com/data-modelling-conceptual-logical.html). Figure 1.9 shows a conceptual data model of an airport system.

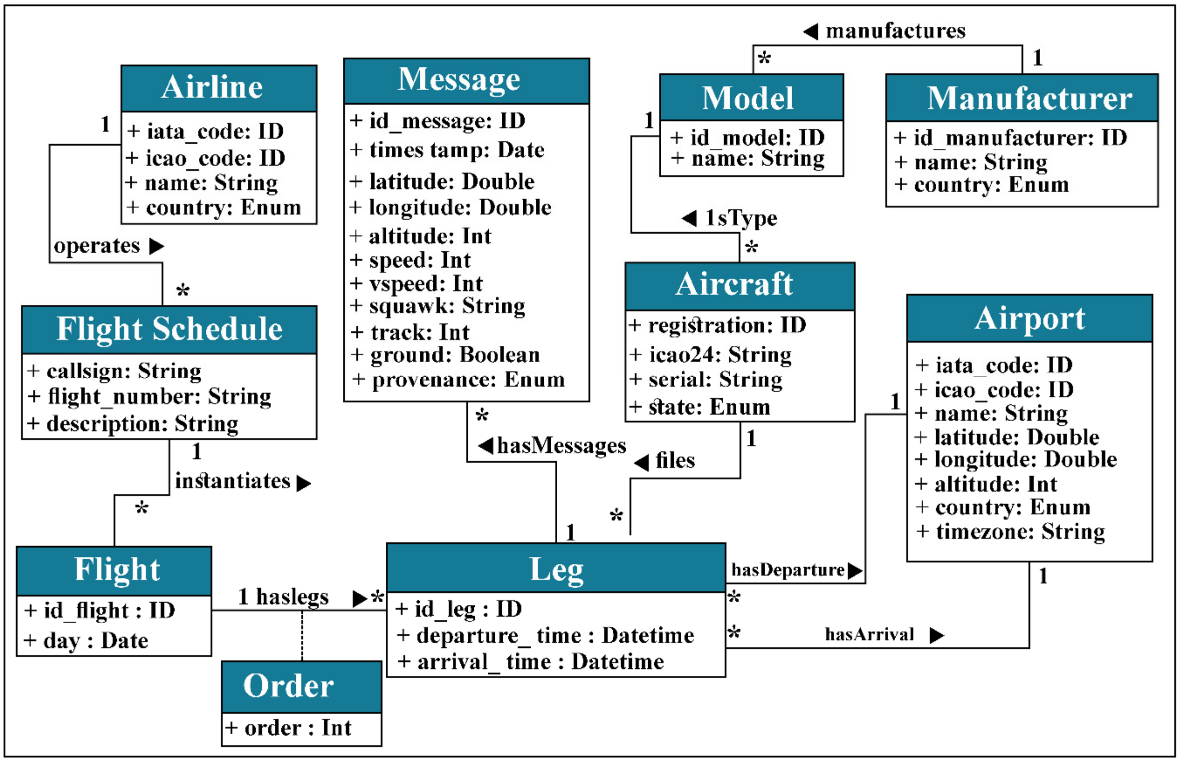


Figure 1.9 Conceptual data model of an airport system

Taken from Martínez-Prieto, Bregon, García-Miranda, Álvarez-Esteban, Díaz and Scarlatti, D. (2017)

1.9 Conclusion

In conclusion, this chapter has reviewed and determined the main concepts related to business process, business process management, and business process modeling (BPM). It has also discussed the usefulness and importance of creating robust business process models to support process improvement, process understanding, and process communication within an organization. Moreover, it reported the different initiatives within this context discussed in the literature.

The need to represent the business process from various perspectives in a typical BPM project was also highlighted. These perspectives should complement each other and include the relevant business process elements and information for each stakeholder's needs which are often very different in nature. The benefit of using an MLA process modeling architecture to help represent process information that addresses the concerns of different types of stakeholders in a structured way was also shown. The various publications found in the literature, aiming at achieving process documentation using MLA, have also been summarized.

A novel BPM approach, BPM+, is introduced. BPM+ has been designed to provide a process modeling architecture using the MLA concept to allow different process model representations to suit various stakeholder perspectives better. BPM+ adopts MLA concepts to model business processes at three levels of abstraction: strategic (Level 1), tactical (Level 2), and operational (Level 3). The strategic (Level 1) and tactical (Level 2) has been reviewed and validated in previous research programs in our research lab. In this thesis, the operational level will be designed to fulfill operational-stakeholder needs. We expect this research's primary outcome to be a novel representation perspective integrated at the BPM+ operational level that: could be at the origin of an operational business process repository offering specialized representation perspectives and that meets the needs of different types of operational stakeholders; and allows the generation and validation of business process models, at the operational level, that can be easily understood and used to facilitate intra-organizational business process communication. The many possible operational models that are currently used by all sorts of specialists in different occupations was demonstrated. Among the many possible perspectives for operational representation were presented a detailed work instruction procedure, a decision tree diagram, a threat-risk diagram and a database model were presented as examples of the many modeling possibilities that the operational level could offer to specialized staff for their representation needs.

The next chapter presents this research methodology. It provides information concerning this research motivation, its objective, and specific proposal as well as the various research stages, including their input and outputs, to show the reader precisely what was done up to the case study validation and the interpretation of results.

CHAPTER 2

RESEARCH METHODOLGY, ACTIVITES AND EXPECTED RESULTS

2.1 Overview

This thesis uses the software-engineering research framework proposed by Basili, Selby and Hutchens (1986) to address the research questions introduced in the previous chapter. This research framework allows the researcher interested in software engineering research to describe its intended research using four research activity phases: the definition of the research, its planning, the development leading to its main contribution, and its interpretation.

2.1.1 Definition phase

The definition phase, presented in Table 2.1, clarifies this thesis's research motivation, objective, proposal, and users.

Table 2.1 Definition phase

Motivation	Objective	Proposal	Users
How multiple representation perspectives for the operational level of abstraction can effectively improve the existing organizational-business process model repository.	Objective is to study possible business process operational representations and integrate/validate one specialized representation to the operational level of BPM+ as an example of a new representational perspective.	- Demonstrates how a specialized/operational BPM-stakeholder perspective can be used to improve the existing BPM approaches; - Show how to validate BPM representations for the operational level (Level 3 of BPM+ MLA).	BPM stakeholders, vendors, researchers, and operational professionals interested in modeling at the operational abstraction level (i.e., Level 3).

2.1.2 Planning phase

The planning phase (see Table 2.2) describes knowledge required and preparation of the research for each stage of the research, for example: the literature review, the ontological validation of a graphical notation, the preparation of a survey and how to extend a graphical notation to add new modeling constructs.

Table 2.2 Planning phase

Stage	Inputs	Output
• Selection of new representation perspective to be integrated at the operational level of abstraction	• The literature review of: • BPM • The BPM+ approach • Potential representation perspectives • State of the art of BPM notations	• Operational level decision tree representation perspective • Selected BPM notations
• Design of initial version of decision tree representation perspective	• BWW representation model • BPMN and Qualigram • Decision tree concepts	• Focused representational analysis of decision tree perspective • A set of BPM constructs specifically selected for supporting decision tree representation perspectives • Propositions to be tested with a survey • Research protocol for the validation of the reviewed decision tree perspective to be presented to the ÉTS Ethics Committee for research for ethical acceptability

Stage	Inputs	Output
• Evaluation of the decision tree representation perspective and the operational BPM+ level through a survey that reviews business process models modeled using Qualigram and BPMN notations at this level to evaluate the proposed theory	• BPMN and Qualigram specifications • Decision tree representation perspective • Survey of participants with experience in BPM and IT domains • Research team reflections	• Evaluated scope and elements of decision tree representation perspectives • Evaluated scope and elements of the operational level of BPM+ • BPMN extensions

2.1.3 Development phase

This research's development phase presents the activities that support new knowledge and theories, and describes the definition and preparation of each experimentation and validation required. Finally, it describes key research activities that seek to answer this thesis's main research question. To demonstrate the potential of the operational level perspective, one operational model had to be chosen. We arbitrarily chose the decision tree to demonstrate the feasibility of the proposal and elaborate the experimentation in this research. This phase includes two action items: the development of the decision tree perspective; and the development of the evaluated version of the same decision tree perspective within the scope of the operational BPM+ level. The development of these two action items includes the evaluation of deliverables and an analysis of results. Table 2.3 presents a summary of the development phase.

The decision tree perspective is subjected to a focused ontological analysis (Rosemann, Green and Indulska, 2004) that proposes a theory-based design that systematically identifies real-world elements that should be modeled on results from the focused ontological analysis that will be included in the next chapter (Wand and Weber, 1955; Rosemann, Green and Indulska, 2004).

An initial version of the decision tree perspective is developed according to this thesis's literature review results. This initial version scopes the decision tree as a new representation perspective at the operational level and identifies a preliminary set of BPM elements to be modeled when using the decision tree perspective. The initial version of the decision tree perspective is evaluated and enhanced based on representational analyses of the BPMN and Qualigram notations.

The representational analyses help identify specific elements that should be modeled when using the decision tree perspective. The focused representational analyses are performed based on two references (Knuth, 1997; Cormen, Leiserson, Rivest and Stein, 2008) for identifying relevant decision tree concepts. A survey is conducted questioning practitioners with different level of BPM experience. The results of the focused representation analysis are used to evaluate the scope and contents of decision tree and working instructions perspectives at the operational level of BPM+.

To evaluate the reviewed decision tree version, a survey is conducted. This survey targets the evaluation of the scope and content of the decision tree perspective and the notion of operational level as a whole, as well as modeling preferences, according to various levels of experienced BPM practitioners involved in the survey. Finally, a reviewed and validated version of the decision tree perspective is developed.

Table 2.3 presents a summary of these two action items of the development phase. Section 2.2 presents the representational analyses' design. Section 2.3 presents the survey design.

Table 2.3 Development phase

Development of decision tree perspective	**Validation**	**Analysis**
• Development of the decision tree representation perspective.	• The initial version of the decision tree representation is evaluated by performing focused representational analysis.	• Reviewed version of the decision tree perspective. • Publication.
• Development of the reviewed version of decision tree perspective.	• The decision tree-representation perspective and the operational level of BPM+ are validated by conducting a survey of practitioners with BPM and IT experience. The survey will evaluate the BPM+ operational abstraction level.	• Validated version of the BPM+ operational level. • Validated version of the scope and content of the decision tree representation at the BPM+ operational level. • Validated preferences of the BPM notations used in this research to represent the decision tree perspective. • BPMN extensions of the decision tree perspective • Publication.

2.1.4 Interpretation phase

Finally, in the interpretation phase, an analysis-based interpretation of all findings and feedback (see Table 2.4) was performed. Extrapolation of the results is then discussed as well as future work to improve this proposal.

Table 2.4 Interpretation phase

Context	Extrapolation	Future Work
• One example of a proposed and successful operational model • Method of validating new graphical representation demonstrated • Survey shows that the concept is relevant	• Possible use of the notion of operational representations in many popular graphical BPM notations • Possibility of offering repository of ontologically validated models	• Introduce new representation perspectives at the BPM+ operational level (e.g., different target stakeholders or purposes of modeling). • Publish new results.

2.2 Research methodology for performing the representational analysis

As reported by Green et al. (2006), several BPM transformations might be required to make a real-world-sourced final representation (i.e., to map from the real world to a representational model and from the representational model to a conceptual model), each of which involves a specific mapping (Green et al., 2006). This thesis's research efforts begin with mapping from a specific domain (the decision tree's applied representation technique, as used in industry). As an intermediate step, the decision tree concepts to the BWW representation model, and BWW constructs to a BPM-notation representation of decision trees are transposed. This work requires two mapping sets: the mappings between the real-world domain and the BWW representation model; and the mappings between the BWW representation model and the BPM notation.

Besides the reference ontology for the representational analyses (Green et al., 2006), possible shortcomings with the representational-analysis process have exposed popular reference ontologies to criticism (Rosemann, 2004). To minimize and address potential representational analysis shortcomings, the analytical methodology and recommendations from Green et al. (2006) was followed: perform representational analyses mappings with the assistance of a modeling language metamodel; involve two or more researchers in the representational analyses; and conduct various representational analyses mapping iterations among researchers such that those iterations lead to a consensus of representational analyses findings.

Gehlert and Esswein (2007) assert that all ontological analysis activities should comply with the following rules: the same set of ontological constructs must be used during all ontological analyses steps; the comparison's modeling language must be stated; mapping results state whether construct mapping is to be equivalent, similar, or different; and a criteria of construct similarity and dissimilarity across all analyses is maintained.

We complied with the above recommendations: We involved two researchers in each representation mapping activity and established teamwide consensus of the final analysis. We used the BPMN 2.0.2 modeling language metamodel for the BPMN representation analyses activity. BPMN representational analyses results from (Wohed et al., 2006) are used for cross validation.

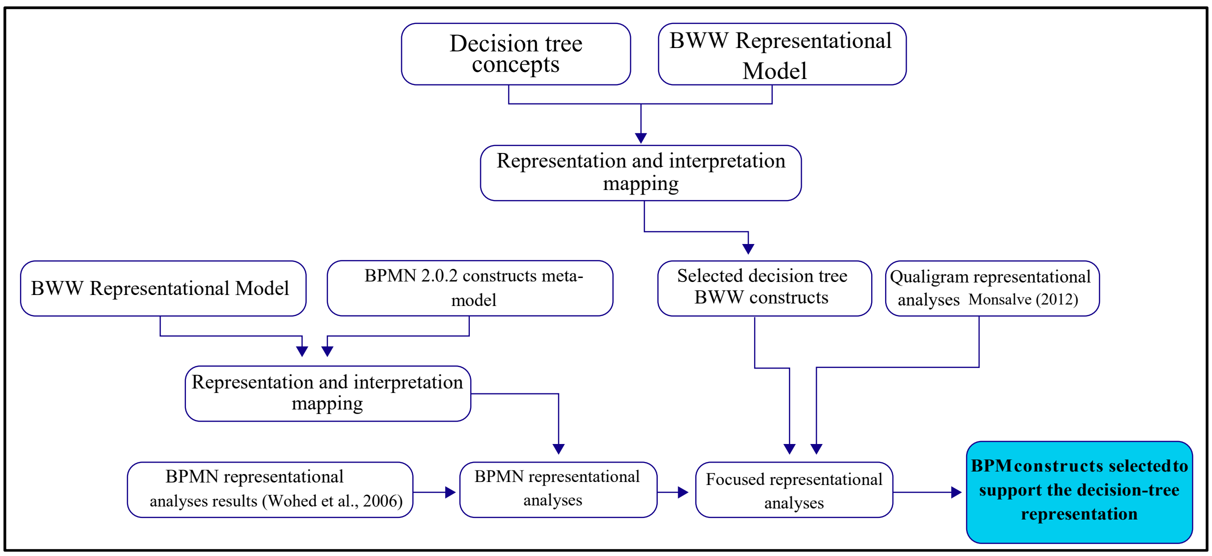


Figure 2.1 Methodology for experimenting with the decision tree focused representational analysis

For Qualigram representation analysis, the same results observed by Monsalve (2012) are used. In this research, an analysis methodology using four steps is followed:

1. An introductory meeting between researchers is conducted to define and clarify the scope of the research;

2. A representation mapping of ontological constructs, based on one operational representation selected (i.e., the decision tree), with selected BWW constructs that represent its most relevant concepts is done (this step is named *scoping*);
3. A representation mapping using BPMN 2.02 and the Qualigram modeling notations is performed to analyze their capacity for representing the BWW representation model constructs of an operational representation (i.e., the decision tree); and
4. An interpretation mapping that compares the Qualigram and BPMN representational mappings with the BWW set of constructs are executed (see Figure 2.1 above).

Three validity threat types of the focused representation analyses are taken into consideration: lack of understandability, lack of objectivity, and lack of formalism. We mitigate the lack of understandability by using the Qualigram and BPMN metamodels for the mapping process. The lack of objectivity is mitigated by involving multiple researchers in the mapping processes and by conducting multiple iterations to reach consensus among the researchers. The lack of formalism is mitigated by using a single set of ontological concepts and BPM notations during all the mappings. All mapping results constitute either an equivalence or a difference between the compared concepts.

2.3 Survey

To validate results, a survey was designed and conducted by following Salant and Dillman (1994) and Kitchenham and Pfleeger (2008)'s recommendations, based on which, a protocol was elaborated.

This survey's design objective was to test findings from the focused representational analyses. A questionnaire was designed and pretested with the help of practitioners and academic researchers with some level of BPM experience. The pretests were conducted to: confirm and improve question quality; and test and identify the proper timeframe required for answering the questionnaire.

This research considered the proven advantages of online surveys (Wietsma, 2013; Andrews, Nonnecke and Preece, 2007) when designing and building the survey. The estimated time needed for participants to complete the online survey was 30 minutes and that time was distributed as follows:

1. Participants were requested to review an example of an operational business process they would relate to when answering the qualification questions (five minutes);
2. Participants were requested to answer a prequestionnaire asking for information related to their respective work profiles, including job title, years of experience, etc. (five minutes); and
3. Participants were invited to answer a questionnaire in which they were asked for their opinions on different operational business process models modeled at the operational level using Qualigram and BPMN modeling notations (20 minutes).

The survey's target audience are practitioners (e.g., cybersecurity engineers, business analysts, or professionals from related backgrounds) with some level of BPM experience. Since our target audience was very specialized, a large population was difficult to reach. For this reason, a non-probabilistic sample for this survey was chosen (Salant and Dillman, 1994; Kitchenham and Pfleeger, 2008). To ensure a representative number of participants, we asked the research lab to obtain the assistance of BPM specialized companies to share the survey with their BPM partners and customers.

Since the survey is online, participants could stop and withdraw from the survey at any time. Section 4.2.1 describes the actual participant profile. The survey's research protocol has been presented to the ÉTS Ethics Committee for Research for evaluation and approval. The survey's validity threats and limitations are discussed below.

The questionnaire design followed well-accepted guidelines from the literature to increase construct validity and used a structure already validated by similar studies (Monsalve, 2012). In this survey, questions were formulated based on the propositions to be tested. Moreover, the questionnaire was pretested and discussed with professionals fitting the target audience profile.

To increase internal validity, participants had to have some level of BPM experience and background, though they did not all present the same levels of experience, which is normal.

In terms of external validity, we identified the sample size as the survey's main threat. Larger sampling possibilities greatly benefit online surveys. To mitigate the size problem, our results are supported by the fact that the propositions being tested are derived from previous theoretical studies described in this thesis. Supported propositions, therefore, meant that the survey results converged with the literature review and the representational analyses results, establishing a chain of evidence that reinforces the final conclusions.

Finally, to increase reliability and to identify the proper population, the survey protocol was elaborated and the questionnaire was retested with professionals possessing more than 10 years of BPM and IT experience and with the help of Mr. Daniel Emond, a statistician. Closed questions were preferred to reduce researcher bias when coding and analyzing responses.

Figure 2.2 summarizes the research methodologies this thesis uses, including inputs, research methods, deliverables, and outcomes.

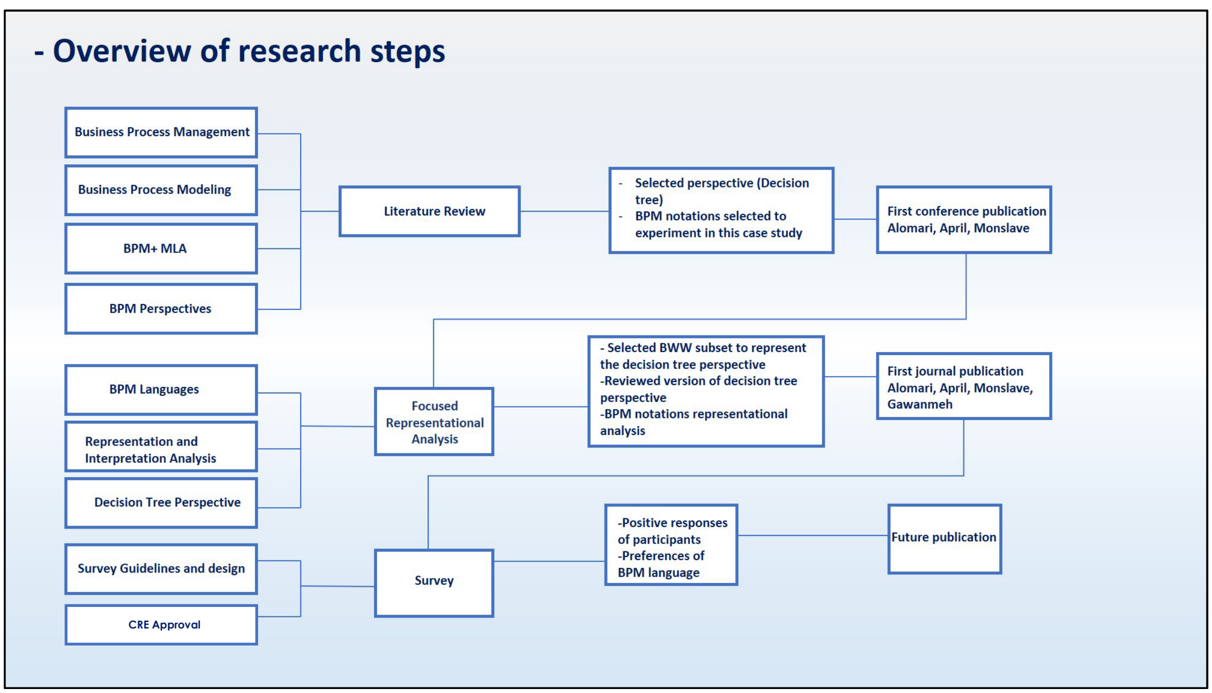


Figure 2.2 Summary of research methodology

This section identified and described limitations and validity threats to this research. Table 2.5 presents an overview of these limitations and validity threats.

