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An Approach For Key Performance Indicators Management Fostering Business Process Improvement

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List of Abbreviations

AHP	Analytic Hierarchy Process
BP	Business Process
BPM	Business Process Management
BPMN	Business Process Model and Notation
BPMS	Business Process Management System
DM	Data Mining
EC	Emergency Care
ED	Emergency Department
KPIs	Key Performance Indicators
KDB	Knowledge Database
PPIs	Process Performance Indicators
SMART	Specific, Measurable, Attainable, Realistic, Time-Based

Part I

General Introduction

Chapter 1

Introduction

In this introductory chapter, we first describe the general context of our work in section 1.1. Section 1.2 explains our motivation. In section 1.3, we highlight the state of the problem that our thesis is concerned with. Section 1.4 introduces the aims of this research. Finally, in section 1.5, we present the thesis structure.

1.1 Research Context

Continuous improvement initiatives can be significantly enhanced by the management of Key Performance Indicators (KPIs). These indicators present useful information which facilitate understanding the situations encountered by the decision-maker.

Business Process Management is a well-established set of principles, methods, and tools bringing the necessary answer to improve company performance. It combines knowledge from information technologies, management sciences, and industrial engineering with the purpose of improving business processes. Business Process (BP) is one of the key concepts addressed in this dissertation. It is defined as a coordinated set of activities intended to produce an organization's competitive advantage [GREENWOOD et GHIZZIOLI, 2009]. To achieve improved processes, it is important to evaluate their performance. Basically, it is possible to find several business processes in a company and their performance usually determines the degree of the success of the company. In [KRONZ, 2006], Kronz notes that collecting and analyzing performance related KPIs is the first prerequisite for holistic process management and forms the basis for consistent and continuous process optimization. In this thesis, we focus on several terms associated with the process such as process measurements as a way to determine the performance of the BP through a set of performance indicators. They provide critical information to the organization to measure progress towards their goals. Furthermore, process monitoring can also be used as a set of actions to take a careful look at a specific situation, significant business events, accomplished by gathering data or KPIs to reveal something about the considered BP. We can also deal with process evaluation to evaluate the compliance of process measurements with recommended practices, based on evidence or the consensus of experts. Another concept, named process improvement, reflects the basic idea associated with the different BP perspectives or the possible features that need to be considered by the decision-maker for the BP enhancement.

1.2 Motivation

A key aspect of any process-oriented organization is the evaluation of process performance for the achievement of its strategic and operational goals. KPI definition, configuration, use, evaluation, and improvement are playing an increasingly important role in BPM. The management of Process Performance Indicators (PPIs) cannot be restricted to the evaluation phase, but it must be extended throughout the whole BPM life-cycle [DEL-RÍO-ORTEGA, 2012]. In [VAN DER AALST *et al.*, 2016], Van Der Aalst *et al.* claim that KPIs related to common process performance dimensions such as time, quality, costs, and compliance are often mentioned in research on process improvement, but it is often unclear how research results and related BPM technology concretely contribute to better KPIs. We know that the essence of BP analysis is to address various measurements of the current short-term decision making as well as long-term strategic BP planning. In fact, in an early analysis, the process execution logs might appear to be a specialization of the BP model: while the BP model refers to how the company should perform a general business case, the process execution data refers to what actually happened when a specific business case has been carried out. However, even analyzing such amounts of data presents many new obstacles and challenges. In addition, the execution may not contain the knowledge of the model because it is not the purpose of its semantic representation. To interpret the values of indicators correctly, many measures that either directly or indirectly influence other indicators need to be examined. In some cases, the data logs interpretation and the knowledge meaning that we are representing, for example for two periods of time, or for a specific number of process instances can be substantially different. In this sense, it would be of special interest to manage KPIs based on a BPM approach. The proposed approach aims to establish and maintain efficient measurement as well as BP enhancement.

1.3 Problem Statement

The evaluation of BP is the key means for measuring organizations' progress towards their goals. Indicators are used, among others, as a way of finding out how to improve BPs. In this regard, academic research suggests a strong link between BP performance and organizational performance [VAN LOOY et SHAFAGATOVA, 2016]. Performance measurement criteria, i.e., performance metrics or Key Performance Indicators, are often used in a variety of domains to either reveal performance deficit or improve a certain process [KATTNER *et al.*, 2016]. Therefore, in this stage, we outline that our research question is "How can KPI management impact BP management?". In order to answer this general question under consideration, we will split it into a list of sub-problems detailed in the third chapter (section 3.6).

This thesis represents an initial step in addressing this challenge. It proposes an approach that will guide decision-makers in identifying insights to be considered in evaluating and improving KPIs as well as BPs.

1.4 Research Goals

The main goal of this thesis is to propose a continuous cycle involving defining, monitoring and improving KPIs. For this reason, we develop a KPI life-cycle step for each BPM life-cycle step, including the corresponding tools and methods overcoming the problems that existing proposals suffer from.