Table 2.5 Summary of limitations and validity threats
Adapted from Monsalve (2012, p. 97)

Research method	**Threat or limitation**	**Compensation**
Representational analysis	Lack of understandability	We used the BPMN metamodels for the mapping process.
	Lack of objectivity	Multiple researchers were involved in the mapping processes. Several iterations were required to reach consensus among the researchers.
	Lack of formalism	The same BPM notations and set of ontological concepts were used during all the mappings. All the mapping results constitute either an equivalence or a distinction between the concepts compared.
Survey	Construct validity	The design of the questionnaire followed well-accepted directions and was pretested.
	Internal validity	A considerable effort was made to ensure participant experience in both IT background and BPM.
	External validity	The findings were supported by the fact that the tested propositions were derived from prior research. A chain of evidence that supports the findings was developed.
	Reliability	A survey protocol was established, the questionnaire was retested, and to decrease coding bias, closed questions were used.

2.4 Conclusion

This chapter has thus presented and discussed the research methodology and all related activities. The Basili framework was followed, identifying four research phases:

1. The definition phase, clarifying research motivation, objective, proposal, and users;
2. The planning phase, describing deliverables that address the research questions;
3. The development phase, presenting the activities supporting the new knowledge and theories and describing the definition and preparation conducted for each experimentation and validation; and
4. The interpretation phase, covering the feedback based on the findings analysis.

The main research methods used in this thesis have been presented in this chapter. First, the research methodology for performing the representational analysis has been explained and two mapping sets were required: the mappings between the real-world domain and the BWW representation model; and the mappings between the BWW representation model and the BPM notations. The representational analysis is used to review the contents of the decision tree perspective and identify the decision tree set of concepts for modeling business processes. Second, a survey is conducted to validate findings from the focused representational analyses. Survey participants are practitioners with some level of BPM experience.

Limitations and threats for each research methodology have been identified and compensation controls are taken to mitigate the threats accordingly. Research activities conducted following the research methodology and main outcomes are explained in the next chapter.

CHAPTER 3

ADDING A REPRESENTATION PERSPECTIVE AT THE OPERATIONAL LEVEL OF BPM+

3.1 Overview

In order to research this topic, one operational modeling representation had to be chosen to show the detailed research activities involved in adding a new process perspective to BPM+. We have presented, in the literature review (section 1.8.2), a few operational model examples. For this research the decision tree model has been selected to be used as the model to develop the theory around this new representation perspective. Note that we could have taken any specialized modeling technique that a specialist uses in his daily work. We found that decision-making is an essential daily process required for effective operations, particularly in science, engineering, economics, and management and is a good example of a model often used by specialists (Magee, 1964; Kamiński, Jakubczyk & Szufel, 2018). Decision trees are often used to represent complex decision-making processes. A decision tree is a diagram that displays the potential outcomes from a series of choices. Decision trees have contributed significantly to decision-making in many different fields, such as critical thinking, machine learning, management science, computer science, and chemical science. The graphical representation of decisions has also been widely used for both exploratory data analysis and predictive modeling applications for over three decades (https://www.decision-making-solutions.com/decision-making-tree.html). Decision trees assist users in making well-informed decisions. Decision tree graphical representation provides a compact and systematic documentation of the decision-making process https://www.decision-making-solutions.com/decision-making-tree.html. Decision making includes the difficulty of identifying and considering the implications of all possible options. However, well-designed decision trees should address this concern and ensure all alternatives are considered (Magee, 1964). Decision trees are an important perspective that should be offered at the BPM+ operational level.

This chapter proposes how to assess the representational capabilities of decision trees used as specialized representation perspectives at the business process operational level.

3.2 Representational analysis of a decision tree

The representational analysis of a decision tree helps identify relevant concepts that should be considered when using the decision tree perspective to model a business process at the operational abstraction level. The first step of the representational analysis for a decision tree identifies the set of relevant decision tree concepts that should be taken into consideration when developing a process model. Table 3.1 shows decision tree concepts for analyzing the BWW representation model of a decision tree from the works reported in (Knuth, 1997; Cormen, et al., 2001).

Table 3.1 Decision tree concepts

Concepts	**Description**
Root node	Root node has no incoming edges and zero or more outgoing edges (top node in the tree)
Child	A node directly connected to another node when moving away from the root
Parent	The converse notion of a child
Siblings	A group of nodes with the same parent
Internal node	A node with one child or more
Branch	The arrows connecting nodes with conditions
Edge	Relationship between nodes
Leaf	A node with no children
Level	The number of edges between the node and the root
Degree	The number of subtrees of a node
Height of node	The number of edges on the longest path between that node and a leaf
Height of tree	The height of the tree’s root node
Path	A series of nodes and edges connecting a node with a descendant

Figure 3.1 shows a decision tree that describes the data-security-encryption requirements for payment card industry data. This example describes all possible outcomes and decision points that could occur chronologically.

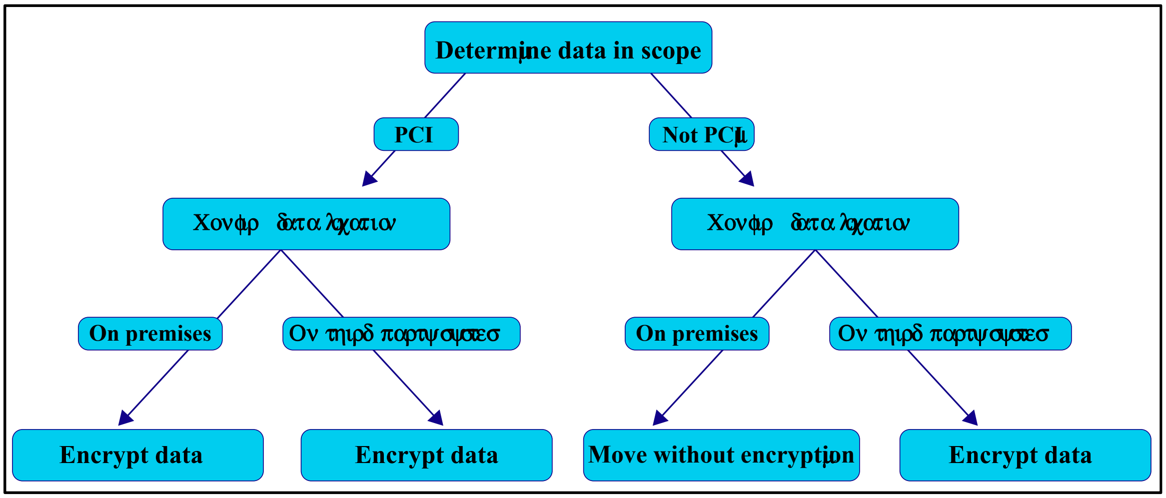


Figure 3.1 Decision tree of a data-encryption process

3.3 Decision tree concepts mapping: results and analysis

During this step, two activities were conducted: a representational mapping in which the decision tree concepts described in Table 3.1 were mapped to the BWW-representation-model constructs (as depicted in Figure 2.1); and an interpretation mapping in which the BWW-representation-model constructs were mapped to the decision tree concepts identified in Table 3.1. The outcomes of these two mappings result in a subset of concepts from the BWW representation model that were selected based on their capabilities to represent the relevant decision tree concepts.

Table 3.2 Representation mapping of the BWW representation model based on selected decision tree concepts

Decision tree Concepts	**BWW Constructs**
Root node	Transformation
Child	Transformation
Parent	Transformation
Siblings	System decomposition, subsystem
Internal node	Transformation
Branch	Lawful transformation
Edge	Coupling, act on, lawful transformation
Leaf	Transformation
Level	Level structure
Degree	No mapping construct
Path	No mapping construct
Height of node	No mapping construct
Height of tree	No mapping construct

We obtained the representation mapping shown in Table 3.2 and the interpretation mapping listed in Table 3.3 using the methodology described in section 2.2. Table 3.2 shows that the decision tree concept's degree, path, height of node, and height of tree have no BWW representative constructs. A possible reason for this is that the BWW representation model incompletely describes the decision tree concepts. The research group observed, however, that such modeling concepts are unnecessary for decision tree models.

As shown in Table 3.2, the transformation BWW construct includes mapped root node, child, leaf, internal node, and parent decision tree concepts. The decision tree concept state is transferable based on interaction levels (e.g., leaf and child nodes can be parents).

Within the same context, lawful transformation represents branches and edges. Any interaction or relationship between nodes can be represented by either branch or edge, however, Table 3.2 shows that edge has also been mapped to “coupling” and “act on” BWW constructs.

Table 3.2 shows how siblings map to system-decomposition and subsystem BWW constructs and how the level decision tree concept maps to the level structure BWW construct.

Table 3.3 Interpretation mapping based on selected decision tree concepts

BWW Constructs	**Decision Tree Concepts**
Transformation	Child, parent, internal node, leaf, root node
Lawful transformation	Edges, branch
Act on	Edge
Coupling	Edge
Subsystem	Siblings
System decomposition	Siblings
Level structure	Level

Table 3.3 shows the BWW representational constructs that map to the decision tree concepts identified in Table 3.2. Based on the mapping results presented in Tables 3.2 and 3.3, a subset of BWW-representation-model constructs that are most applicable to decision tree perspectives was selected. Table 3.4 describes this subset.

Table 3.4 Selected subset of BWW representation model constructs

Cluster	**BWW Constructs**
Events and transformations occurring on things	Transformation
	Lawful transformation
	Coupling
	Act on
Systems structured around things	Level structure
	System decomposition
	Subsystem

Rosemann et al. (2004) suggested that a specialization of ontological constructs of some particular domains, which is called focused ontology, can enhance and simplify the representational analyses process.

3.4 BPMN and Qualigram: mappings and comparisons

As depicted in Figure 2.1, and from the representational analyses performed in the previous section, only the selected BWW subset summarized in Table 3.4 has been used for the subsequent representational analyses with BPMN and the Qualigram notations. We evaluate and compare the completeness of BPMN and Qualigram to represent this subset of the BWW representation model constructs selected for the decision tree perspective.

Table 3.5 presents the results of the representation mapping using both BPMN and Qualigram operational level constructs. With regards to BPMN, the same representation mapping results as reported by Recker et al. (2005) are observed for the subset of the BWW representation model selected for the decision tree perspective. BPMN 2.0.2 constructs including choreography task, collapsed sub-choreography and expanded sub-choreography are mapped to the same subset of BWW representation model constructs as shown in Table 3.5.

Table 3.5 Representation mapping of Qualigram and BPMN based on the selected subset of BWW representation model constructs for the decision tree perspective

BWW Constructs	Qualigram	BPMN
Transformation	Macro-operation, alternative operation, operation, corrective operation, Self-checking operation.	Activity, task, collapsed sub-process, expanded sub-process, nested sub-process, transaction, choreography task, collapsed sub-choreography, expanded sub-choreography
Lawful transformation	Information arrow, up-stream action, down-stream action.	Default flow, exception flow, uncontrolled flow
Coupling	Information arrow, up-stream action, down-stream action.	Message flow

BWW Constructs	Qualigram	BPMN
Act on	Information arrow, up-stream action, down-stream action.	Message flow
Level structure	Macro-operation, alternative operation, operation.	Pool, lane
System decomposition	Alternative operation, macro-operation, operation.	Pool, lane
Subsystem	Alternative operation, macro-operation, operation.	Pool, lane

Table 3.5 shows that no deficit deficiencies were observed when representing the selected set of BWW representational model constructs. As both modeling notations experimented offer at least one construct, corresponding BWW representational model constructs are selected to describe concepts related to decision tree perspectives. It can also be seen that the BWW model constructs *transformation* and *lawful transformation* present several redundancies for both modeling languages.

Some potential representational shortcomings, based on the situations described in section 1.7, were observed in the representational analyses of both BPMN and the Qualigram notation. From a clarity perspective, both situations of construct redundancy and overloading are present. The redundant BWW model constructs are *transformation, lawful transformation, coupling, act on, level structure, and system decomposition*. Both modeling notations offer construct redundancy for the BWW representation model constructs described in Table 3.5.

For the redundancy of *transformation*, 9 BPMN constructs mapped to the BWW transformation including: *collapsed sub-choreography*, *expanded sub-choreography*, and *choreography task*. For this reason, it is possible that users could be confused as to which construct is to be used when representing a transformation. The BPMN constructs differ in terms of visualization, however, as reported by Recker, Indulska, Rosemann and Green (2005), no significant semantic differentiation can be stated in terms of their use.

Next, the BWW representation model constructs *level structure*, *subsystem*, and *system decomposition* mapped to *lane* and *pool* notions of BPMN. *Lawful transformation* mapped to *default flow, exception flow*, *uncontrolled flow*, demonstrating the same results of the representational analyses performed by Recker et al. (2005).

Lawful transformation, *coupling*, *act on*, *level structure*, *system decomposition*, and *subsystem* BWW model constructs also present redundancies, particularly in the Qualigram notation.

With respect to construct overloading, both BWW model constructs *act on* and *coupling,* mapped to the same BPMN construct, *message flow*. *Level structure*, *system decomposition*, and *subsystem* mapped to same BPMN constructs of *pool* and *lane*. In this experiment, we did not observe any construct excess or construct deficit.

The Qualigram notation has shown the ability to represent all of the selected set of BWW representational model constructs, where construct overloading and construct redundancy are present. In terms of overloading BWW constructs, *level structure*, *subsystem* and *system decomposition,* have been mapped to the same set of Qualigram concepts *alternative operation, macro-operation, operation*. As well, BWW constructs *act on*, *coupling*, and *lawful transformation* mapped to the equivalent Qualigram constructs of *information arrow*, *up-stream action*, and *down-stream action*. Finally, these results suggest that the BPMN notation offers a higher level of representational clarity for the decision tree perspective.

3.5 Conclusion

This chapter shows the representational analysis of a decision tree conducted to identify relevant concepts that should be considered when using the decision tree perspective to generate a business process model at the operational abstraction level. During the representational analysis, a set of relevant decision tree concepts that should be taken into consideration when developing a process model has been identified. A representation mapping in which decision tree concepts were mapped to the BWW-representation-model constructs, and an interpretation mapping in which the BWW-representation-model constructs were mapped to identified decision tree concepts were discussed. The results of these two mappings result in a subset of concepts from the BWW representation model that were selected based on their capabilities to represent the relevant decision tree concepts.

Subsequently, the selected BWW subset was used for the representational analyses with BPMN and the Qualigram notations. The completeness of BPMN and Qualigram to represent this subset of the BWW representation model constructs selected for the decision tree perspective was evaluated and compared.

The representational analyses with the BPMN and Qualigram notations showed that the Qualigram notation has the ability to represent all of the selected set of BWW representational model constructs, where construct overloading and construct redundancy deficiencies are present. The identified deficiencies can be useful for modeling practitioners to select modeling notation that offers a higher level of representational clarity when modeling at the operational level. Finally, the representational analyses results showed that the BPMN notation offers a higher level of representational clarity for the decision tree perspective representation. In the next chapter, the results of the survey to validate the outcomes obtained from the representational analyses will be presented.

CHAPTER 4

A SURVEY OF PRACTITIONERS WITH EXPERIENCE

This chapter presents the findings of a survey of experienced BPM practitioners conducted to test a set of propositions defined to evaluate the operational level of BPM+. Moreover, the set of propositions has been formulated to support specifications in the design of the operational level.

These propositions are developed based on the results of the literature review and representational analyses. The research design of the survey has already been discussed in section 2.3. The survey questionnaire can be found in Appendix II.

4.1 The survey questions propositions

Based on the findings of the representational analyses presented in section 3.4 and the literature review, a set of 9 survey questions propositions are formulated:

P1: Modeling business processes at the operational level of abstraction is helpful for generating business process models representing the day-to-day operations as conducted by practitioners.

P2: The decision tree perspective provides useful level of details for some practitioners when modeling business processes at the operational level.

P3: The working instructions perspective offers an important and useful level of details for practitioners when modeling business processes at the operational level.

P4: The decision tree perspective is preferred over the working instructions perspective when generating business processes at the operational level of abstraction using Qualigram notation.

P5: Modeling business processes at the operational level is important to operational stakeholders because it defines tasks, data and tools required to perform a specialized activity.

P6: BPMN notation offers an accepted level of details when modeling operational business processes.

P7: Qualigram notation offers a higher level of details than BPMN when modeling at the operational level of abstraction.

P8: Qualigram notation is preferred over BPMN notation by practitioners to model business processes when representing operational business processes at the operational level of abstraction.

P9: BPMN notation is the most used notation by practitioners with high experience in BPM for modeling business processes.

4.2 Data analysis and findings

The data analysis in this thesis followed a qualitative approach, using frequency analysis based on a sample of the 51 participants who completed the survey. The participants had various occupations and years of experience with BPM (see Figure 4.1). However, the majority had a high level of experience with process modeling and worked frequently with process models. The participants surveyed were requested to share their experiences with process modeling.

Based on these findings, the participants were divided into two groups:

1. High level of experience in process modeling (30 participants): Most members of this group have 4 years or more of experience in business process modeling;

2. Low level of experience in process modeling (21 participants): For the participants in this group, there was no in-depth contact with process modeling and they had little experience in process modeling.

Table 4.1 shows the participants' BPM experience. It can be noted that the participants with less than one year or between one and two years of experience with BPM are both 17.6% and participants with experience between two and four years is 5.9%. These three groups, as defined in this research, are included in the low level of experience group and form 41.1% of the participants (21) in this study. In contrast, participants defined with the high level of experience consist of 58.9% (30 participants) in this study.

Table 4.1 BPM experience of the participants

BPM Experience	Frequency	Percent	CP
Less than 1 year	9	17.6	17.6
1 to less than 2 years	9	17.6	35.2
2 to less than 4 years	3	5.9	41.1
4 to less than 6	7	13.7	54.8
6 years or more	23	45.2	100.0
Total	51	100.0	

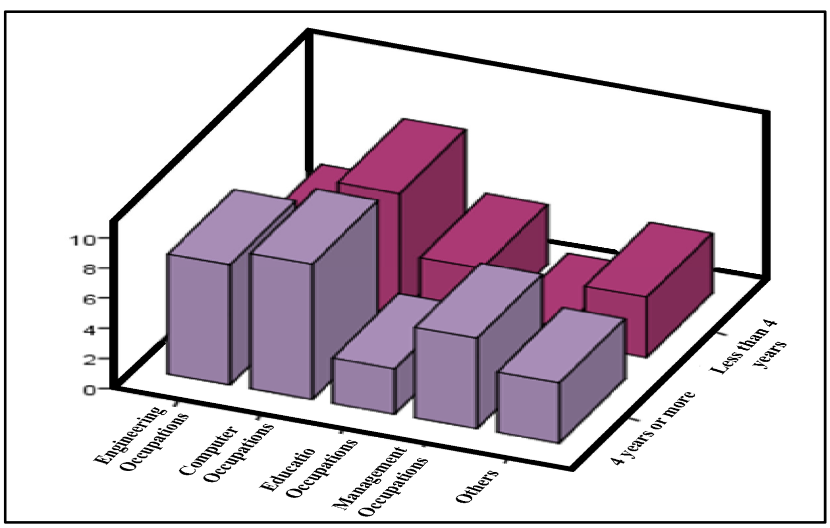


Figure 4.1 Distribution of the 51 participants according to their professions and BPM experience

Modeling business processes at the operational level of abstraction helps generate business process models representing the day-to-day operations (**Proposition P1**). Two survey questions are used to test this: the first is about the usefulness of modeling daily operations, and the other concerns the usefulness of modeling at multiple levels of abstraction. 83.7% of the participants expressed the usefulness of modeling daily operations and the usefulness of modeling at multiple levels of abstraction (see Table 4.2) (Appendix I, section A.1 presents the Tables and Figures summarizing the survey results with respect to the usefulness of modeling the business processes of daily operations at multiple levels of abstraction.).

Table 4.2 Usefulness of using business process models representing daily operations and modeling business processes at multiple levels of abstraction

		VLU	**LU**	**N**	**HU**	**VHU**	**Total**	**Mode**
Usefulness of using business process models representing daily operations	Frequency	2	1	5	20	21	49	VHU
	Percentage	4.1	2.0	10.2	40.8	42.9	100	
Modeling business process at multiple levels of abstraction	Frequency	1	0	7	20	21	49	VHU
	Percentage	2.0	0.0	14.3	40.8	42.9	100	

VLU: Very Low usefulness; **LU**: Low usefulness; **N**: Neutral; **HU**: High usefulness; **VHU**: Very High usefulness

If we consider the relationship between proposition P1 and the participant's experience, the results show that the majority of both groups (high or low level of modeling experience) agree that modeling daily operations is useful (very high usefulness/high usefulness). However, in total, 3 of the 51 participants disagree; they perceive a low level of usefulness regarding using business process models to represent daily operations. Moreover, results show that the participants with a high level of experience strongly agree with the usefulness of modeling business processes at multiple levels of abstraction. The majority of both groups (high or low level of modeling experience) agree that the usefulness of modeling business processes at multiple levels of abstraction is useful (high usefulness/ very high usefulness). These results **support proposition P1.**

The Fisher exact test is used to examine the relationship between participant experience in BPM and the usefulness of modeling daily operations and modeling at multiple levels of abstraction. Cross tabulation and Pearson Chi-square test of independence are not considered since the expected frequency is lower than five for some categories, which means the Pearson Chi-square test assumption is violated. Furthermore, it is worth mentioning that the Cross tabulation and Pearson Chi-square test assumption is violated even when the level of usefulness is merged in two groups: Group A (i.e., VHU and HU) represents a positive level of usefulness and Group B (i.e., VLU, LU, and N) represents a negative degree of usefulness. Therefore, the best choice is to use the Fisher exact test. (Table-A I-2 in Appendix I presents the Fisher exact test results for the usefulness of using business process models for representing daily operations and modeling business processes at multiple levels of abstraction).

The Fisher exact test results indicate that the participant's experience in BPM is independent of the response regarding the usefulness of modeling daily operations (p=0.274) and modeling at multiple levels of abstraction (p=0.067). This confirms that using BPM in day-to-day operations and modeling at multiple levels of abstraction is very useful for both groups of participants, regardless of their experience level.

Regarding the decision tree perspective, the summary of the ranking for the importance of the level of detail for modeling business processes using the decision tree perspective in Qualigram (i.e., Very High = 5; High = 4; Neutral =3; Low=2 and Very low =1) and various levels of details usefulness (i.e., Very High = 5; High = 4; Neutral =3; Low=2 and Very low =1) according to their experience was analysed. (Appendix I, section A.2 presents the Tables and Figures summarizing the survey results with respect to the importance of modeling business processes using the decision tree perspective.).

Participants with experience of four years or more present the highest scaled total for the high/very high level of details usefulness using the decision tree perspective (63 and 35). Also, the median/mode for the high/very high level of usefulness is high for those with more experience and very high for less experienced participants. The relationship between the participant's degree of experience and importance and usefulness of the level of detail of the decision tree perspective with Qualigram is examined using the Fisher exact test since the Chi-square test assumption will not be met, even if we ignore or merge the VL and L categories.

The null hypothesis is that *the experience level of the two groups of participants (based on their experience of less than four years or of four years or more) and the importance and usefulness of the level of detail of the decision tree perspective are statistically independent*.

The *p*-value of the Fisher exact test is more than 0.05 level (*p*-value =0.079). There is statistical evidence to indicate that there is no relationship between the practitioner's experience and the importance and usefulness of the level of detail of the decision tree perspective. This finding indicates that high/very high usefulness of the level of details of the decision tree perspective is necessary for most participants, regardless of their level of experience. Moreover, the decision tree perspective provides participants with a very useful and high importance level of details when modeling business processes at the operational level and generates a high comprehensible business process model. These findings support **proposition P2**.

Concerning the importance of the level of detail representing business processes at the operational level using the "working instructions" perspective in the Qualigram notation, the results show that 31 participants considered the level of detail in the business process of high/very high importance. (Appendix I, section A.3 and A.4 present the Tables and Figures summarizing the survey results with respect to the importance of the level of detail and the usefulness of modeling business processes using the working instructions perspective.). Moreover, the experience level of the participant is independent of the importance level of working instructions (test statistic = 2.525, p-value = 0.524). These findings support **proposition P3**.

Regarding the participant's opinions for modeling business processes at the operational level of abstraction using the "working instructions" perspective in the Qualigram notation, results show that 60 % of participants regardless of their modeling experience consider the working instruction perspective of high usefulness/very high usefulness (see Table-A I-6 in Appendix I). Moreover, the participant experience is independent of the usefulness of the operational level (test statistic = 5.04, p-value = 0.170). These findings also support **proposition P3**.

According to the participant's preferences for representing business processes at the operational level of abstraction using either decision tree and working instructions perspectives in Qualigram notation, most participants prefer the decision tree perspective. The results show that 68% of those with more experience and 47.1% of those with less experience prefer the decision tree to represent operational business processes. It is worth noting that the second preference for those with low levels of experience (less than four years) is working instructions perspective (35.2%). (Appendix I, section A.5 presents the Table and Figure summarizing the survey results with respect to the preference between the decision tree and the working instructions perspectives.). Moreover, the Fisher exact test results show that the participant's preference for representing operational business processes using either decision tree or working instructions is independent of the experience with BPM (test statistic = 3.667, p-value = 0.313). These findings support **proposition P4.**

Moreover, most participants with high or low levels of modeling experience strongly agree (48%) that modeling the business process at the operational level is important because it defines tasks, data, and tools required to perform an activity. 63.2% of participants with less experience agree, and 58.6% of those with more experience strongly agree with this result. The relationship between a participant's experience and the level of agreement tested using the Fisher exact test, at significance level 0.05, showed that both variables are independent (test statistic =4.645, p-value = 0.087). These findings support **proposition P5.** (Appendix I, section A.6 presents the Table and Figure summarizing the survey results with respect to the importance of modeling business processes at the operational level.).

Also, 37% of participants have expressed a high level of importance for representing operational business processes using BPMN notation; results show that 50% of participants with the low level of experience see a high/very high level of details importance vs. 64.3% for participants with the high level of experience. This observation shows that a participant's experience in the BPM domain can be reflected in their BPM notation preference. By comparing both groups, the results show that most of the participants with a high level of experience (64.3%) claim that the level of details is either of high importance (46.4%) or of very high importance (17.9%) for operational business processes represented using BPMN notation. Furthermore, results show that 50% of participants with low level experience consider the BPMN level of details at the operational level to be of high and very high importance. The Fisher exact test confirms these results with test statistic value of 3.95 and p-value= 0.245, indicating there is no relationship between the experience level and the level of importance of using BPMN notation. Regardless of their experience, most respondents agree on the importance of using BPMN. These results support **proposition P6**. (Appendix I, section A.7 presents the Table and Figure summarizing the survey results with respect to the importance of modeling business processes of using BPMN notation).

The results show that 45% of participants with high or low experience in BPM expressed high usefulness of the business process model represented using BPMN. Participants with high experience responded with higher frequencies (see Table-A I-10 in Appendix I). Findings show that participants claim high usefulness in modeling operational business processes using BPMN notation with percentages 50% and 41.4% for low level and high level of experience, respectively. These findings support **proposition P6.**

The survey showed the participant's opinions about the level of details of the business process model represented using Qualigram notation vs. that using BPMN notation. Most participants with a high level of experience (72%) consider the level of details offered by the Qualigram notation to be better than that of BPMN notation. In comparison, there is no clear preference for participants with lower levels of experience as they consider both graphical notations to offer the same level of details. The Fisher exact test (that the experience level is independent of the preferences) has a p-value = 0.204. However, by if we consider adding the frequency of the choice of "both" BPM notations to that of "Qualigram" and "BPMN" notations (see Table-A I-12 of Appendix I), the results still show that Qualigram notation is the most selected type of notation. These findings support **proposition P7.** (Appendix I, sections A.9 and A.10 present the Tables and Figures summarizing the survey results with respect to the modeling business processes of using Qualigram versus BPMN notation.).

Most participants prefer Qualigram notation over BPMN notation to model business processes at the operational level. However, considering the experience level, the results show that 73.9% of participants with a high level of experience prefer Qualigram, while for those with a low level of experience, 42.9% prefer Qualigram and 50% prefer BPMN. By testing the relationship between the experience level and the preference, the Fisher exact test indicated no relationship between these variables with p-value = 0.102. When we consider adding the frequency of the choice of "both" BPMN notations to the choice of either Qualigram or BPMN notation (see Table-A I-12 of Appendix I), the results still show Qualigram notation as the preferred notation to model business processes at the operational level. These findings support **proposition P8**. (Appendix I, section A.10 presents the Table and Figure summarizing the survey results concerning the preference of Qualigram versus BPMN notation.).

Also, according to participants, BPMN (37 %) and Qualigram (20 %) are the most often used BPM notations. The Fisher exact test value (12.049) and p-value (0.032) indicate that there is a relationship between the participant's experience and the graphical notation variable. In comparing both groups, the results showed that the participants with a high level of experience use BPMN (43.3%), while those with a low level of experience use either BPMN or none with the same percentage value (28.6%). Since the results depend on the participant's experience, these findings partially support **proposition P9**. (Appendix I, section A.11 presents the Table and Figure summarizing the survey results concerning the BPM notations most used.).

4.2.1 Interpretation and summary of the results

This section summarizes the results of the survey conducted to assess the possible contribution of the operational level of BPM+ to modeling and representing day to day operations in specialized operational graphical representations. The results show that participants with a high level of experience strongly support modeling business processes at multiple levels of abstraction. The majority of both groups (those with high and low levels of modeling experience) considered modeling business process at multiple levels of abstractions to be useful.

The results also show that the level of detail when using the decision tree was deemed necessary by all participants, regardless of their level of experience. The decision tree perspective provides participants very useful details with a high level of importance when modeling business processes at the operational level and generates a highly comprehensible business process model. In addition, the working instructions perspective of Qualigram notation, was considered of high/very high usefulness by participants.

Regarding a practitioner's preference for representing business processes at the operational level of abstraction using either decision tree and working-instructions perspectives in Qualigram notation, most of the participants preferred the decision tree perspective. Also, results show that the second preference for participants with a low level of experience is the working instructions perspective. The survey confirms that most participants with any level of modeling experience strongly agree that modeling the business process at the operational level is important and supports defining tasks, data, and tools required to perform an activity.

When considering BPMN notation, results show that participants attribute a high level of importance to representing operational business processes using BPMN notation; 39 % of participants with a high level of experience chose high/very high level of detail importance vs. 20% for those with a low level of experience. This finding reveals that the experience in the BPM domain can be reflected in the user preference of a BPM notation.

Questions comparing the level of detail offered by both modeling notations demonstrated that most participants with a high level of experience selected the Qualigram notation over the BPMN notation. While there is no clear preference for participants with a lower level of experience, they consider both notations to offer the same level of details. Also, the majority of the survey participants preferred the Qualigram notation over the BPMN notation for modeling business processes at the operational level.

This survey shows that practitioners selected BPMN notation as the most commonly used BPM notation. The results indicated a relationship between the participant's experience level and the choice of notation, where those with a high level of experience prefer BPMN. In contrast, participants with a low level of experience prefer either BPMN or none.

CHAPTER 5

BPMN EXTENSIONS OF DECISION TREE PERSPECTIVE

5.1 Overview

To be usable, an operational representation, like a data model or a decision tree representation graphical constructs must be represented correctly in any graphical notation to be usable. Currently, BPMN does not support the graphical representation of decision trees graphical constructs natively as well as many other operational models. This chapter discusses the need for a BPMN extension to incorporate the graphical representation of the decision tree perspective into business process diagrams (BPD). This would allow the use of decision trees in BPMN models when a stakeholder would prefer using it to represent his or her models. However, among the set of symbols used for the construction of the BPD (OMG, 2013), our research considers BPMN constructs selected for modeling business processes at the BPM+ operational level. Table 5.1 shows the operational level of BPM+ construct representation in BPMN notation to be incorporated into the metamodel shown in Figure 5.1

Table 5.1 Representation of operational-level BPM+ in BPMN notation
Adapted from Monsalve (2012, p. 81)

BPM+ Modeling Concepts	BPMN
Task	Task
Role	Lane
Relationship between actions	Sequence flow
Physical tool	Not available: use text annotation, attached with an association.
Document	Data object
Triggering event	Start event
End event	End event
Control flow pattern	Gateways

BPM+ Modeling Concepts	BPMN
Business rules	Not available: use text annotation, attached with an association.

The intersection between the standard constructs of BPMN and the operational level of BPM+ identifies the constructs that coincide with the integration of the BPM+ at the operational level as variable [B]:

- Task and Relationship between actions in a specific role that requires Physical tool and Document;
- Each Task should be triggered by an event START and finished by an event END;
- The sequencing of activities is subordinated by Boolean logic in logical gateways (OR / AND);
- Each actor (lane) defines a business rule.

The [A] variable is the metamodel variable, resulting from the theorization of unified models, namely UML. It uses the object-oriented paradigm to enrich existing models with the new concepts of the new extension using BPMN as shown in the below formula:

$$\textit{Formula: } [A] \cap [B] \tag{4.1}$$

5.2 Decision tree formal definition

As presented in section 3.3, the representation analysis of a decision tree has identified relevant concepts that should be considered when using the decision tree perspective to model a business process at the operational level of abstraction. As shown in Table 3.3, relevant decision tree concepts are required to generate a process model.

The [C] variable represents the relevant concepts associated with a decision tree for analyzing the BWW representation model within the specific span of the decision tree adapted from (Alomari, April, Monsalve and Gawanmeh, 2018).

The final formula to generate the extension using BPMN concepts for the decision tree (DT) perspective is completed by performing the cartesian product between variables [A] and [B]:

$$\textit{Formula: } DT = \left([A] \cap [B]\right) \times C \quad (4.2)$$

Considering the definitions of the operational level concepts listed in Table 5.1, and the known metamodel of BPMN shown in Figure 5.1, a metamodel of the operational level of BPM+ has been created and is described in Figure 5.2.

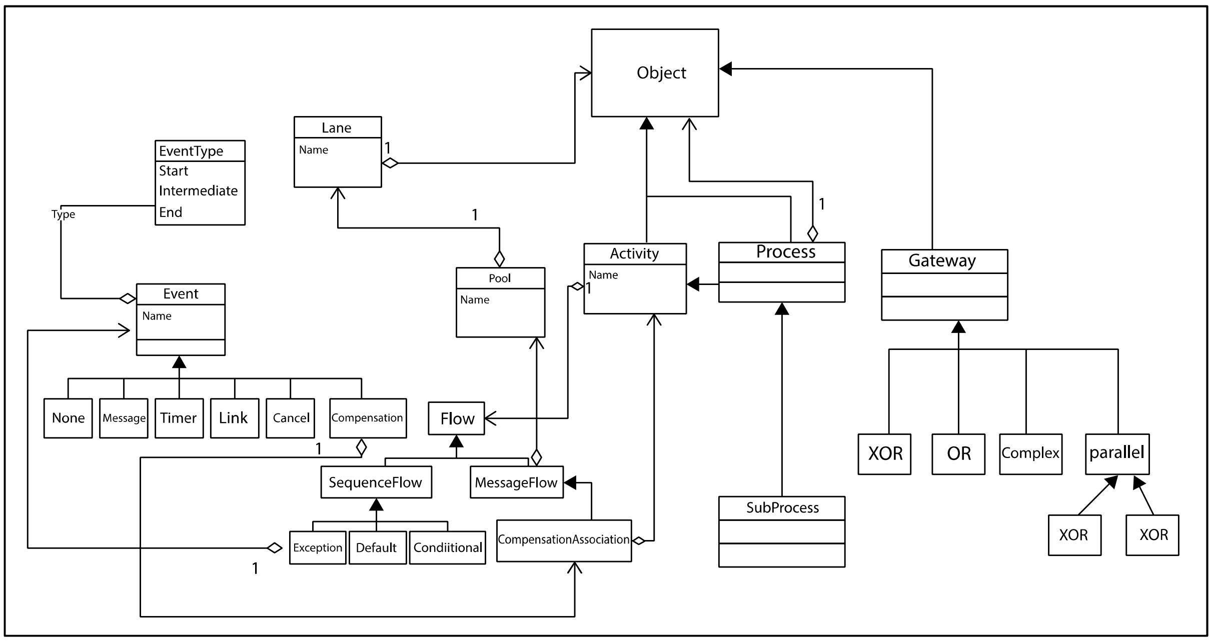


Figure 5.1 Metamodel of BPMN

The steps below define the metamodel of BPM+ at an operational level as the [A] variable:

- Object class equals BPMN Object, which means BPMN is based on the object-oriented paradigm of the unified UML notation enriched by new concepts namely, activities, events, business processes, and message, which are all represented as abstract objects using the principle of inheritance, and composition of aggregation specific to this paradigm;

- Elaboration of an intersection between the operational level of BPM+ concepts and the metamodel shown in Figure 5.1;
- Foundation of the metamodel of operational level of BPM+.

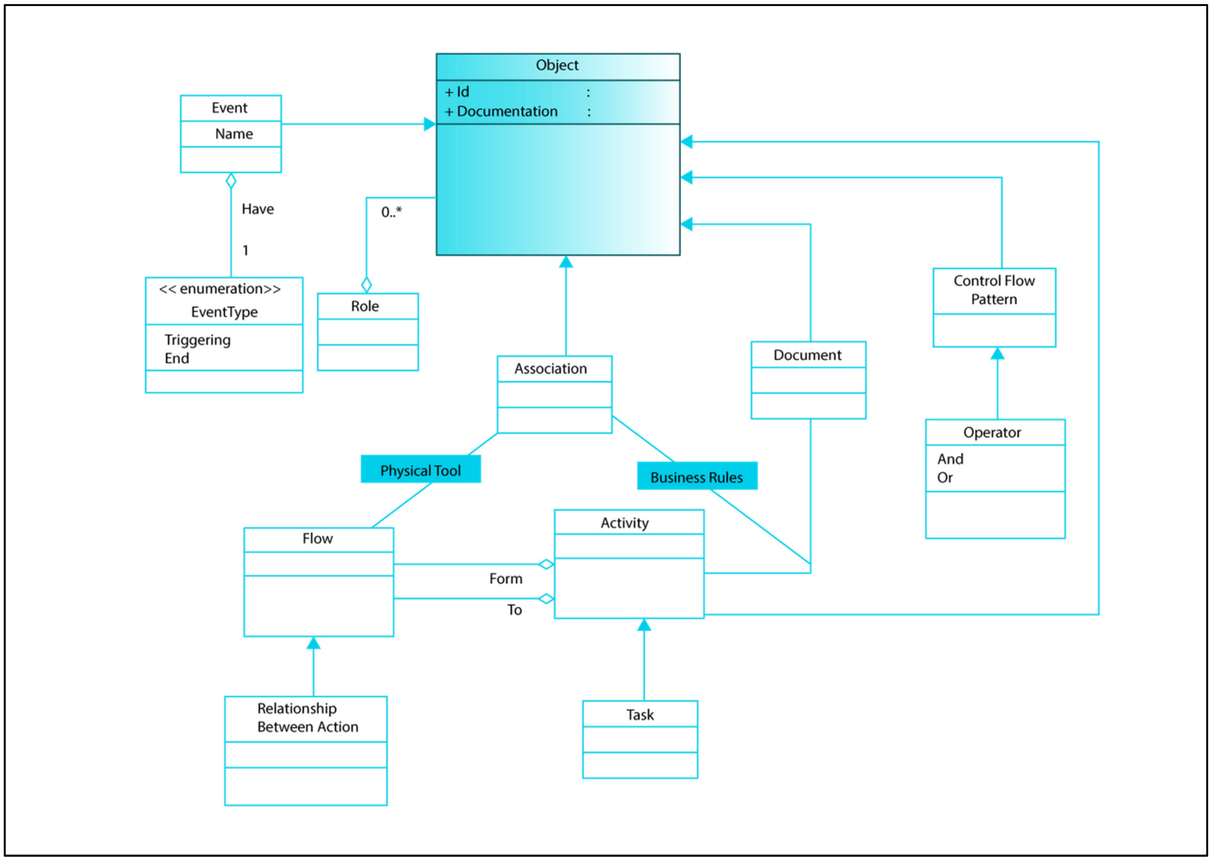


Figure 5.2 Metamodel of operational level of BPM+

5.3 BPMN 2.0 extension mechanism

BPMN 2.0 adds an extensibility mechanism that allows extending standard BPMN elements with additional attributes (OMG, 2013). The new mechanism can be used by modelers and modeling tools to add non-standard elements or artifacts to satisfy a user's specific needs, and still have valid BPMN core. Extension attributes must not conflict with the semantics of any BPMN element. Also, while extensible, BPMN diagrams should still have the basic look-and-feel so that any viewer of the diagram can easily understand a diagram provided by any modeler. Therefore, the essential flow elements "Events, Activities, and Gateways" must not be changed.

BPMN 2.0 is the most recent version of the BPMN notation. The extension mechanism is used to integrate the decision tree perspective in BPMN 2.0 (Figure 5.1) and shows an UML class diagram of a simplified extract from the BPMN 2.0 metamodel. The Definitions class extends the BaseElement class, which provides the basis for all BPMN 2.0 elements. Each class with name Definitions is composed of one or more Extension classes to technically integrate the decision tree elements in BPMN 2.0.

In the business process, we extend the class Extension Definition. The new class is called Decision Tree (DT) (see Figure 5.3). BPMN 2.0 is a formal definition with standard notation in the form of a metamodel, that is a precise definition of the constructs and rules needed for creating specific models.

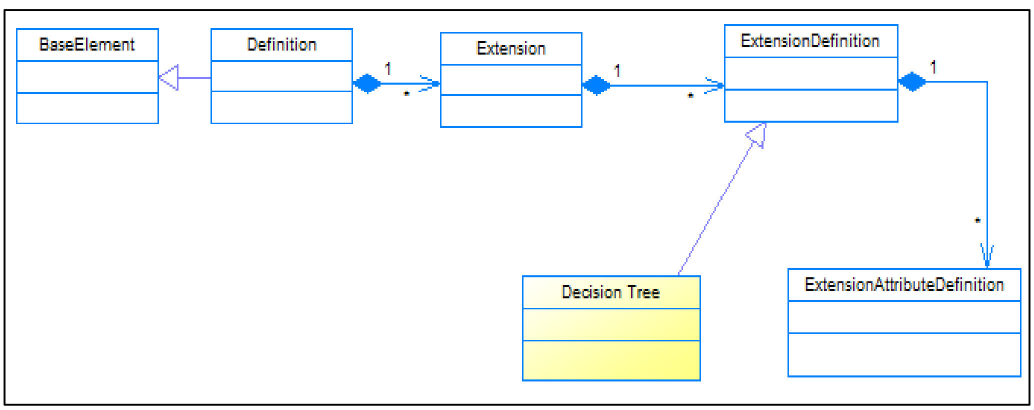


Figure 5.3 Basic mechanism for new extension "Decision Tree"

Intersection of the metamodel of BPMN and the operational level's metamodel is executed, then a projection is made on the decision tree perspective to define a variable DT/ Annotation special for the decision tree. This methodology is a standard general method for the implementation of a new extension.

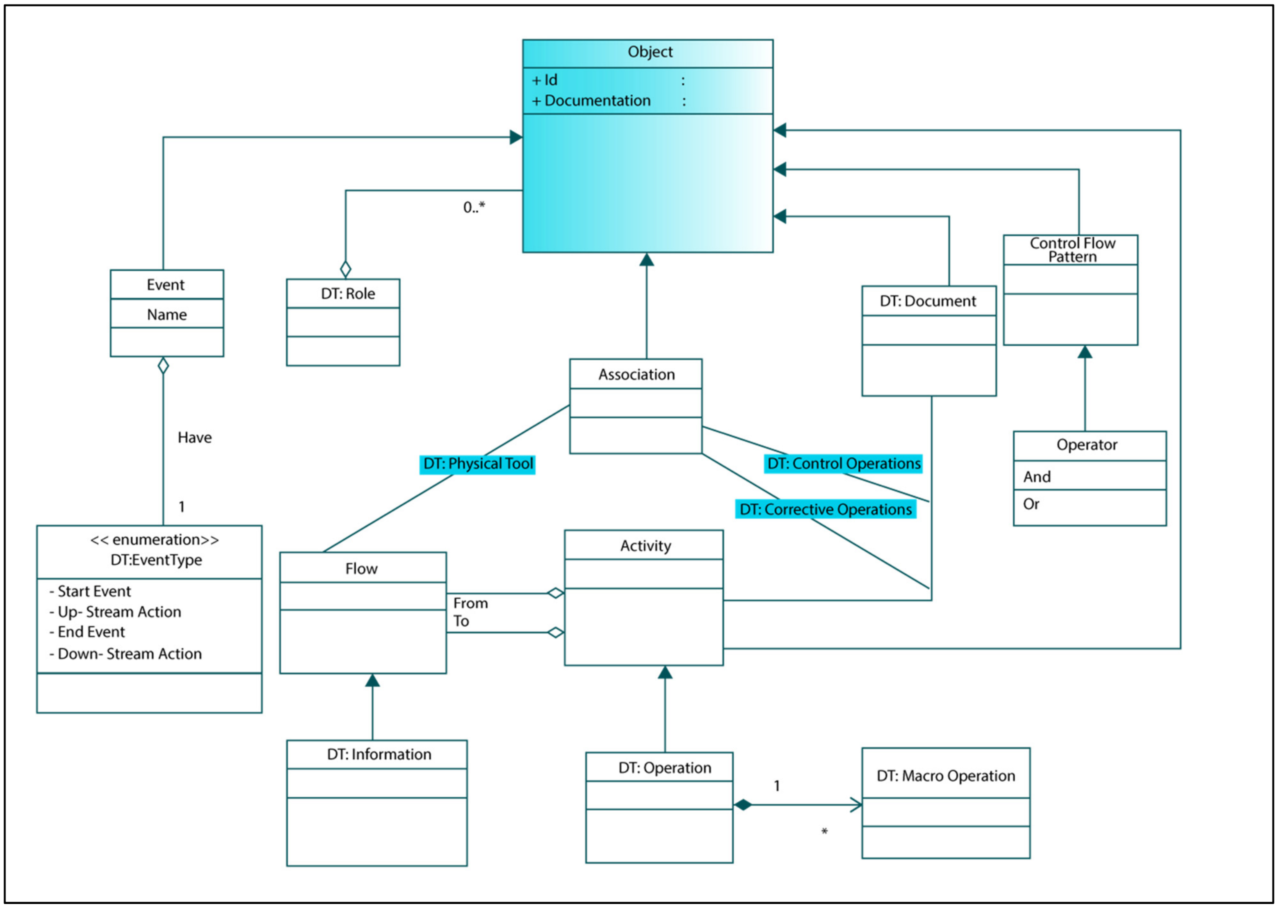


Figure 5.4 Metamodel of BPM+ operational level with variable DT / annotation special of decision tree

5.3.1 BPMN extension for decision tree perspective

Figure 5.4 shows a model of the decision tree perspective that we want to incorporate into the metamodel shown in (Figure 5.1). The extension mechanism in BPMN allows for the addition of marks or indications to the already defined graphical elements. This research represents the decision tree in a standard way. Each decision tree concept is specified with capital letters "DT" in the centre of the symbol (see details in Table 5.2). Free annotation denoting DT is assigned to each BPMN symbol to indicate that we are working in a decision tree perspective while respecting the general scheme. The general form of this extension is a succession of activity (Sub process) but specified by an entry OR clause which links the different pathways of decision tree perspective, and each subprocess can be any form of BPMN 2.0 extension and can contain the whole notation.

Table 5.2 BPMN extension of decision tree perspective

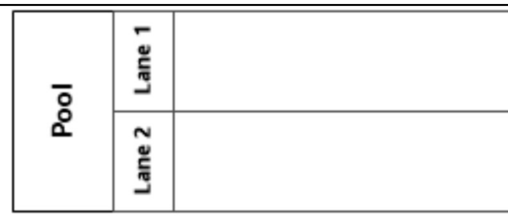
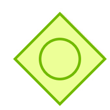
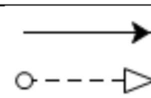
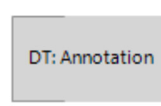
DT: Lane	
DT: Start Event	 DT:START
DT: End Event	 DT: END
Activity for action in decision tree	
Gateway	 DT : AND  DT : OR
Sequence Flow **Message Flow**	
Physical Object, Document, Text	 DT:Data Object  DT:Data Store 

Figure 5.5 describes a firewall process used by the firewall and security engineers to review firewall rule changes and identify network security violations before deployment into

production. Figure 5.6 presents a representation of the firewall review process using the BPMN decision tree extension. The figure shows sequential activities and several gateways, including the first “AND”, which separates the decision tree’s pathways.

As shown in Figure 5.6, the firewall engineer is identified in the Pool “Firewall review team” (the team who receives firewall review requests and controls the process). The pool is divided into two lanes that show the firewall engineer and the security engineer involved in the review and who approve firewall changes. For Pool “Firewall review team” the aim is to clearly represent the decision required from the firewall engineer in the case that a security impact has been identified. He is to transfer the firewall request to the security engineer over the sequence flow that goes from the lane Firewall engineer to the lane Security engineer for security and compliance review. The security engineer completes the security review, and the “OR” gateway has branched the process into two paths where each sequence flow becomes active upon the execution of the “OR” gateway. Finally, the “AND” gateway in the firewall engineer branch receives the process flow either from the Firewall engineer lane or from the Security engineer lane, and each path is considered in the process flow.

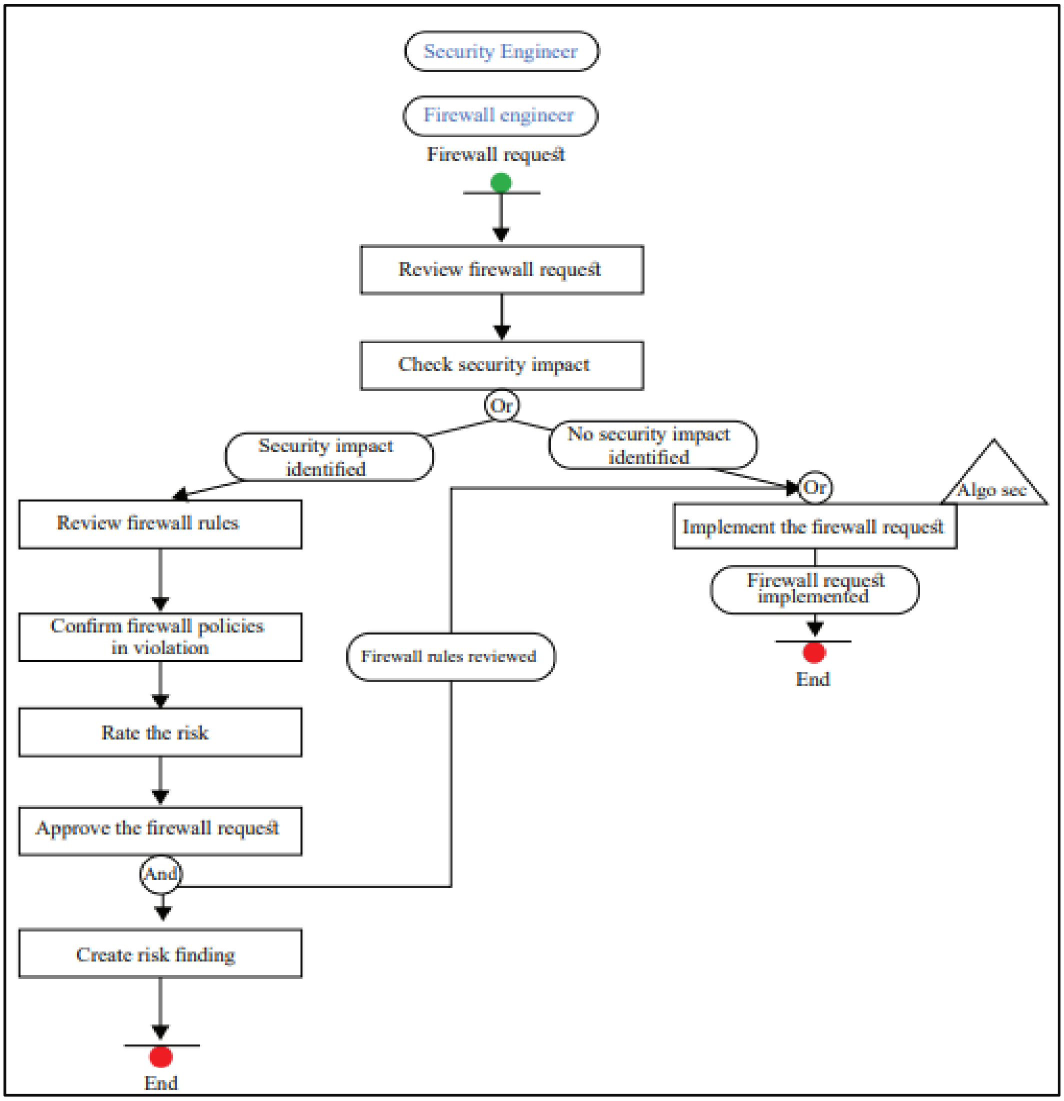


Figure 5.5 Representation of the firewall review process using Qualigram notation

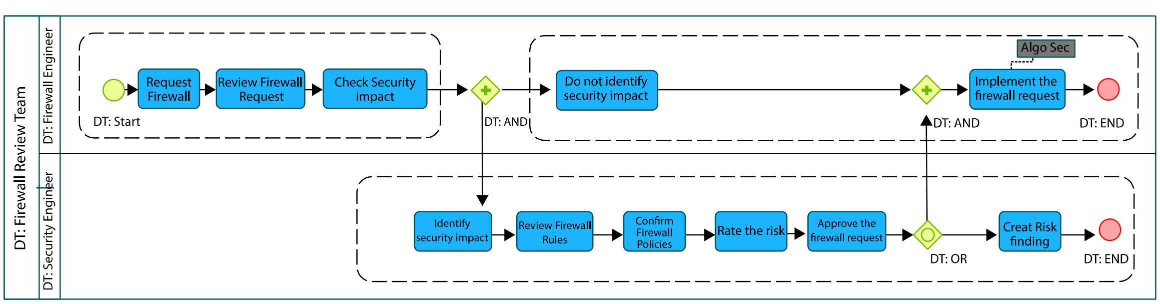


Figure 5.6 Representation of firewall review process using BPMN decision tree extension

5.4 Conclusion

This chapter presented the effort of incorporating a decision tree perspective into the BPMN notation for business processes modeling. The BPMN metamodel was presented with the core elements and extension that allow for the integration of decision tree concepts into business process diagrams to provide flexibility for users. This extension allows us to model decisions trees within the BPMN notation showing the use of an operational level concept in the most popular BPM notation.

CONCLUSION

Summary

This thesis has addressed the problems associated with the representation of operational business processes. The research investigated the possibility to generate multiple representation perspectives for the operational level of abstraction to allow specialized stakeholders to use their preferred modeling representation at the operational level of the process repository.

The overall goals were to demonstrate:

1. There are many possible specialized operational representations that have the potential for use;
2. How to validate one of them using the Bunge-Wand-Weber (BWW) representation model;
3. What potential users think of using this type of representation at the operational level; and
4. How the existing BPMN notation can be extended to add this newly validated representation so as to be easily used in future BPM initiatives.

By considering these goals, this thesis's objective was to study possible business process operational representations and select a specialized representation to be added to the operational level of BPM+ as a new representational perspective. The following specific research sub-objectives were defined:

1. Identify the set of relevant concepts of the representational perspective that should be considered when developing a process model at the operational level;
2. Determine the modeling concepts that should be used to represent this new perspective (e.g., the decision tree);
3. Evaluate how well current BPM notations represent this new perspective;
4. Identify the modeling constructs needed to represent such a new perspective.

A method for implementing the decision tree perspective was described (see Figure 2.2). An initial version of the implementation of the decision tree perspective was designed based on the findings of our literature review. The a priori version was refined based on the results of a series of representational analyses (refer to section 3.3) and a survey of practitioners with experience in BPM.

The representational analyses helped to identify concepts and review the contents of the decision tree perspective. The survey helped to evaluate the scope and content of the perspectives at the operational level. The survey also helped to identify modeling and BPM notation preferences according to the different types of participants and their experience with BPM.

This thesis's primary research objective concerns how multiple representation perspectives for the operational level of abstraction can effectively improve the existing organizational-business process model repository.

The initial step to answering this objective was to review possible representation perspectives that can be implemented at the operational level. Three perspectives were studied and reviewed among many possible perspectives section 1.8.2. The decision tree perspective was selected to be further investigated and studied as a new representational perspective at the operational level.

We continued to identify a set of decision tree concepts. As a next step, a mapping of the identified set of concepts to the BWW representation model was performed to identify a subset of ontological concepts which, according to the studied references, represents concepts that are relevant to the decision tree. The selected subset of ontological concepts was presented in Table 3.4. These ontological concepts should be included in the model when representing business processes using the decision tree perspective. In the ideal scenario, each of these ontological concepts should be represented by a specific modeling construct of the BPM notation used to create the business process models.

How well is the operational level of abstraction and its modeling constructs represented by modeling notations? BPMN has a high degree of completeness, and therefore, it was selected to be used in this research. BPMN is considered to be an appropriate standard to assess the capability of other BPM notations to represent business processes at the operational level of abstraction. Evidence shows that organizations often look for simplicity and ease of use in a BPM notation; however, BPMN is complex. To consider and address this concern, the management-oriented notation of Qualigram was selected in this thesis because it is considered an easy to understand modeling notation.

The capability of the two BPM notations to represent the selected set of modeling concepts was assessed; the modeling constructs of these modeling notations were mapped with the selected set of ontological concepts relevant to the decision tree. The mapping results were presented in Table 3.5, showing that BPMN and Qualigram are equally capable of representing the selected concepts. The results also showed that Qualigram provides a higher capability for representing ontological concepts confirmed by the literature as concepts that allow for describing and representing business processes using a decision tree. BPMN and Qualigram are equally capable of representing all of the selected relevant concepts.

The capability of BPMN and Qualigram to support the operational level of abstraction was assessed by conducting a survey that confirmed Qualigram is capable of supporting the decision tree perspective.

A BPMN extension for modeling decision tree in business processes was developed. The new extension provides modelers the option to model decisions in their day to day business processes. A specific set of BPMN elements were extended with additional decision tree attributes.

Contributions and outcomes of this research

The main contribution of this thesis is the demonstration of how an operational perspective, required by specialized stakeholders, can be validated and used based on the results of ontological analysis/validation. This contribution opens the door to adding potentially any operational perspective to current graphical notations, as we have shown by extending the BPMN notation to use a decision tree representation for example.

In addition to the main contribution, other less important contributions have been achieved in the process of developing this thesis:

1. A set of ontological concepts selected to represent the relevant concepts when modeling using the decision tree perspective (Table 3.4);
2. A capability assessment of Qualigram and BPMN notations to represent a subset of ontological concepts of the most applicable concepts to decision trees (section 3.4);
3. The representational analysis of newly added constructs of BPMN version 2.0.2;

Expected industry impacts

The contributions of this thesis may generate the following benefits for the evolution of notations when modeling operational business processes:

1. How to validate proposed operational perspectives using ontological analysis;
2. The possibility to create a repository of multiple representation perspectives, at the operational level, that would help various operational staff represent and document their operational business processes;
3. An example of how a BPMN extension can be done as was shown by the example of the integration of the decision tree perspective;
4. An example of how to evaluate/improve graphical notations as demonstrated by the evaluation of BPMN and Qualigram notation capabilities.

Limitations

The scope of this thesis included some limitations and validity threats that were presented in Table 2.5. Additional limitations are described below:

1. The literature presented different perspectives that can be integrated at the operational level. However, this thesis has considered and studied one perspective (the decision tree). Future research work is required to explore the integration of other perspectives at the operational level to meet different specialized needs to mitigate this threat;
2. The development of the decision tree perspective was conducted using research methods, representational analysis, and survey. However, other research methods could have been included (e.g., case study, interview with experts);
3. For the scope of this research, two business process modeling notations were used (BPMN and Qualigram), among other notations that have been reviewed in the literature. To avoid this limitation, future research should consider other BPM notations to study the applicability of the results.

Further research work

The contributions presented in this thesis could be developed and extended to the following lines of research:

1. Studying new representation perspectives to be integrated at the operational level and validating the generalization of the operational level perspective;
2. Researching the operational level perspectives with other BPM notations and conducting new experiments for business process models generated using these other BPM notations;
3. Conducting a case study to further test the new BPMN extension developed for the decision tree perspective with practitioners to generate business process models using the decision tree perspective;

4. Conducting a case study using BPM and a specialized audience to further study the applicability of the decision tree perspective and its benefits.

Finally, this thesis has published contributions to the following:

Journal:

Alomari, A., April, A., Monsalve, C. and Gawanmeh, A. (2018). Integrating a decision tree perspective at the operational level of BPM+. *Computer Systems Science and Engineering*, *33*(3), 219-227.

Conference:

Alomari, A., April, A. and Monsalve, C. BPM+: Proposal of Specialized Stakeholders Operational-Level Perspectives and their BPMN Extensions.

APPENDIX I

SURVEY RESULTS

This appendix includes tables and figures for analysis of the survey results discussed in Chapter 4:

A.1 Usefulness of modeling at multiple levels of abstractions

Table-A I-1 Usefulness of modeling daily operations and modeling business processes at multiple levels of abstractions

		VLU	LU	N	HU	VHU	Total	Scaled Total	Mode
Usefulness of using business process models representing daily operations	Less than 4 years	2	1	2	6	8	19	74	VHU
	4 years or more	0	0	3	14	13	30	130	HU
Modeling business process at multiple level of abstraction	Less than 4 years	1	0	5	8	5	19	81	HU
	4 years or more	0	0	2	12	16	30	134	VHU

VLU: Very Low usefulness; **LU**: Low usefulness; **N**: Neutral; **HU**: High usefulness; **VHU**: Very High usefulness

The scaled total presented in the above table has been calculated as a weighted sum of the frequencies for the VHU, HU, N, LU, and VLU, as 5, 4, 3, 2 and 1, respectively, to determine the total ranks of usefulness.

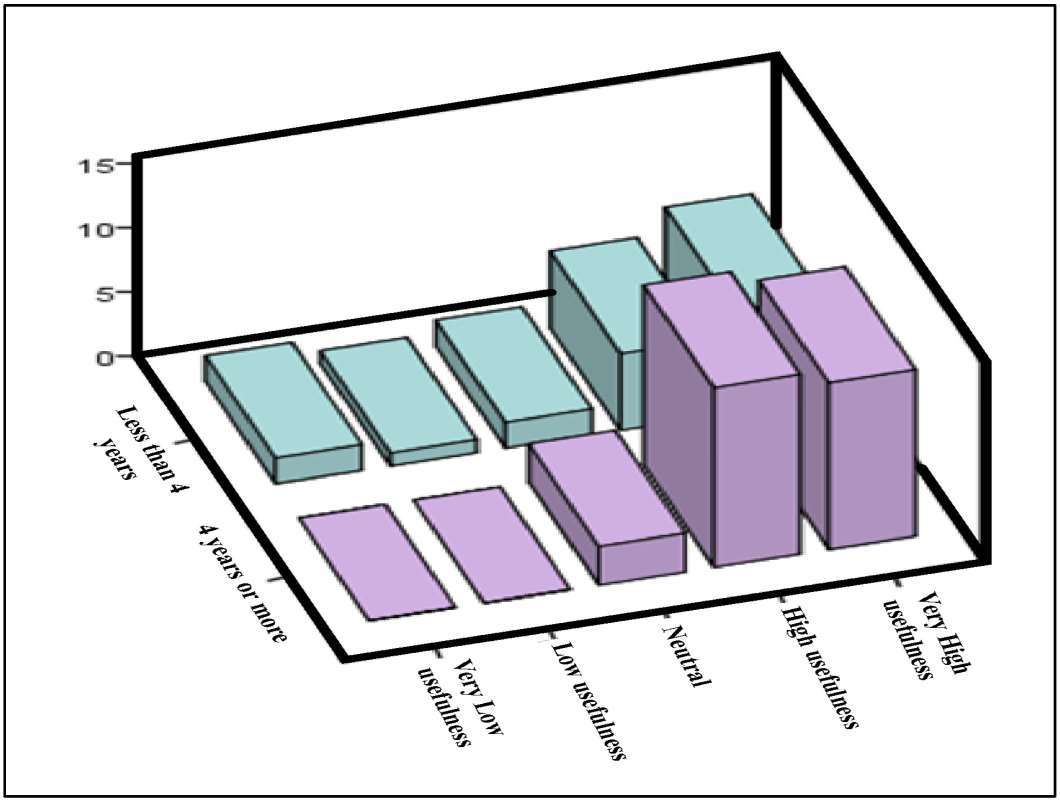


Figure-A I-1 Usefulness of modeling daily operations according to a participant's experience

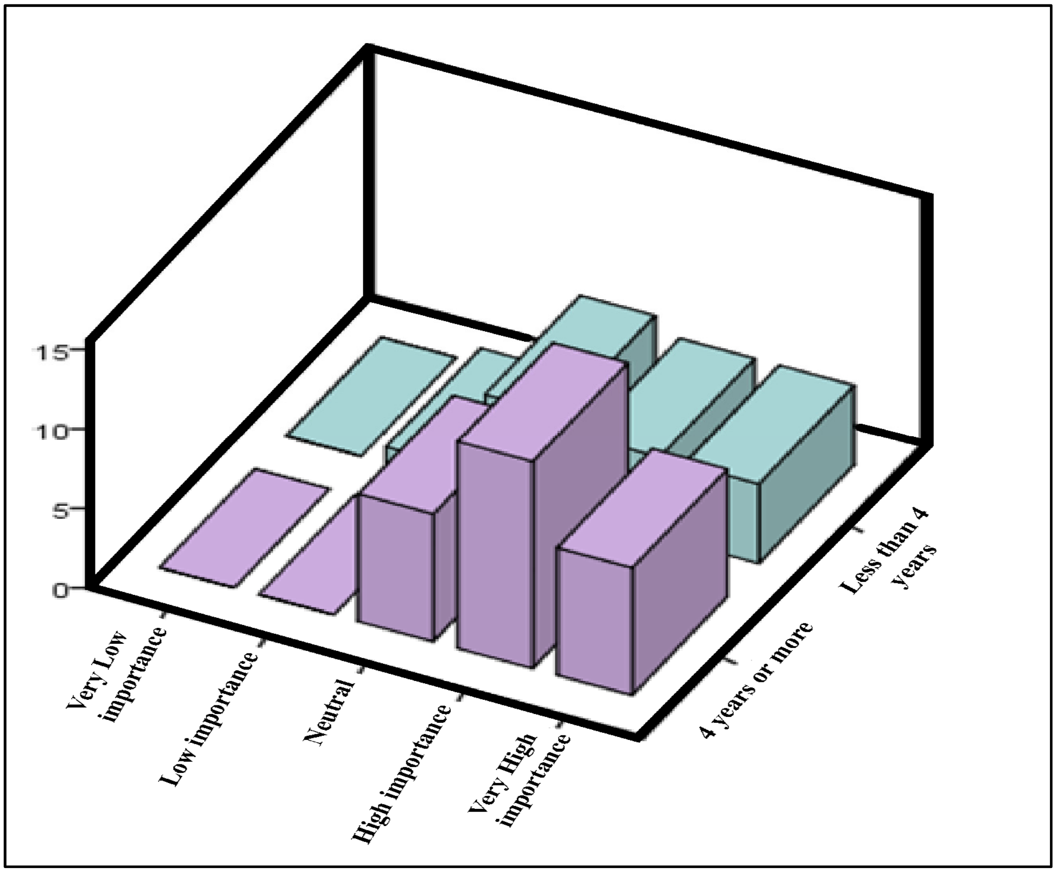


Figure-A I-2 Usefulness of modeling at multiple levels of abstraction according to a participant's experience

Table-A I-2 Fisher exact test results

	Test Statistic	**P-Value**	Results
Usefulness of using business process models representing daily operations	4.903	0.274	There is no relationship between experience and: • usefulness of modeling daily operations. • modeling at multiple levels of abstraction.
Modeling business process at multiple levels of abstraction	6.423	0.067	

A.2 Importance of modeling using the decision tree perspective

Table-A I-3 Importance of modeling using the decision tree perspective in Qualigram

Experience	**Level of usefulness**	**Frequency of importance rank**					**Total**	**Scaled Total**	**Median**	**Mode**
		VL (1)	L (2)	N (3)	H (4)	VH (5)				
Less than 4 years	VL	0	0	0	0	0	0	0	NA	NA
	L	0	1	0	0	0	1	2	L	L
	N	0	1	1	3	0	5	17	H	H
	H	0	1	1	5	0	7	25	H	H
	VH	0	0	0	2	4	6	28	VH	VH
4 years or more	VL	0	0	0	0	0	0	0	NA	NA
	L	0	0	0	0	0	0	0	NA	NA
	N	0	0	2	2	0	4	14	N/H	N/H
	H	0	0	4	9	5	18	63	H	H
	VH	0	0	0	0	7	7	35	VH	VH

VLU: Very Low usefulness; **LU**: Low usefulness; **N**: Neutral; **HU**: High usefulness; **VHU**: Very High usefulness
NA: Not applicable

The scaled total presented in the table above has been calculated as a weighted sum of the frequencies for VH, H, N, L, and VL ranks of the level of details importance, where the weights are 5, 4, 3, 2 and 1 respectively.

Table-A I-4 Contingency table for the high level of usefulness of Qualigram

	Frequency of importance rank			
Usefulness of the level of detail of the decision tree perspective	L	N	H	VH
Less than 4 years experience	3	2	10	4
4 years or more of experience	0	6	11	12
P-value =0.079; N = 51; Fisher exact test statistic value = 6.584				

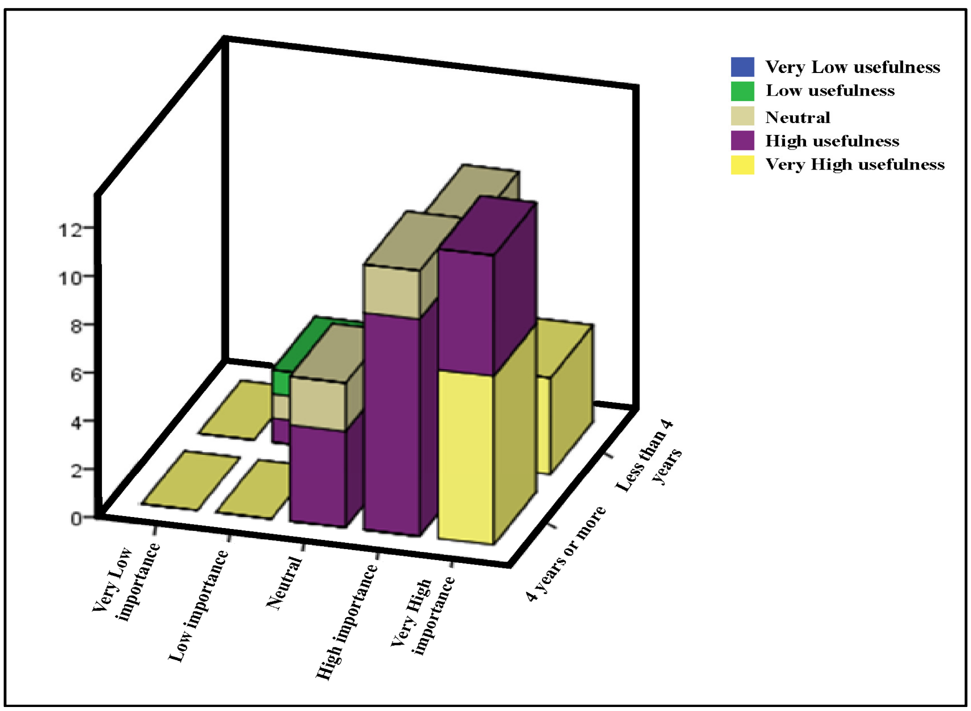


Figure-A I-3 Usefulness of modeling at the operational level
using decision tree perspective

A.3 Importance of the level of detail using working instructions

Table-A I-5 The importance of the level of detail representing business processes at the operational level using working instructions

Importance level of working instructions		**Experience**	
		Less than 4 years	**4 years or more**
Low importance	Count	1	0
	% within experience	5.9%	0.0%
Neutral	Count	6	8
	% within experience	35.3%	27.6%
High importance	Count	5	13
	% within experience	29.4%	44.8%
Very high importance	Count	5	8
	% within experience	29.4%	27.6%
Total	Count	17	29
	% within experience	100.0%	100.0%
P-value =0.524; N = 51; Fisher exact test statistic value = 2.525			

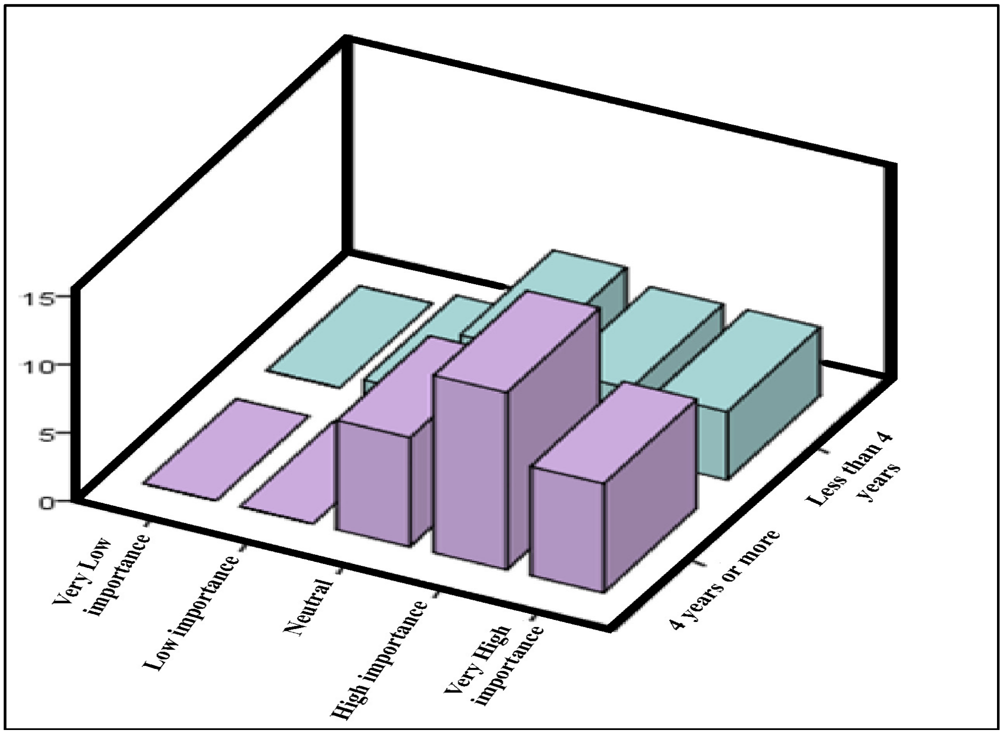


Figure-A I-4 The importance of the level of detail representing business processes at the operational level using working instructions

A.4 Usefulness of modeling using working instructions

Table-A I-6 Usefulness of modeling business processes at the operational level using the working instructions perspective

Usefulness of operational level		**Experience**	
		Less than 4 years	**4 years or more**
Low usefulness	Count	3	0
	% within experience	15.8%	0.0%
Neutral	Count	7	9
	% within experience	36.8%	31.0%
High usefulness	Count	6	13
	% within experience	31.6%	44.8%
Very High usefulness	Count	3	7
	% within experience	15.8%	24.1%
Total	Count	19	29
	% within experience	100.0%	100.0%
P-value =0.170; N = 51; Fisher exact test statistic value = 5.04			

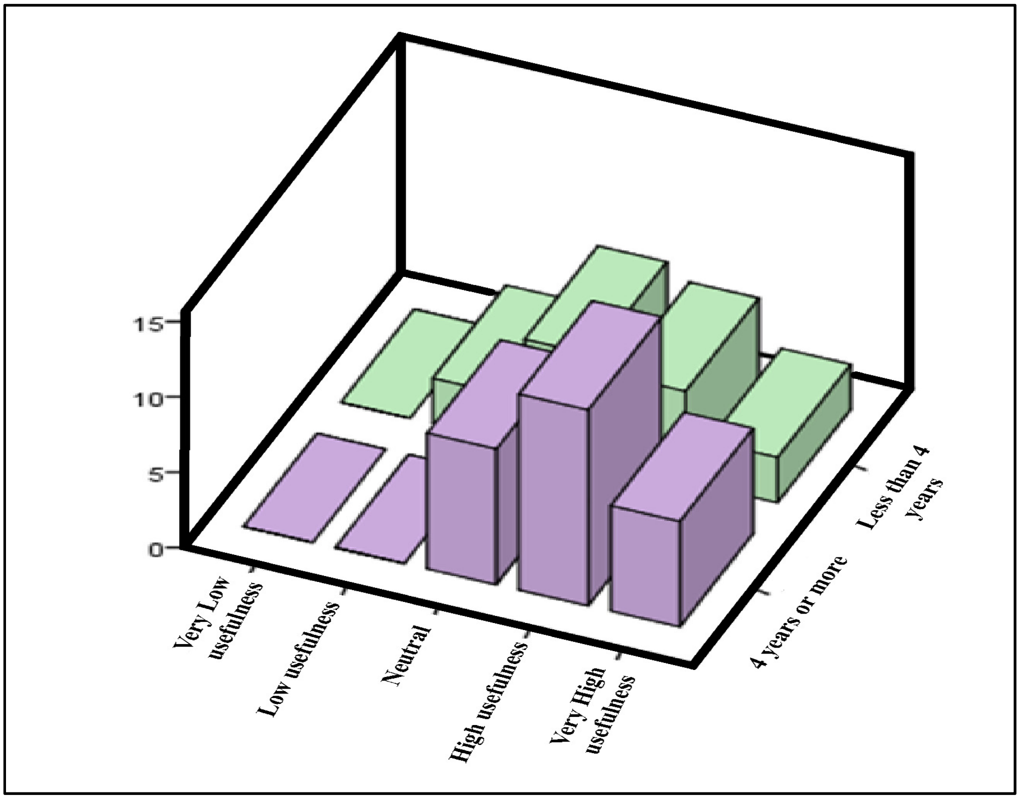


Figure-A I-5 Usefulness of modeling business processes at the operational level using the working instructions perspective

A.5 Participant's preference

Table-A I-7 Participant's preference for representing operational business processes using decision tree and working instructions

Preference	**Experience**		
	Statistics	**Less than 4 Years**	**4 years or more**
No preference	Count	1	1
	% Within experience	5.9%	4.0%
Decision Tree	Count	8	17
	% Within experience	47.1%	68.0%
Working Instructions	Count	6	3
	% Within experience	35.2%	12.0%
Both	Count	2	4
	% Within experience	11.8%	16.0%
Total	Count	17	25
	% Within experience	100.0%	100.0%
P-value =0.313; N = 51; Fisher exact test statistic value = 3.667			

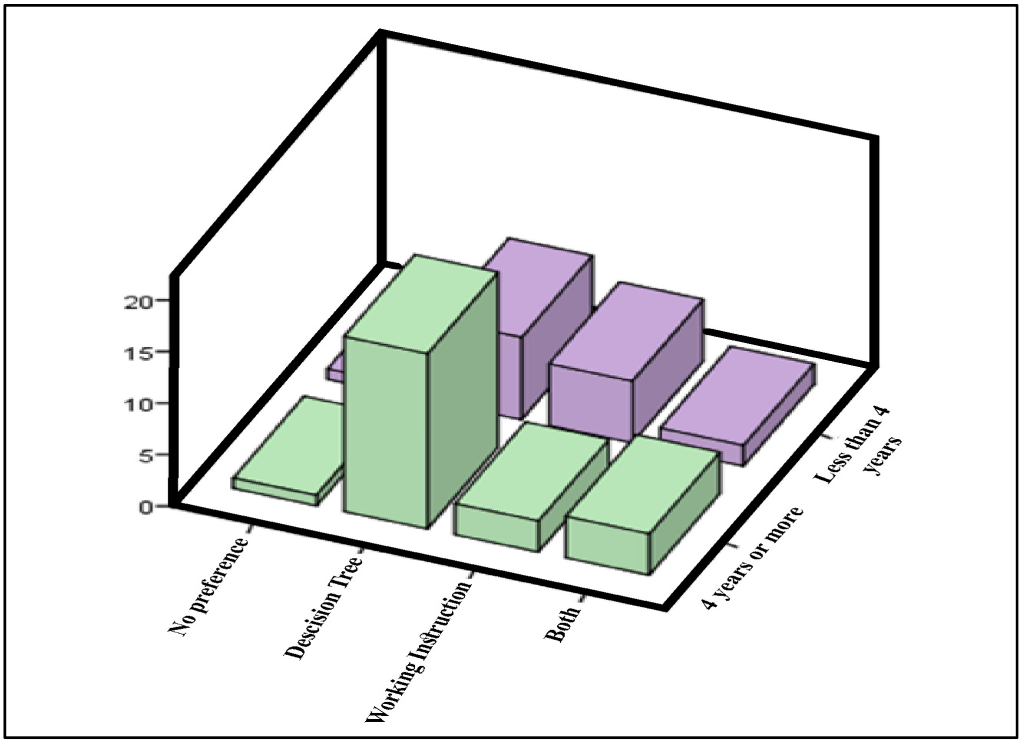


Figure-A I-6 Participant's preference for representing operational business processes using decision tree and working instructions

A.6 Importance of modeling at the operational level

Table-A I-8 Importance of modeling business processes at the operational level for defining tasks, data and tools required to perform an activity

Level of agreement	Experience		
	Statistics	**Less than 4 years**	**4 years or more**
Neutral	Count	1	3
	% Within experience	5.3%	10.3%
Agree	Count	12	9
	% Within experience	63.2%	31.0%
Strongly Agree	Count	6	17
	% Within experience	31.6%	58.6%
Total	Count	19	29
	% Within experience	100.0%	100.0%
P-value =0.087; N = 51; Fisher exact test statistic value = 4.645			

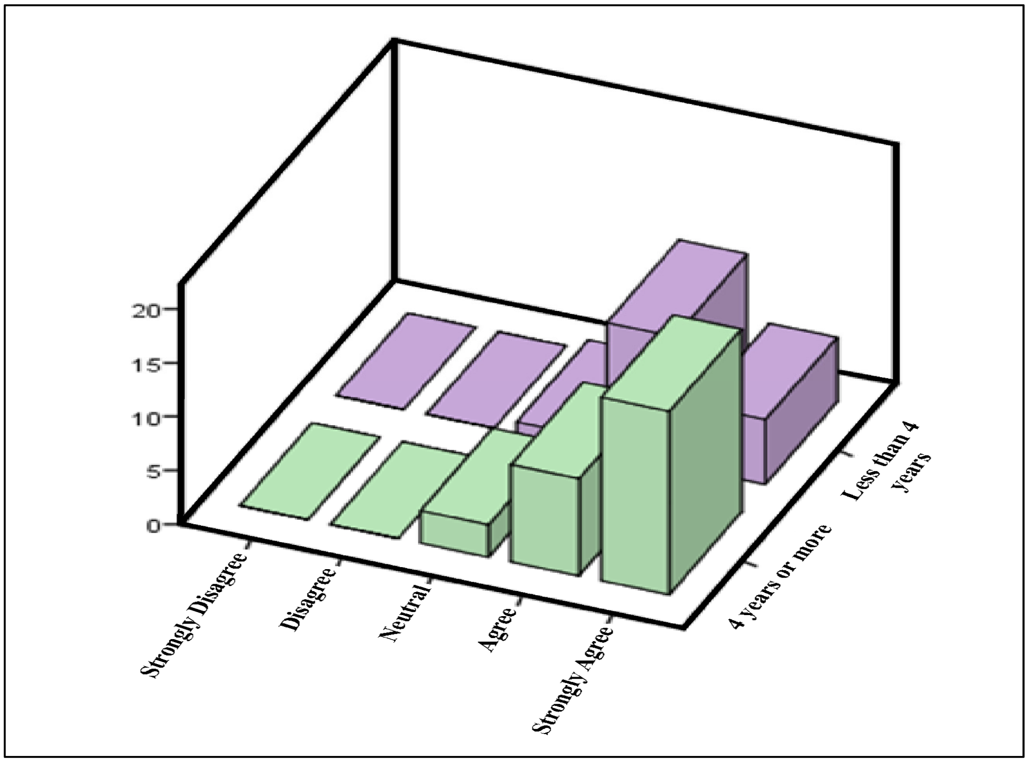


Figure-A I-7 Importance of modeling business processes at the operational level for defining tasks, data and tools required to perform an activity

A.7 Importance of the level of detail using BPMN

Table-A I-9 The importance of the level of detail of operational business processes represented by BPMN notation

Level of importance	Experience		
	Statistics	Less than 4 years	4 years or more
Very Low importance	Count	1	0
	% Within experience	5.6%	0.0%
Neutral	Count	8	10
	% Within experience	44.4%	35.7%
High importance	Count	4	13
	% Within experience	22.2%	46.4%
Very High importance	Count	5	5
	% Within experience	27.8%	17.9%
Total	Count	18	28
	% Within experience	100.0%	100.0%
P-value =0.245; N = 51; Fisher exact test statistic value = 3.946			

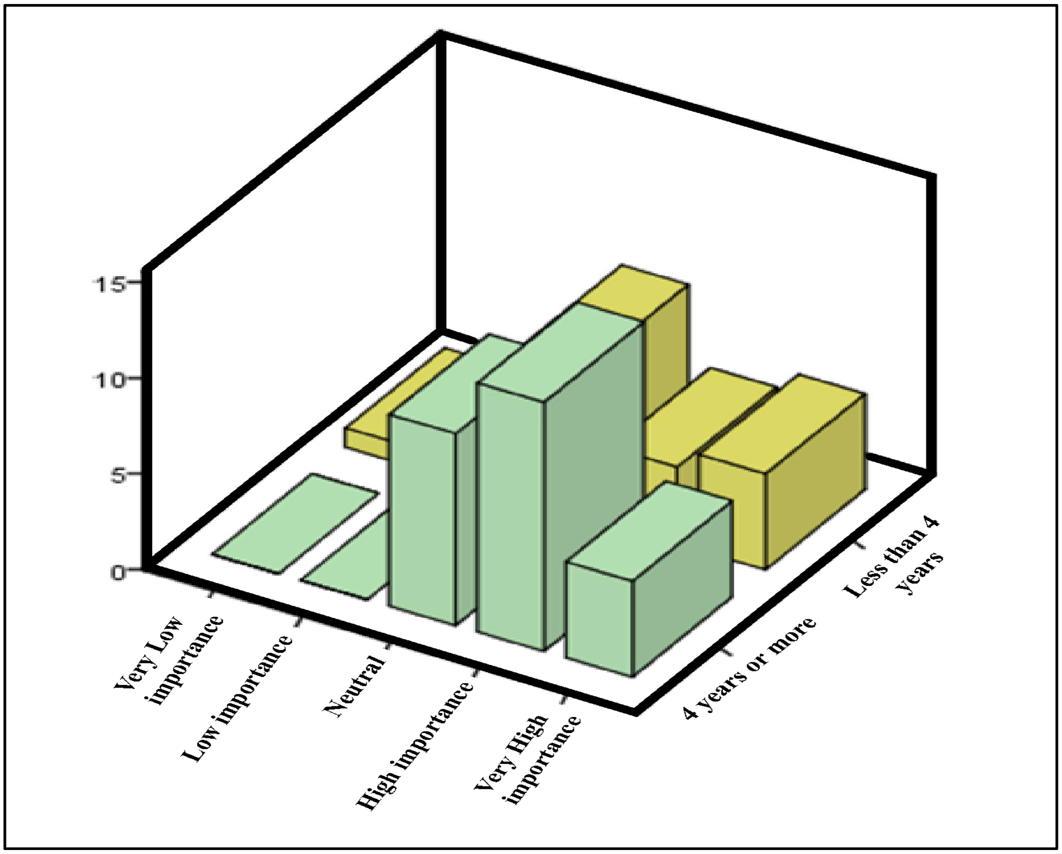


Figure-A I-8 The importance of the level of detail of operational business processes represented by BPMN notation.

A.8 Usefulness of modeling using BPMN notation

Table-A I-10 Usefulness of modeling operational business processes using BPMN notation

Level of BPMN's usefulness	**Experience**		
	Statistics	**Less than 4 years**	**4 years or more**
Low usefulness	Count	0	2
	% within experience	0.0%	6.9%
Neutral	Count	8	8
	% within experience	44.4%	27.6%
High usefulness	Count	9	12
	% within experience	50.0%	41.4%
Very high usefulness	Count	1	7
	% within experience	5.6%	24.1%
Total	Count	18	29
	% within Experience	100.0%	100.0%
P-value =0.216; N = 51; Fisher exact test statistic value = 4.109			

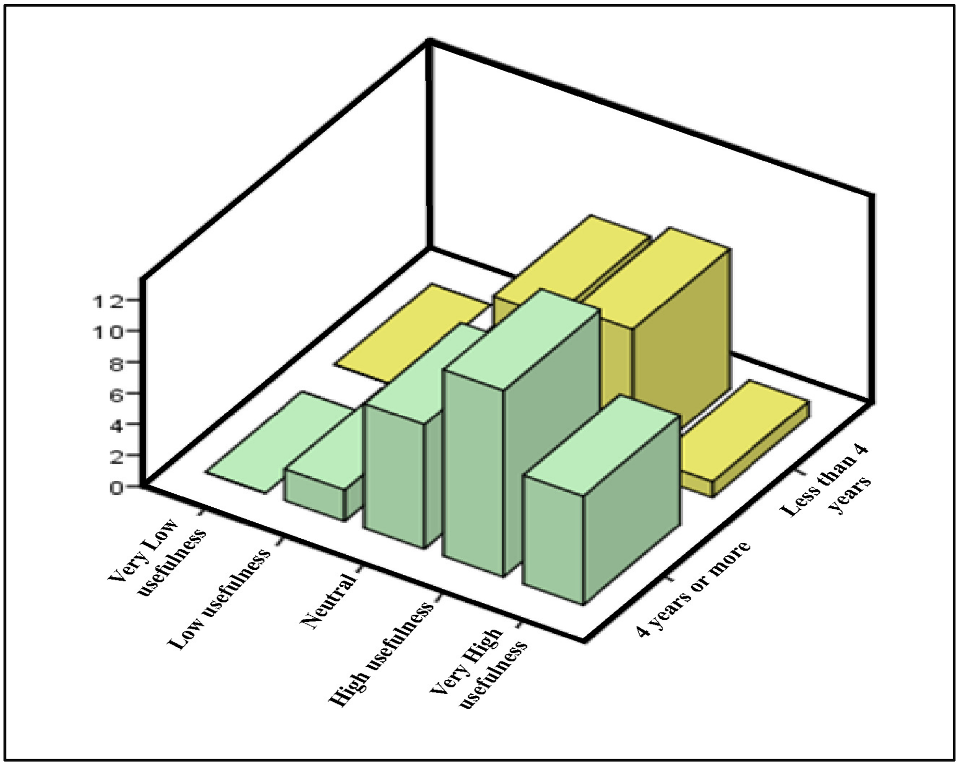


Figure-A I-9 Usefulness of modeling operational business processes using BPMN notation

A.9 Comprehensive level of detail

Table-A I-11 Comprehensive level of detail provided by Qualigram vs. BPMN

Notation	Experience		
	Statistics	**Less than 4 years**	**4 years or more**
BPMN	Count	9	7
	% within experience	50.0%	28.0%
Qualigram	Count	9	18
	% within experience	50.0%	72.0%
Total	Count	18	25
	% within experience	100.0%	100.0%
P-value =0.204; N = 51; Fisher exact test statistic value= 2.168			

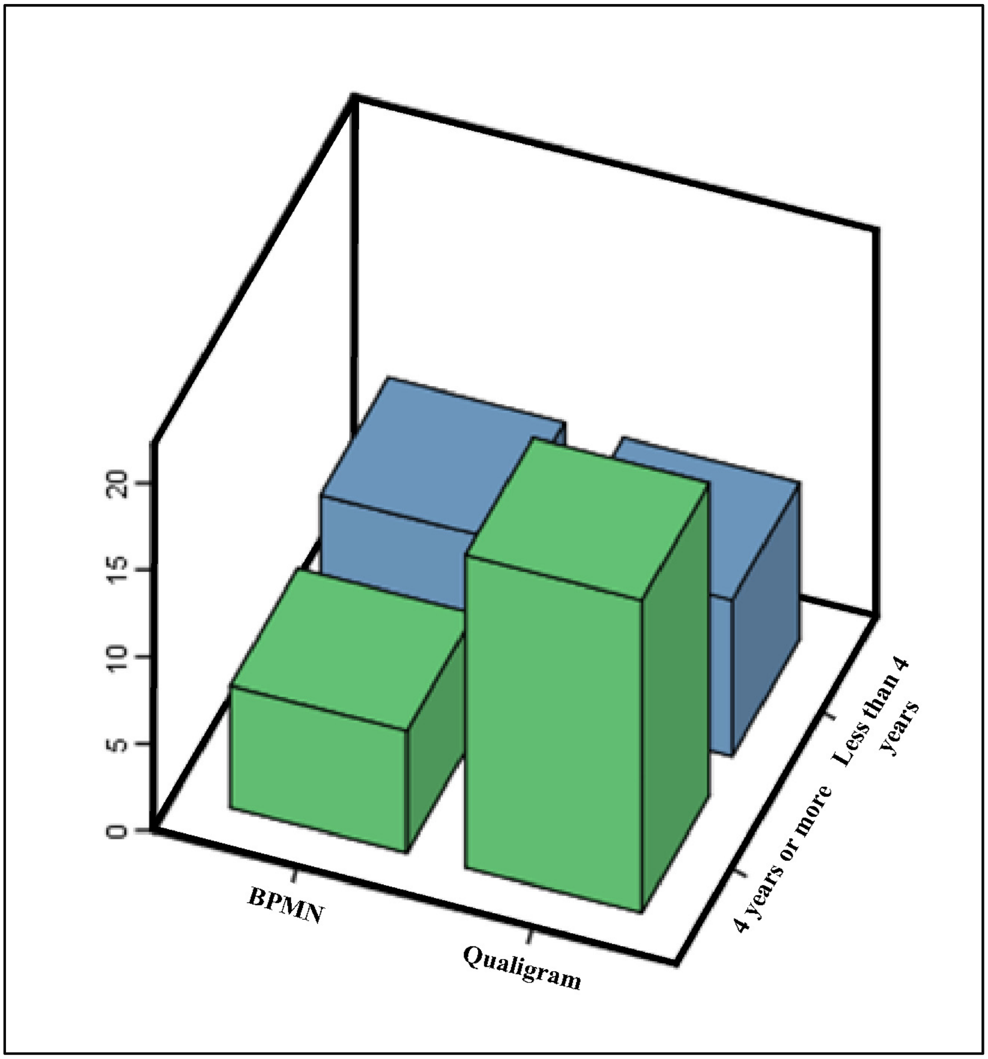


Figure-A I-10 Comprehensive level of detail provided by Qualigram vs. BPMN

A.10 BPM Notation preferences

Table-A I-12 BPM notation preferences according to participants

Preference	**Experience**		
	Statistics	**Less than 4 years**	**4 years or more**
BPMN	Count	7	6
	% within experience	50.0%	26.1%
Qualigram	Count	6	17
	% within experience	42.9%	73.9%
Both	Count	1	0
	% within experience	7.1%	0.0%
Total	Count	14	23
	% within experience	100.0%	100.0%
P-value = 0.102; N = 51; Fisher exact test statistic value= 4.255			

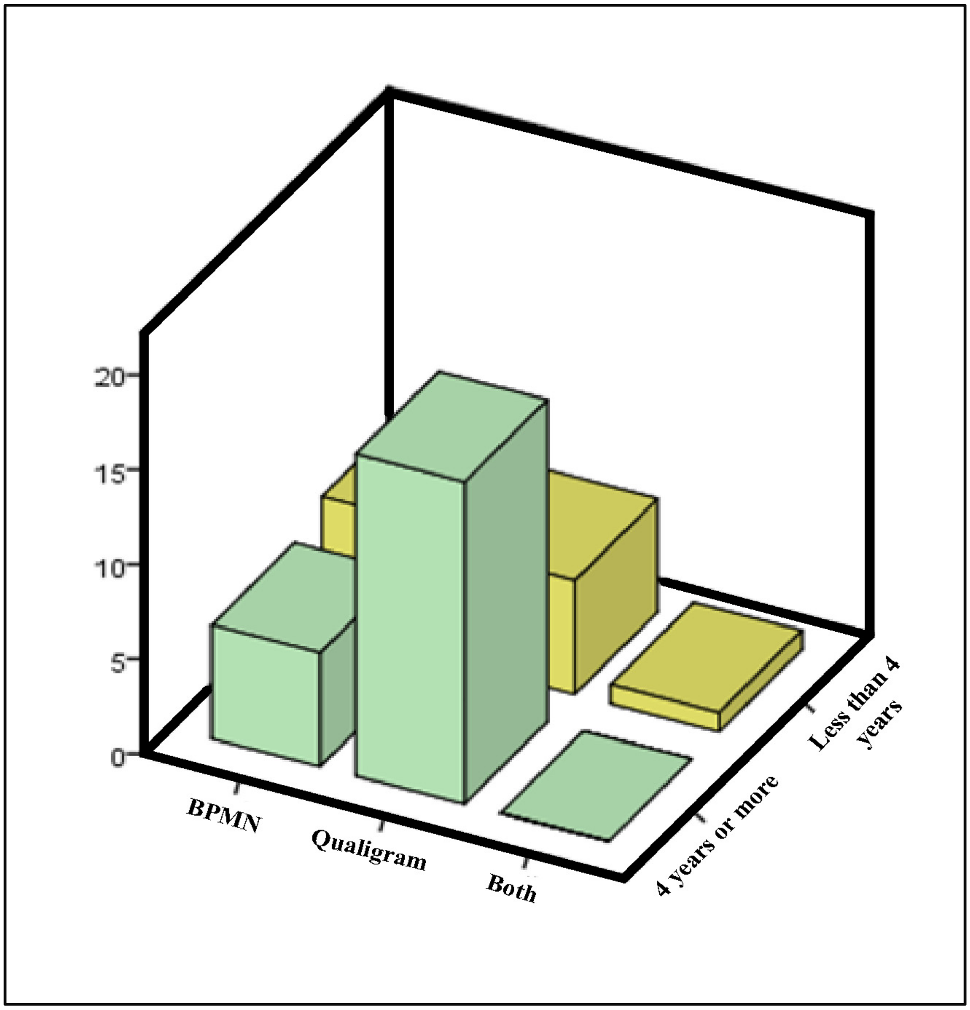


Figure-A I-11 BPM notation preferences according to participants.

A.11 BPM notation most commonly used

Table-A-13 BPM notation most commonly used

Notation	Experience		
	Statistics	Less than 4 years	4 years or more
ARIS	Count	2	7
	% within experience	9.5%	23.3%
BPMN	Count	6	13
	% within experience	28.6%	43.3%
EPC	Count	1	2
	% within experience	4.8%	6.7%
Qualigram	Count	4	6
	% within experience	19.0%	20.0%
R	Count	0	1
	% within experience	0.0%	3.3%
Visio	Count	2	1
	% within experience	9.5%	3.3%
None	Count	6	0
	% within experience	28.6%	0.0%
Total	Count	21	30
	% within experience	100.0%	100.0%
P-value = 0.032; N = 51; Fisher exact test statistic value = 12.049			

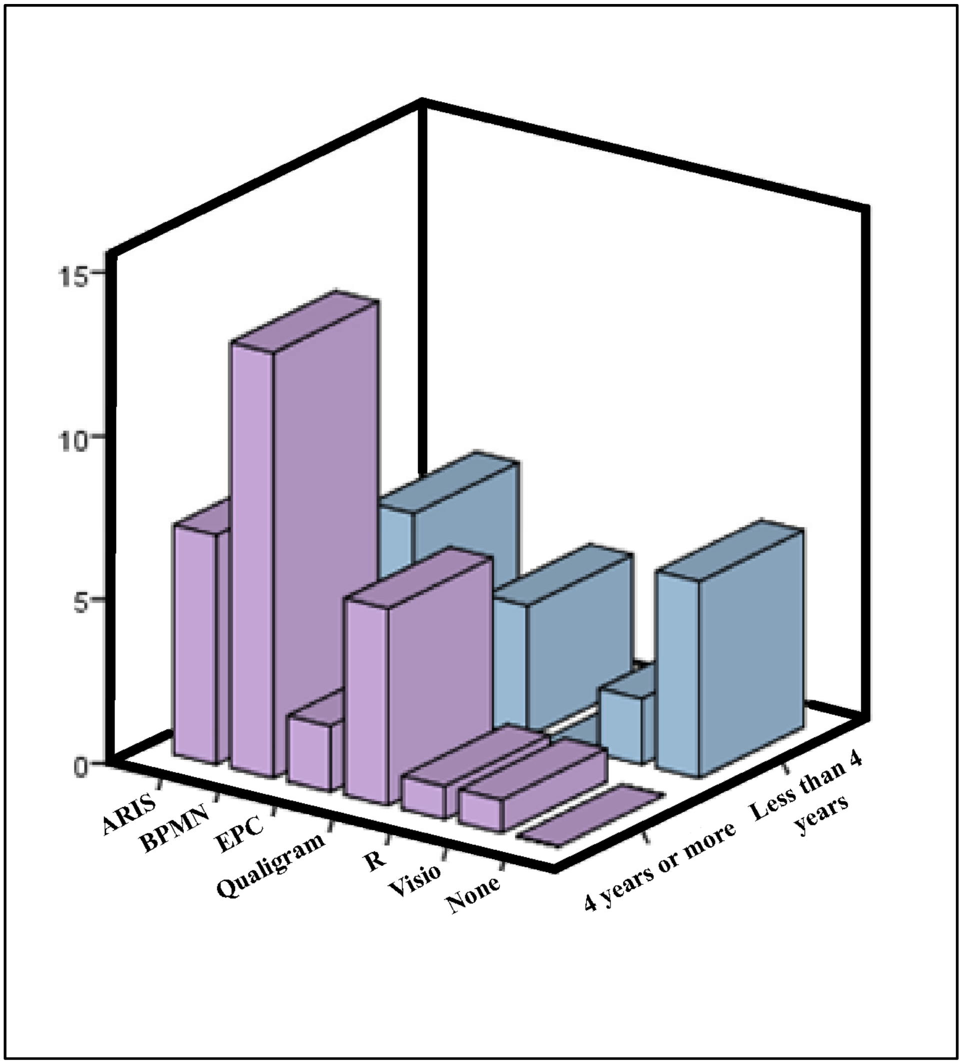


Figure-A I-12 BPM notation most commonly used

APPENDIX II

SURVEY QUESTIONNAIRE

As a researcher in business process modelling, Ahmad Alomari from École de technologie supérieure of Montreal is pleased to invite you to participate in an experiment involving business process modelling. We absolutely believe that your contribution to our research will bring value to the improvement of the state of the art and the state of the practice of business process modelling. The objective of this research is to demonstrate the benefits of integrating new modelling representation perspectives; these perspectives can effectively and efficiently be used to improve the existing organizational business process model repository.

What is expected:

- Read an overview (5 minutes).
- Complete a background questionnaire (estimated time: 5 minutes).
- Survey: Complete questionnaire (estimated time: 20 minutes).

We expect this entire experience to last no more than 30 minutes. Your data will remain confidential, and you can stop the experiment at any time. Your collaboration is greatly appreciated.

Thank you for your participation!

Best Regards,
Ahmad Alomari
École de technologie supérieure

Overview: Please read this overview before you move into the background questionnaire.

This section describes an example of how to model an operation process. To illustrate the process, the steps below describe the tasks that are carried out by the Security Analyst for incident handling. The process is as follows:

- Security Analyst receives an alert.
- Confirms and checks the alert in Arcsight.
- Determines and collects suspicious events and;
- Analyzes events through WireShark and confirms incident.
- Security Analyst collects artifacts and creates the case.

After verification that events were added to the case, the Security Analyst can proceed and submit the case to the incident response team for further analysis.

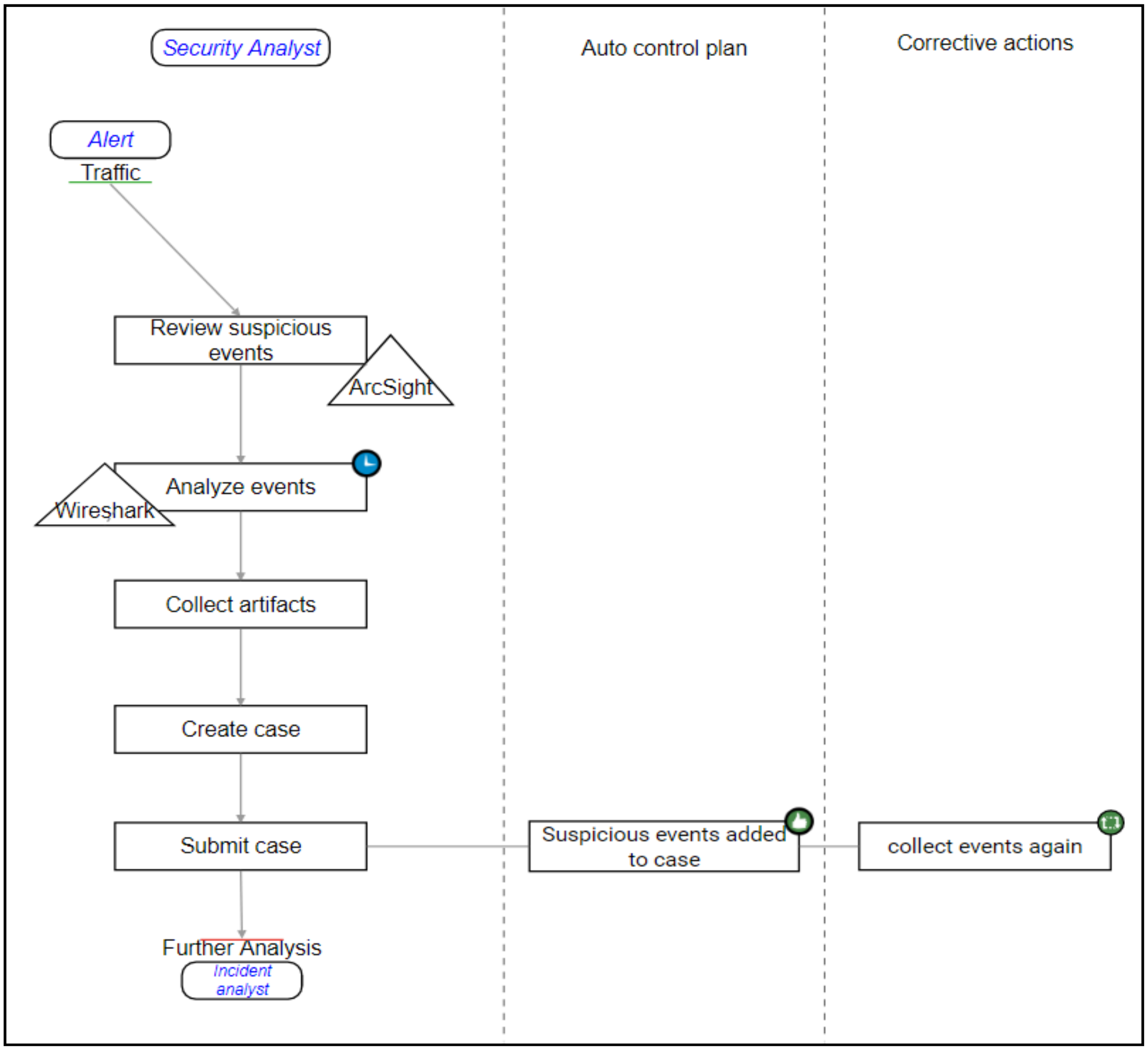


Figure-A II-1 Business process describe the tasks that are carried out by the Security Analyst for incident handling

Background Questionnaire:

1. Which of the following best describes your current occupation?

   Choose one of the following answers:

   - *Business and Financial Operations Occupations*
   - *Computer and Mathematical Occupations*
   - *Production Occupations*
   - *Community and Social Service Occupations*

- *Installation, Maintenance, and Repair Occupations*
- *Legal Occupations*
- *Protective Service Occupations*
- *Healthcare Practitioners and Technical Occupations*
- *Farming, Fishing, and Forestry Occupations*
- *Food Preparation and Serving Related Occupations*
- *Arts, Design, Entertainment, Sports, and Media Occupations*
- *Management Occupations*
- *Education, Training, and Library Occupations*
- *Architecture and Engineering Occupations*
- *Healthcare Support Occupations*
- *Office and Administrative Support Occupations*
- *Sales and Related Occupations*
- *Building and Grounds Cleaning and Maintenance Occupations*
- *Personal Care and Service Occupations*
- *Life, Physical, and Social Science Occupations*
- *Construction and Extraction Occupations*
- *Transportation and Materials Moving Occupations*
- *Other (please specify)*

2. What is the title of your current position?

3. How many years of experience do you have in your current position?

   Choose one of the following answers:

   - *Less than one year*
   - *1-2 years*
   - *2-4 years*
   - *4-6 years*
   - *More than 6 years*
   - *Don't know/Not sure*

4. How strategic is it to model your operational business processes?

   Please, in a scale 1 to 5 rate this question; where 1 means very low strategic and 5 means very high strategic.

5. Are business processes documented and modelled? Please indicate your organization's overall level of performance?

   Please, in a scale 1 to 5 rate the performance of your organization; where 1 means *very low performance and 5 means very high performance.*

6. During the past 12 months, approximately, how many hours did you spend working on modeling business process?

   Choose one of the following answers:
   Les that an hour
   1 to 5 hours.
   5 to 10 hours.
   More than 10 hours.

7. Approximately, for how many years have you been involved professionally with business process modeling?

   Choose one of the following answers:

   - *Less than one year*
   - *1-2 years*
   - *2-4 years*
   - *4-6 years*
   - *More than 6 years*
   - *Don't know/Not sure*

8. What business process modelling software do you use most often?

   - Pyx4
   - Pegasystems
   - Appian
   - Oracle
   - Bizagi
   - K2
   - Tibco
   - AgilePoint
   - Microsoft Visio
   - Software AG
   - Other (please specify)

9. When you are designing a business process model, which graphical notation are you using the most often?
   - BPMN
   - EPC
   - ETVX

- IDEF
- Qualigram
- other: specify_________

Survey Questions:

1. In your opinion, how useful is it, in your daily work, to use a business process model representing the operations of your organization?

   Please answer this question using the scale 1 to 5; where 1 means very low usefulness and 5 means very high usefulness.

2. In your opinion, how useful is it to model a business process at multiple levels of abstraction?

   Please answer this question using the scale 1 to 5; where 1 means very low usefulness and 5 means very high usefulness.

3. The figure below shows a business process modelled at the operational level using the decision tree in the Qualigram notation. In your opinion, how important is the level of details for you?

   Please answer this question using the scale 1 to 5; where 1 means very low importance and 5 means very high importance.

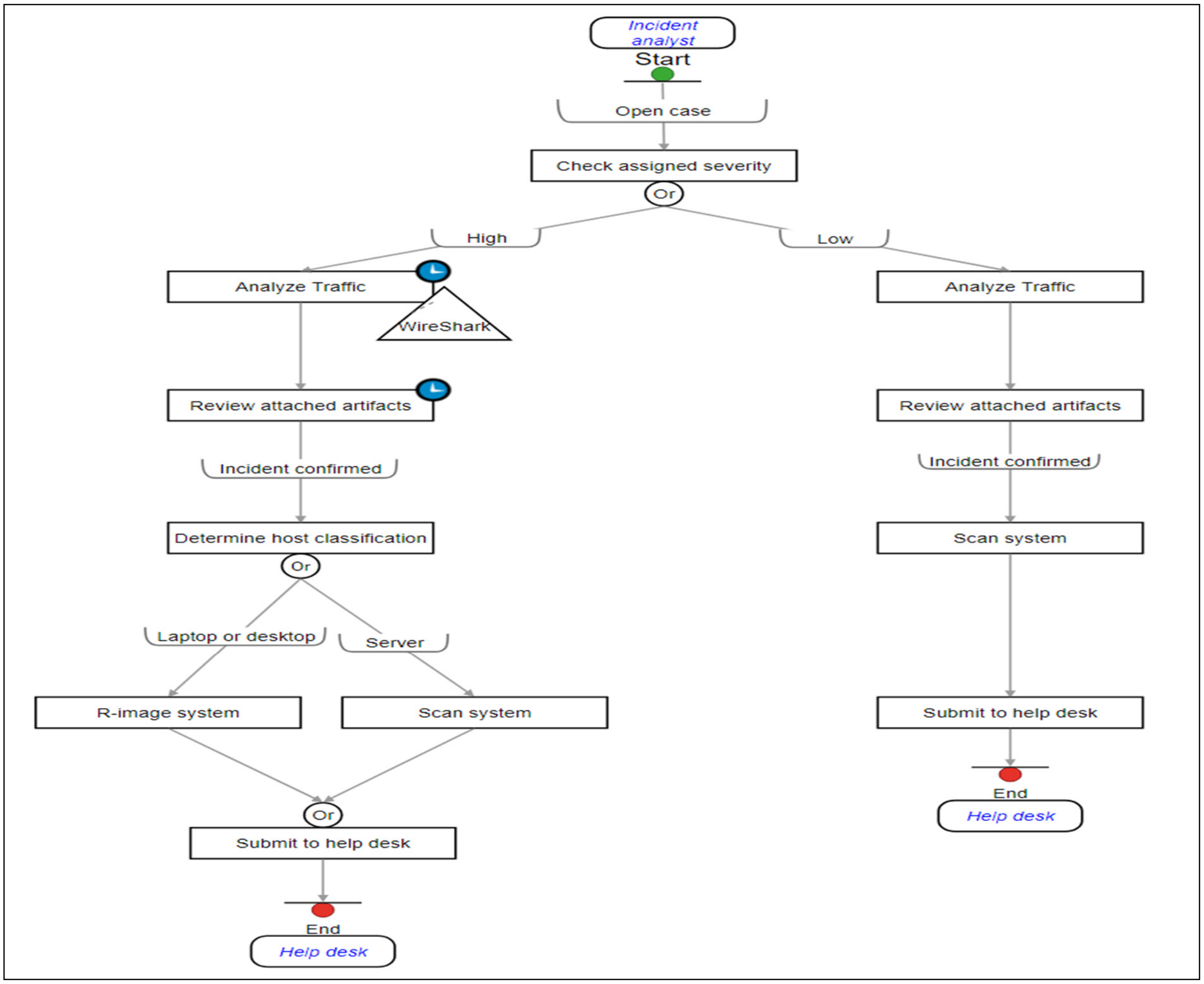


Figure-A II-2 Business process modelled at the operational level using the decision tree in the Qualigram notation

4. The figure below shows another business process modelled at the operational level using the Qualigram notation. In your opinion, how useful would it be to model business processes using a decision tree perspective?

   Please answer this question using the scale 1 to 5; where 1 means very low usefulness and 5 means very high usefulness.

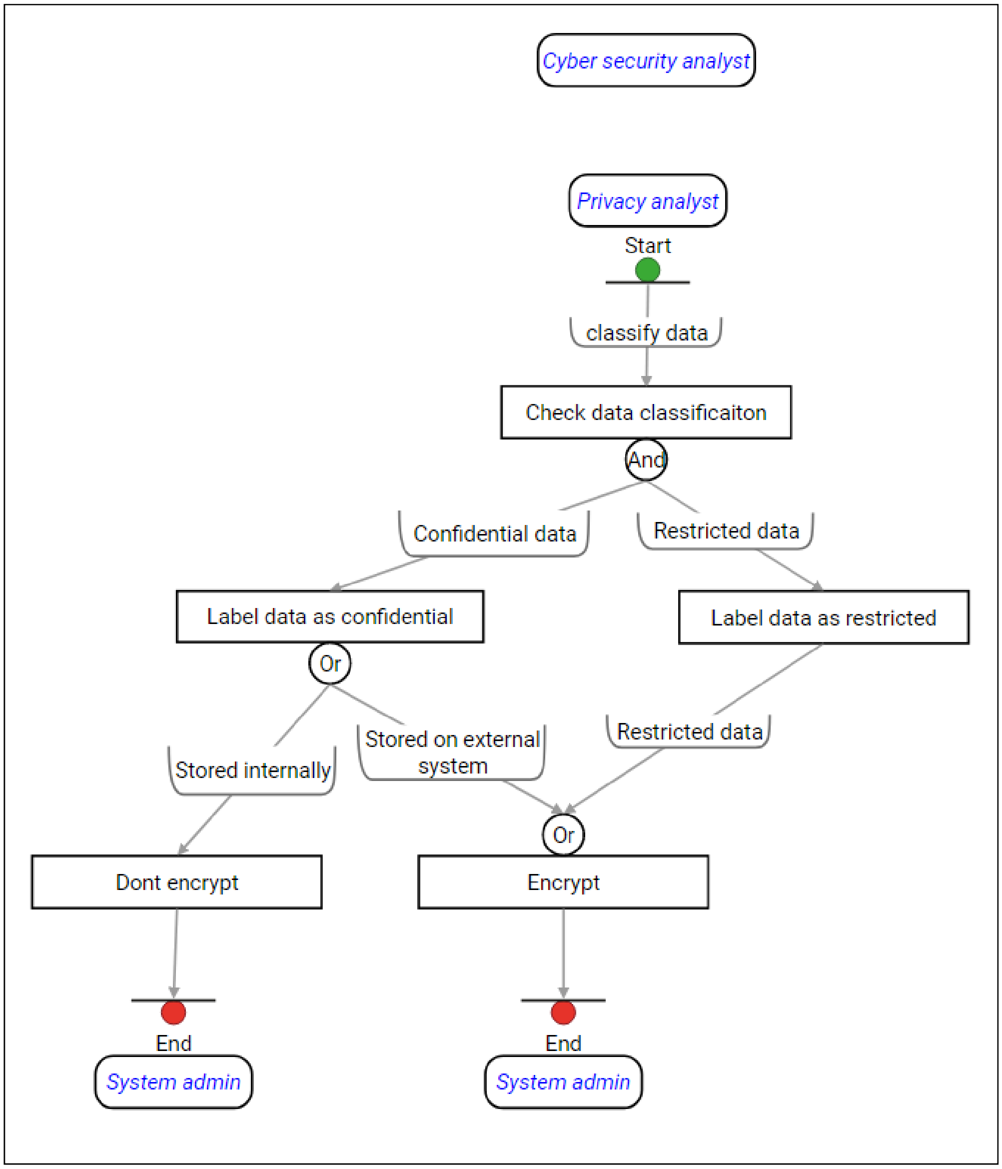


Figure-A II-3 Business process modelled at the operational level using the decision tree perspective in the Qualigram notation

5. In your opinion, how comprehensible were the two previous business process models presented in questions 3 and 4?

   Please answer this question using the scale 1 to 5; where 1 means very low comprehensible and 5 means very high comprehensible.

6. In your opinion, how useful was it to use “OR” and “AND” operators when modeling using the decision tree perspective in the previous two business process models?

   Please answer this question using the scale 1 to 5; where 1 means very low usefulness and 5 means very high usefulness.

7. Operational processes can be described using many representations. The figure below shows another way of describing a business process modelled at the operational level. It shows “working instructions” on the left, an auto control plan to verify a condition, as well as a corrective action when this condition happens. In your opinion, how important is the level of details for you?

   Please answer this question using the scale 1 to 5; where 1 means very low detailed and 5 means very high detailed.

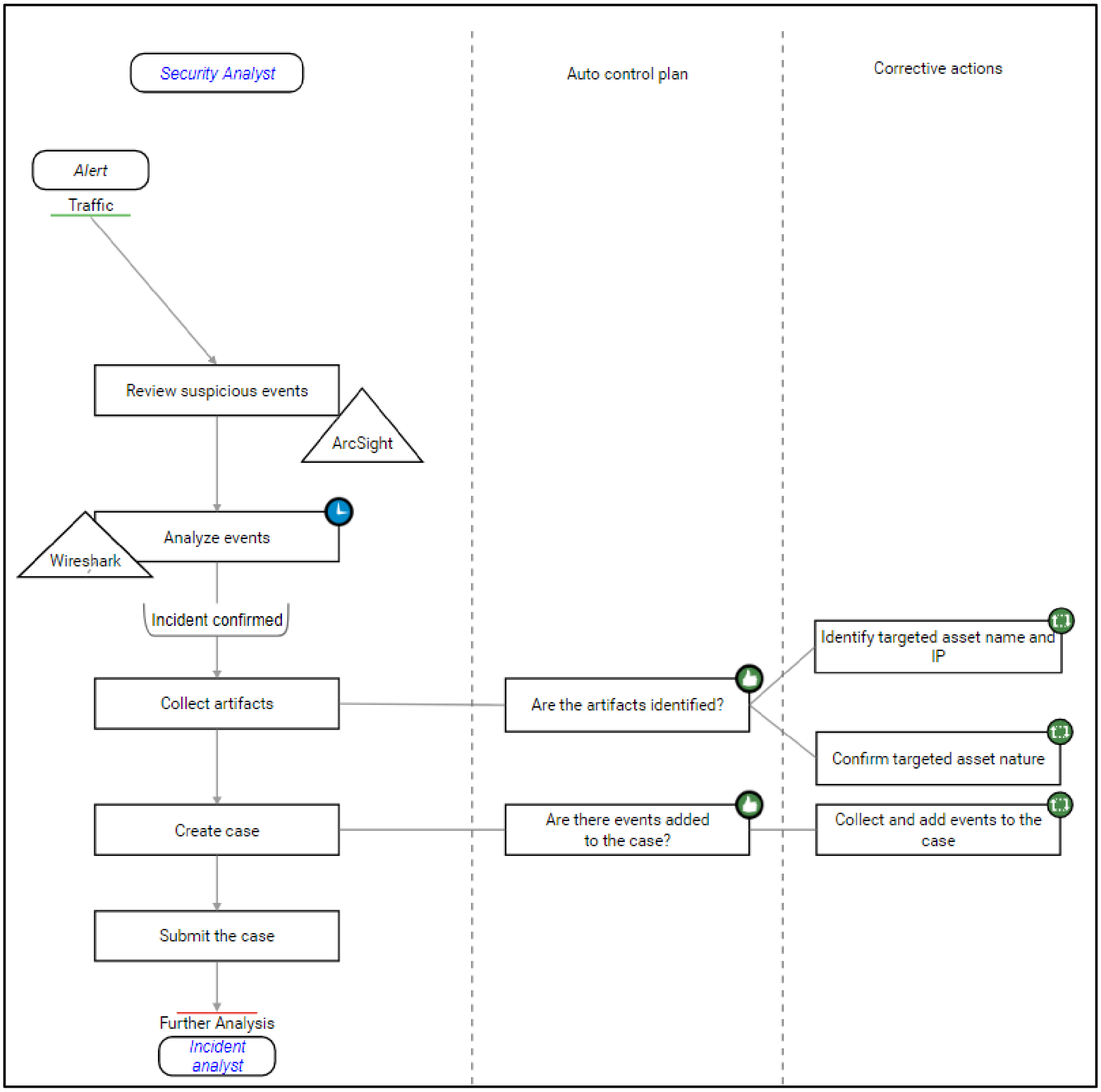


Figure-A II-4 Business process modelled at the operational level using the working instructions

8. Using the business model in the previous question, in your opinion, how useful do you think it would be to model operational tasks using this working instructions perspective?

   Please answer this question using the scale 1 to 5; where 1 means very low usefulness and 5 means very high usefulness.

9. In your opinion, how comprehensible was the previous business process model presented in questions 7?

   Please answer this question using the scale 1 to 5; where 1 means very low comprehensible and 5 means very high comprehensible.

10. Between the two operational business process representations shown before: decision tree and work instructions perspectives. In your opinion, which one do you prefer? Why? _______________

11. Modeling business processes at the operational level is important because it defines tasks, data and tools required to perform an activity.

    Please use the 1 to 5 scale to rate this statement; where 1 means strongly disagree and 5 means strongly agree.

12. The figure below shows a business process model modelled using the BPMN graphical notation and represents a "Firewall review process". In your opinion, how important is the level of details for you?

    Please answer this question using the scale 1 to 5; where 1 means very low importance and 5 means very high importance.

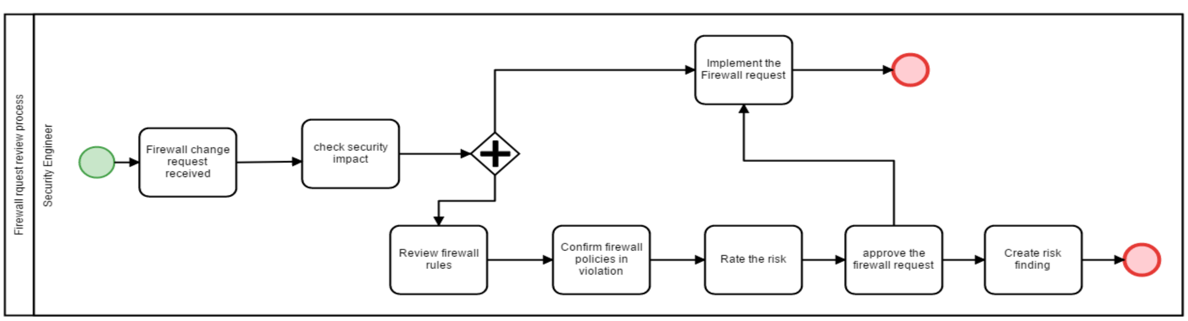


Figure-A II-5 Business process model modelled using the BPMN graphical notation and represents a "Firewall review process"

13. Using the business process model from question 12, in your opinion, how useful is it to model a business process at the operational level using the BPMN notation?

Please answer this question using the scale 1 to 5; where 1 means very low usefulness and 5 means very high usefulness.

14. In your opinion, how comprehensible was the previous business process model presented in questions 12?

    Please answer this question using the scale 1 to 5; where 1 means very low comprehensible and 5 means very high comprehensible.

15. Figures below show business process models of "firewall review process" modelled using A) the BPMN notation, B) Qualigram notation? In your opinion, which business process model provides more comprehensive level of details?

    A:

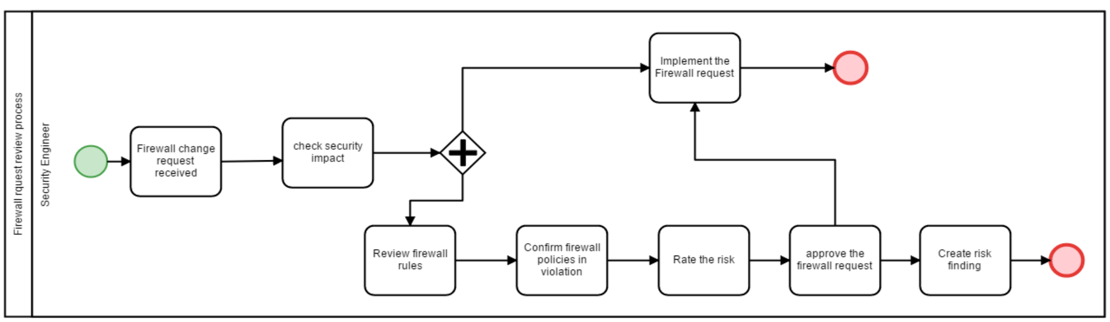


Figure-A II-6 Business process model modelled using the BPMN graphical notation and represents a "Firewall review process"

B:

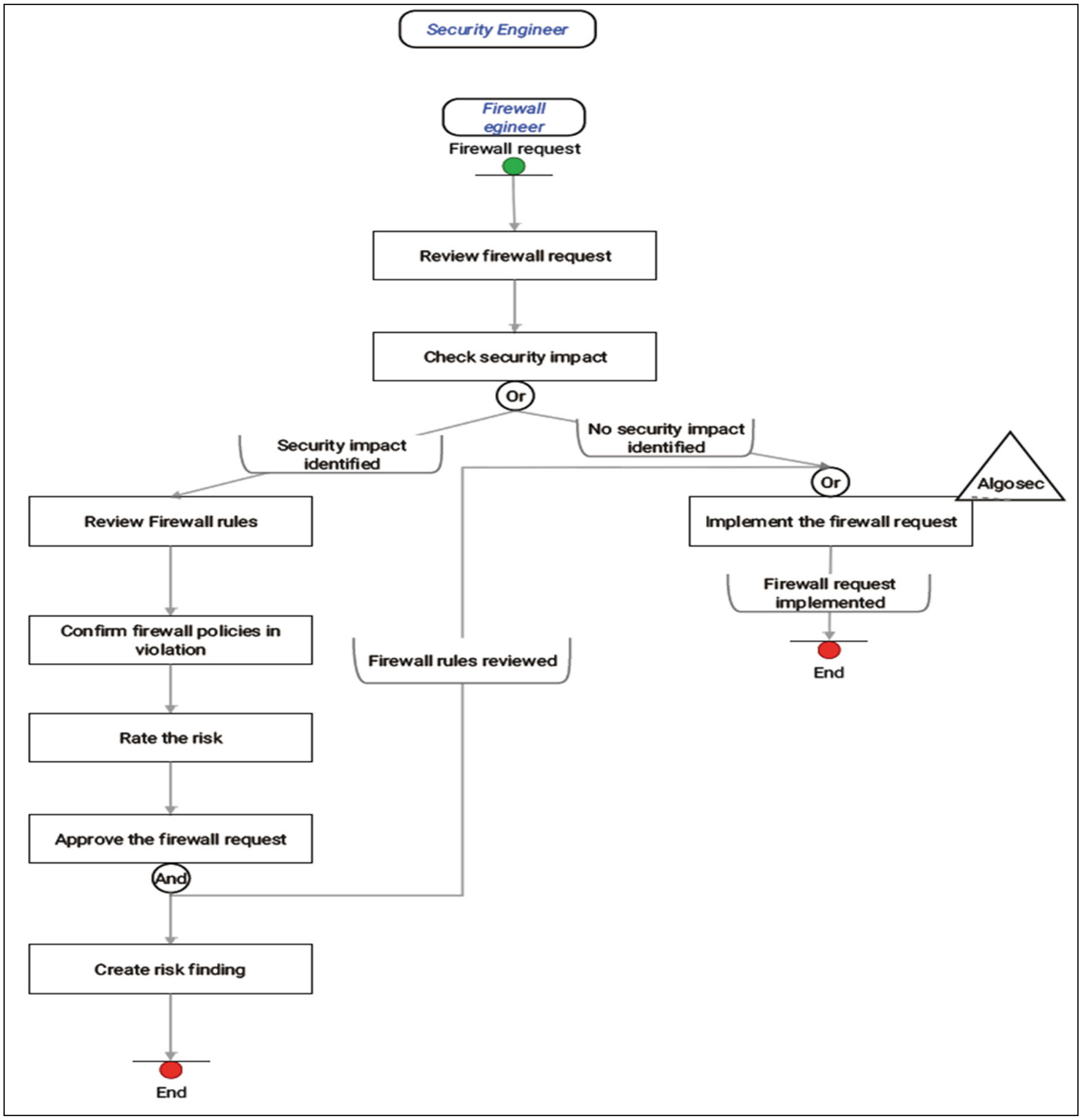


Figure-A II-7 Business process model modelled using the decision tree in the Qualigram notation "Firewall review process"

16. Using the business process models from the previous question, which modeling notation would you prefer to model at the operational level? BPMN or Qualigram? Why? _______________

LIST OF BIBLIOGRAPHICAL REFERENCES

Alomari, A., April, A., Monsalve, C. and Gawanmeh, A. (2018). Integrating a decision tree perspective at the operational level of BPM+. *Computer Systems Science and Engineering*, *33*(3), 219–227.

Andrews, D., Nonnecke, B. and Preece, J. (2007). Conducting research on the internet: Online survey design, development and implementation guidelines. *International Journal of Human-Computer Interaction, 16*(2), 185–210.

Anthony, R. N. (1965). *Planning and control systems: A framework for analysis.* Boston: Division of Research, Graduate School of Business Administration, Harvard University.

Bandara, W., Indulska, M., Chong, S. and Sadiq, S. (2007). Major issues in business process management: An expert perspective. In: Winter, R. (Ed.), *15th European Conference on Information Systems*. University of St Gallen, Switzerland, Switzerland, (pp. 1240-1251). Brisbane: QUT.

Bandara, W. and Rosemann, M. (2005). What are the secrets of successful process modeling? Insights from an Australian case study. *Systèmes d'Information et Management, 10*(3), 47–68.

Basili, V. R., Selby, R. W. and Hutchens, D. H. (1986). Experimentation in software engineering. *IEEE Transactions on Software Engineering, 7,* 733–743.

Becker, J., Rosemann, M. and von Uthmann, C. (2000). Guidelines of business process modeling. In: van der Aalst, W., Desel, J and Oberweis, A. (Eds.). *Business Process Management Lectures Notes in Computer Science* (Vol. 1806, p. 241–262). Germany: *Springer Berlin / Heidelberg.*

Ben Jillali, T. (2012). Évaluation de la qualité du language qualigram en utilisant le modèle de représentation BWW. (Master theses, École de technologie supérieure-ÉTS Montréal).

Berger, C. and Guillard, S. (2000). *La rédaction graphique des procédures. Démarche et techniques de description des processus*, Paris: Association Française de Normalisation, AFNOR, 250 p.

Bhat, J. M. and Deshmukh, N. (2005, June). *methods for modeling flexibility in business processes*. Paper presented at Sixth Workshop on Business process modeling, Development, and Support, BPMDS'05. Porto, Portugal.

Born, M., Dörr, F. and Weber, I. (2007, December). User-friendly semantic annotation in business process modeling. In Weske, M., Hacid, M.-S. and Godart, C. (Eds.).

International Conference on Web Information Systems Engineering (Vol. 4832, pp. 260–271). Berlin, Heidelberg: Springer.

Burton-Jones, A. and Meso, P. N. (2006). Conceptualizing systems for understanding an empirical test of decomposition principles in object-oriented analysis. *Information Systems Research*, *17*(1), p. 38–60.

Cormen, T. H., Leiserson, C. E., Rivest, R. L. and Stein, C. (2001). *Introduction to algorithms* (3rd ed.). Cambridge, MA: MIT Press.

Courtney, J. F. (2001). Decision making and knowledge management in inquiring organizations toward a new decision-making paradigm for DSS. *Decision Support Systems*, 31(1), 17–38.

Curtis, B., Kellner, M.I. and Over, J. (992). Process modeling. *Communications of the ACM 35*(9), 75–90.

Davenport, T. H. (1992). *Process innovation: Reengineering work through information technology*. Boston, Massachusetts: Harvard Business School Press.

Davenport, T. H. (2005). The coming commoditization of processes. *Harvard Business Review, 83*(6), 100–108.

Davis, R. (2008). *ARIS design platform: Advanced process modeling and administration* (1st ed.). London: Springer-Verlag.

Dhillon, D. (2011). Developer-driven threat modeling: Lessons learned in the trenches. *IEEE Security & Privacy*, *9*(4), 41–47.

Dreiling, A., Michael, R., van der Aalst, W. M. P. and Sadiq, W. (2008). From conceptual process models to running systems: A holistic approach for the configuration of enterprise system processes. *Decision Support Systems, 45*(2), 189–207.

Dumas, M., Van der Aalst, W. M. and ter Hofstede, A. H. (2005). *Process-aware information systems: bridging people and software through process technology*. New York, N.Y., United States: John Wiley & Sons.

Elzinga, D. J., Horak, T., Lee, G-Y. and Bruner, C. (1995). Business process management: survey and methodology. *IEEE Transactions on Engineering Management, 42*(2), 119–128.

Engels, G., Förster, A., Heckel, R. and Thöne, S. (2005). *Process modeling using UML*. Dalam Process-Aware Information Systems, 85–117, John Wiley & Sons.

Eriksson, H.-E. and Penker, M. (2000). *Business modeling with UML: Business Patterns at Work* (1st ed). New York: John Wiley and Sons, Inc.

Gao, M. and Jia, H. (2011, September). *A hybrid integration approach to business process management implementation*. Paper presented at International Conference of Information Technology, Computer Engineering and Management Sciences, Nanjing, Jiangsu, China.

Gehlert, A. and Esswein, W. (2007). Toward a formal research framework for ontological analyses. *Advanced Engineering Informatics, 21*(2), 119–131.

Georgakopoulos, D., Hornick, M. and Sheth, M. (1995). An overview of workflow management: from process modeling to workflow automation infrastructure. *Distributed and Parallel Databases 3*(2), 119–153.

Gorry, G. A. and Scott-Morton, M.S. (1989). A framework for management information systems. *Sloan Management Review*, *30*(3), 49–61.

Green, P., Rosemann, M., Indulska, M. and Recker, J. (2006), Improving representational analysis: an example from the enterprise systems interoperability domain. In: Spencer, S. and Jenkins, A. (Eds), *Proceedings of the 17th Australasian Conference on Information Systems*. (Vol. 52, pp. 1–11). Adelaide, Australia: Australasian Association for Information Systems.

Gulla, J. A. and Brasethvik, T. (2000), On the challenges of business modeling in large-scale reengineering *projects. 4th International Conference on Requirements Engineering, ICRE'00. Schaumburg, IL, USA, June 19-23*, (pp. 17–26). IEEE Computer Society.

Hammer, M. and Champy, J. (1993). *Reengineering the corporation: a manifesto for business revolution*. New York, NY: Harper Business.

Haque, B., Pawar, K. S. and Barson, R. J. (2003). The application of business process modeling to organisational analysis of concurrent engineering environments. *Technovation, 23*(2), 147–162.

Harmon, P. and Wolfe, C. (2016). *The state of business process management 2016* (A BPTrends Report). Business Process Trends, 2016.

Ho, J. K. K. (2015). A Review of frameworks for classification of information systems, notably on the Anthony's Triangle. *European Academic Research, 3*(1), 604–616.

Hoyle, D. (2009). *ISO 9000 quality systems handbook* (9th ed). Oxford, UK, Burlington, Mass: Butterworth-Heinemann, Elsevier.

Kamiński, B., Jakubczyk, M. & Szufel, P. (2018). A framework for sensitivity analysis of decision trees. *Central European Journal of Operations Research*, *26*(1), 135-159.

Kaplan, R. S. and Norton, D. P. (2007). Using the balanced scorecard as a strategic management system. *Harvard Business Review*, *85*(78), 150–161.

Kesari, M., Chang, S. and Seddon, P. (2003). A content analytic study of the advantages and disadvantages of process modeling. ACIS 2003 Proceedings, Retrieved from https://aisel.aisnet.org/acis2003/2.

Kitchenham, B. A. and Pfleeger, S. L. (2008). Personal opinion surveys. In: Shull, F., Singer, J. and Sjøberg, D. I. K. (Eds), *Guide to advanced empirical software engineering*. (pp. 63–92). Springer, London.

Knuth, D. E. (1997). *The art of computer programming: Fundamental algorithms* (3rd ed.). Redwood City, United States: Addison-Wesley Longman Publishing Co., Inc.

Ko, R. K. L., Lee, S. S. G. and Wah Lee, E. (2009). Business process management (BPM) standards: A survey. *Business Process Management Journal, 15*(5), 744–791.

Korherr, B. and List, B. (2007), Extending the EPC and the BPMN with business process goals and performance measures. *9th International Conference on Enterprise Information Systems*. (Vol. EIS, pp. 287–294). Madeira, Portugal.

Krogstie, J. and Slvberg, A. (2003). *Information systems engineering: conceptual modeling in a quality perspective*. Kompendiumforlaget, Trondheim, Norway.

Kühne, T. (2005, March). *What is a Model?* Paper presented at *Dagstuhl Seminars Proceedings*, Schloss Dagstuhl - LZI GmbH (pp. 1-10). Retrieved from https://drops.dagstuhl.de/opus/volltexte/2005/23/

Indulska, M., Green, P., Recker, J. and Rosemann, M. (2009, November). Business process modeling: Perceived benefits. In : Laender, A. H. F., Castano, S., Dayal, U., Casati, F. and de Oliveira, J. P. M. (Eds), *Conceptual Modeling - ER 2009. Lecture Notes in Computer Science*, (Vol. 5829, pp. 458–471). Berlin, Heidelberg: Springer.

Indulska, M., zur Muehlen, M. and Recker, J. (2009 August). *Measuring Method Complexity: The Case of the Business Process Modeling Notation.* BPM Center (Report Number BPM-09-03). Retrieved from www.BPMcenter.org.

ISO. 2008. (2012). *ISO 9000 Introduction and Support Package Guidance on the Concept and Use of the Process Approach for Management Systems*. Coll. Introduction and Support Package, ISOTC 176SC 2N 544R3. London International Standardization Organization, 12 p.

ISO (9000). Introduction and Support Package: Guidance on the Concept and Use of the Process Approach for management systems. Coll. Introduction and Support Package, ISO/TC 176/SC 2/N 544R3. London: International Standardization Organization, 12 p.

Lankhorst, M. (2009). *Enterprise architecture at work: Modeling, communication and analysis* (2nd ed). Berlin: Springer.

Lin, F. R., Meng-Chyn, Y. and Yu-Hua, P. (2002). A generic structure for business process modeling. *Business Process Management Journal, 8*(1), 19–41.

Lind, M. and Seigerroth, U. (2010, January). *Multi-layered process modeling for business and its alignment*. Paper presented at 43rd Hawaii International Conference on System Sciences, Honolulu, HI, (pp. 1–10). DOI: 10.1109/HICSS.2010.280.

List, B. and Korherr, B. (2005), A UML 2 Profile for Business process modeling». In CoMoGIS, eCOMO, and QoIS, ed. Akoka, Jacky et al. (Eds.), *Perspectives in Conceptual Modeling: ER 2005 Workshops AOIS, BP-UML,* (Vol. 3770/2005 pp. 85–96). Coll. Lecture Notes in Computer Science. Germany: Springer, Berlin, Heidelberg

List, B. and Korherr, B. (2006, April). *An evaluation of conceptual business process*. Paper presented at SAC '06: ACM symposium on Applied computing. Dijon, France (pp. 1532–1539). DOI :org/10.1145/1141277.1141633.

Ljungberg, A. (2002). Process measurement. *International Journal of Physical Distribution and Logistics Management*, *32*(4), 254–287.

Luo, W. and Tung, Y.A. (1999). A framework for selecting business process modeling methods. *Industrial Management and Data Systems, 99*(7), 312–19.

Magee, J. F. (1964). Decision trees for decision making. *Harvard Business Review, 42*(4), 126–138.

Maria, A. (1997), Introduction to modeling and simulation. In: Andeadottir, S. and Healy, K. Proceedings of the 29th conference on Winter simulation, pp. 7–13. 1730 Massachusetts Ave., NW Washington, DC, United States, IEEE Computer Society.

Martínez-Prieto, M. A., Bregon, A., García-Miranda, I., Álvarez-Esteban, P. C., Díaz, F. and Scarlatti, D. (2017, September). *Integrating flight-related information into a (big) data lake*. In 2017 IEEE/AIAA 36th Digital Avionics Systems Conference (DASC) (pp. 1-10). IEEE.

Medina-Mora, R., Winograd, T., Flores, R. and Flores, F. (1993). The action workflow approach to workflow management technology. *The Information Society, 9*(4), 391–404.

Mendling, J., Reijers, H. A. and Cardoso, J. (2007), What makes process models understandable?. In: Alonso G., Dadam P. and Rosemann, M. (Eds), *International Conference on Business Process Management, Business Process Management. BPM 2007. Lecture Notes in Computer Science, 4714* (pp. 48–63). Berlin, Heidelberg: Springer.

Milanovic, M. and Gasevic, D. (2009, September). *Towards a language for rule-enhanced business process modeling*. Paper presented at *2009 IEEE International Enterprise Distributed Object Computing Conference*. Auckland, (pp. 64–73), doi: 10.1109/EDOC.2009.12.

Mittal, K., Khanduja, D. and Tewari, P. C. (2017). An insight into decision tree analysis. *World Wide Journal of Multidisciplinary Research and Development, 3*(12), 111–115.

Monsalve, C. (2012). *Representation of business processes at multiple levels of abstraction (strategic, tactical and operational) during the requirements elicitation stage of a software project, and the measurement of their functional size with ISO 19761*. (Doctoral thesis, École de technologie supérieure, Montréal, Canada).

Monsalve, C., April, A. and Abran, A. (2013), How complete are BPM languages for software requirements elicitation? A BABOK insight.

Monsalve, C., April, A. and Abran, A. (2010), Representing unique stakeholder perspectives in BPM notations. In: *Software Engineering Research, Management and Applications (SERA), 2010 Eighth ACIS International Conference on* (pp. 42–49). Montreal, QC: IEEE.

Monsalve, C., April, A. and Abran, A. (2011), BPM and requirements elicitation at multiple levels of abstraction: A review. In: *IADIS International Conference Information Systems 2011, Avila, Spain, March 11-13* (pp. 237–242). International Association for Development of the Information Society.

Monsalve, C., April, A. and Abran, A. (2011), Requirements elicitation using bpm notations: focusing on the strategic level representation. *ACACOS'11, Proceedings of the 10th WSEAS international conference on Applied Computer and Applied Computational Science*, pp. 235–241.

Monsalve, C., April, A. and Abran, A. (2015), Business process modeling with levels of abstraction. *IEEE Colombian Conference on Communication and Computing (IEEE COLCOM 2015*, pp. 1–6). Popayan, Colombia: IEEE.

Myagmar, S., Lee, A. J. and Yurcik, W. (2005, August), Threat modeling as a basis for security requirements. *In Symposium on Requirements Engineering for Information Security 2005*, 1–8.

Nasery, M. (2014). Automating processes in clarity PPM by gel scripting. (Master thesis, at Politecnico di Milano).

OMG. (2013). Business process model and Notation (BPMN) version 2.0.2. Needham, MA, U.S.A.: Object Management Group (OMG). https://www.omg.org/spec/BPMN /2.0.2/.

OMG. (2017). OUML Operational Threat and Risk Model. OMG. Object Management Group, <https://www.omg.org/cgi-bin/doc.cgi?sysa/2014-6-17>.

Opdahl, A. L., and Henderson-Sellers, B. (2002). Ontological evaluation of the UML using the Bunge–Wand–Weber model. Software and systems modeling, 1(1), 43-67. DOI: 10.1007/s10270-002-0003-9

Peixoto, D. C. C., Batista, V. A., Atayde, A., Borges, E., Resende, R. and Pádua, C. (2008). A comparison of BPMN and UML 2.0 activity diagrams. In VII Simposio Brasileiro de Qualidade de Software, Vol. 56. 2008.

Prezel, V., Gasevic, D. and Milanovic, M. (2010). Representational analysis of business process and business rule languages. In: Eiter, T., El Ghali, A., Fernández, S., Heymans, S., Krennwallner, T. and Lévy, F. (Eds), *1st International Workshop on Business Models, Business Rules and Ontologies (BuRO),* (pp. 15–28). Bressanone/Brixen, Italy: Semantic Scholar.

Recker, J. C., Indulska, M., Rosemann, M. and Green, P. (2006), How good is BPMN really? Insights from theory and practice. In Ljungberg J. and Andersson, M. (Eds), *14th European Conference on Information Systems* (2006 ECIS), Göteborg, Sweden, June 12-14, 2006, (PP.1–12).

Recker, J. C., Indulska, M., Rosemann, M. and Green, P. (2005). *Do process modeling techniques get better? A comparative ontological analysis of BPMN*. Paper presented at 16th Australasian Conference on Information Systems, Sydney, Australia.

Recker, J. C., Rosemann, M., Indulska, M. and Green, P. (2009). Business process modeling- a comparative analysis. *Journal of the Association for Information Systems*, *10*(4), Article 1.

Rosemann, M. and Green, P. (2000), Integrating multi-perspective views into ontological analysis. In *21st International Conference on Information systems, ICIS'00*. (Brisbane, Queensland, Australia, December 10–13), pp. 618-627. Association for Information Systems

Rosemann, M., Green, P. and Indulska, M. (2004), A reference methodology for conducting ontological analyses. In Atezni, P., Chu, W., Lu, H., Zhou, S. &Ling, T.W. (Eds), *International Conference on Conceptual Modeling* (pp. 110–121). Springer-Verlag, Berlin, Heidelberg.

Rosemann, M., Recker, J., Green, P. F. and Indulska, M. (2009). Using ontology for the representational analysis of process modeling techniques. *International Journal of Business Process Integration and Management, 4*(4), 251–265.

Runeson, P. and Höst, M. (2009). Guidelines for conducting and reporting case study research in software engineering. *Empirical Software Engineering, 14*(2), 131–164.

Salant, P. and Dillman, D. A. (1994). *How to conduct your own survey* (1st). New York: John Wiley & Sons Inc., 232 p.

SCC. (2008). Supply-chain operations reference-model. SCOR Overview. Supply Chain Council. http://www.supply-chain.org.

Scheer, A. W. and Schneider, K. (1998). ARIS—architecture of integrated information systems. In: Bernus P., Mertins K. and Schmidt G. (eds). *Handbook on architectures of information systems*. (pp. 605–623). Berlin, Heidelberg: Springer.

Scheer, A. W., Thomas, O. and Adam, O. (2005). Process modeling using event driven process chains. In : Dumas, M. Aalst, W. and ter Hofstede, A. H. (Eds.), *Process-aware information systems* (pp. 119–146). Hoboken, New Jersey: John Wiley & Sons, Inc.

Silver, B. (2009). *BPMN method and style*. Aptos, California, USA: Cody-Cassidy Press, 213 p.

Smith, H. and Fingar, P. (2007). *Business process management: the third wave*, (4th ed.). Anniversary Edition. Tampa, Fla., USA: Meghan-Kiffer Press.

van der Aalst, W. M. P., ter Hofstede, A. H. M. and Weske, M. (2003). Business process management: A survey. In: van der Aalst W. M. P., Weske, M. (eds). Business Process Management. BPM 2003. Lecture Notes in Computer Science, Vol. 2678, (pp. 1–12), Berlin, Heidelberg: Springer.

van Nuffel, D. and De Backer, M. (2012). Multi-abstraction layered business process modeling. *Computers in Industry, 63*(2), 131–147.

Wand, Y. and Weber, R. (1995). On the deep structure of information systems. *Information Systems Journal, 5*(3), 203–223.

Wand, Y. and Weber, R. (2002). Research commentary: information systems and conceptual modeling-a research agenda. *Information Systems Research 13*(4), 363–376.

White, S. A. (2004). Introduction to BPMN. Business process trends, 11 p. 54. http://www.bptrends.com/publicationfiles/07-04%20WP%20Intro%20to%20BPMN %20 -%20 White.pdf .

Wiersma, W. (2013). The validity of surveys: Online and offline. *Oxford Internet Institute*, *18*(3), 321–340.

Wohed, P., van der Aalst, W. M. P., Dumas, M., ter Hofstede, A. H. M. and Russell, N. (2006). On the suitability of BPMN for business process modelling. In: Dustdar, S., Fiadeiro, J. L. and Sheth, A. P. (Eds), *Business Process Management: 4th International Conference, BPM 2006, Vienna, Austria, September 5-7, 2006*. *Lecture Notes in Computer Science* (Vol. 4102/2006, pp. 161–176). Germany: Springer, Berlin, Heidelberg.

Yin, R. K. (2003). Case study research: Design and methods (Applied Social Methods, Vol. 5) (3rd ed.). USA: Sage Publications, Inc.

Zairi, M. (1997). Business process management a boundary less approach to modern competitiveness. *Business Process Re-Engineering & Management Journal, 3*(1), 64–80.

zur Muehlen, M. (2004). *Workflow-based process controlling: Foundation, design, and application of workflow-driven process information systems*. Berlin: Logos Verlag.

zur Muehlen, M. and Ho, D. T. (2008, January). *Service process innovation: a case study of BPMN in practice*. Paper presented at the 41st Annual Hawaii International Conference on System Sciences (HICSS 2008), Waikoloa, HI, (pp. 372–372). DOI: 10.1109/HICSS.2008.388.

zur Muehlen, M. and Recker, J. (2008), How much language is enough? Theoretical and practical use of the business process modeling notation. In: Bellahsène Z. and Léonard M. (Eds), *Advanced Information Systems Engineering*, *Lecture Notes in Computer Science* (Vol. 5074, pp. 465–479). Berlin, Heidelberg: Springer.

zur Muehlen, M., Recker, J. and Indulska, M. (2007). *Sometimes less is more: are process modeling languages overly complex*? Paper presented at Eleventh International IEEE EDOC Conference Workshop, Annapolis, MD (pp. 197–204). DOI: 10.1109/EDOC W. 2007.30.