First of all, with the emergence of many indicators, the decision becomes more and more critical. At this point, we first aim to develop a set of Specific, Measurable, Attainable, Realistic and Time-Based (SMART) KPIs based on the integration of the Analytic Hierarchy Process (AHP) method and SMART criteria.

Second, regarding the lack of an explicit representation of KPI semantics, we will explore the use of an ontology as a means for facilitating decision making by creating semantic relationships between all terms. This ontology contextualizes the indicators and allows a meaningful use for it.

Third, concerning many challenges related to KPI monitoring, our goal in this step consists in the analysis and evaluation of KPIs results.

Fourth, about the improvement phase, another goal of this work refers to the use of Data

Mining (DM) techniques that allow extracting implicit information from a KPI dataset and exploiting the generated rules in order to update KPI relationships designed in the ontology. We will also use Process Mining to extract knowledge from event logs and mine KPIs content.

Last but not least, an additional goal of this work is to develop a framework that supports conceptual solutions provided to meet the above goals.

1.5 Thesis outline

This thesis is organized as follows:

The first part is an introduction in which we present a general vision of the thesis including the research context, the motivation, the problem statement and a summary of our research goals.

The second part “Background and Theoretical Foundation” provides essential information and related works regarding the research context. It comprises two chapters. In chapter 2, we introduce the main concepts related to the Business Process Management (BPM), we explore KPIs, the AHP method, SMART criteria, ontologies and their application to this thesis context, and finally, we provide basic information about DM techniques. In chapter 3, we present a detailed summary and analysis of the most relevant previous research work in the corresponding areas that motivated our research work in this dissertation.

The third part “Proposed Approach and Experimental Results” includes three chapters. Chapter 4 is the core of our dissertation, in which we justify the use of methods or techniques in our approach, present our Key Performance Indicators’ Management Assistance approach, introduce our framework and other adopted means for supporting our approach, and provide a general discussion of previous works. Chapters 5 and 6 are reserved for our approach application and present the synthesis of the various achievements and results where two real case studies have been conducted.

A conclusion summarizes the main contributions of our research and highlights some possible future work directions.

Our thesis also includes four appendices. Appendix A provides an overview of the healthcare process execution logs. Appendix B provides an overview of the candidates’ selection process execution logs. Appendix C provides a set of qualitative indicators based on a questionnaire of patient's satisfaction in the emergency care service. Appendix D presents the questionnaire for the qualitative evaluation of the SIAD Master's degree interview.

Part II

Background and Theoretical Foundations

Chapter 2

Basic concepts

2.1 Introduction

This chapter establishes a study of the most important concepts and terms in the context of this thesis. It also presents the fundamental issue dealt with in this dissertation. The effective and intelligent use of these concepts will open a new perspective in making relevant decisions. In the following sections, we stressed on providing a solid understanding of BPM field, we highlight the importance of KPIs, we present the Analytic Hierarchy Process method (AHP) and its fundamental steps, we present some ontology concepts and we explore DM techniques.

2.2 Business Process Definition

In the Business Process Management research area, the concept of Business Process (BP) is essential since it serves to understand how a business operates and what opportunities exist for making its activities more efficient [VAN DER AALST *et al.*, 2016]. Weske defines a Business Process as a set of activities that are performed in coordination in an organizational and technical environment [WESKE, 2007].

According to [KRITIKOS *et al.*, 2017], Business Processes (BPs) enable organizations to formulate and realize internal and external procedures that provide support or enable their core business.

2.3 Business Process Management Definition

According to [BRIOL, 2008], Business Process Management is an approach for steering the company, based on the business process. In [VAN DER AALST *et al.*, 2016], Van Der Aalst *et al.* define Business Process Management (BPM) as a discipline that advocates the use of continuous improvement on processes. This discipline builds upon earlier work on workflow management, operational research, lean manufacturing, six sigma, and BP re-engineering. It also combines knowledge from information technology, management science, and industrial engineering.

According to [DUMAS *et al.*, 2013], BPM is a structured approach using methods, principles, metrics, software tools, management practices, and policies that provide support for continuous improvement of processes. BPM is used to design, analyze, execute and monitor business processes. The last definition is the most complete since it gives a clear idea of BPM, its components and its importance to an organization.

BPM has many advantages such as enhancing processes to suit evolving business needs and measuring and optimizing processes leading to effective overall company performance and ensuring that the processes still meet the goals for which they were created.

2.4 Business Process Management life-cycle

BPM involves a series of phases which can be depicted in a continuous life-cycle. In the literature, there are different BPM life-cycles proposed by several researchers. The BPM life-cycle [DUMAS *et al.*, 2013] denes how to improve processing based on the knowledge of historical executions. In this dissertation, we focus on the BPM life-cycle described by Weske in [WESKE, 2007] as depicted in Figure 2.1.

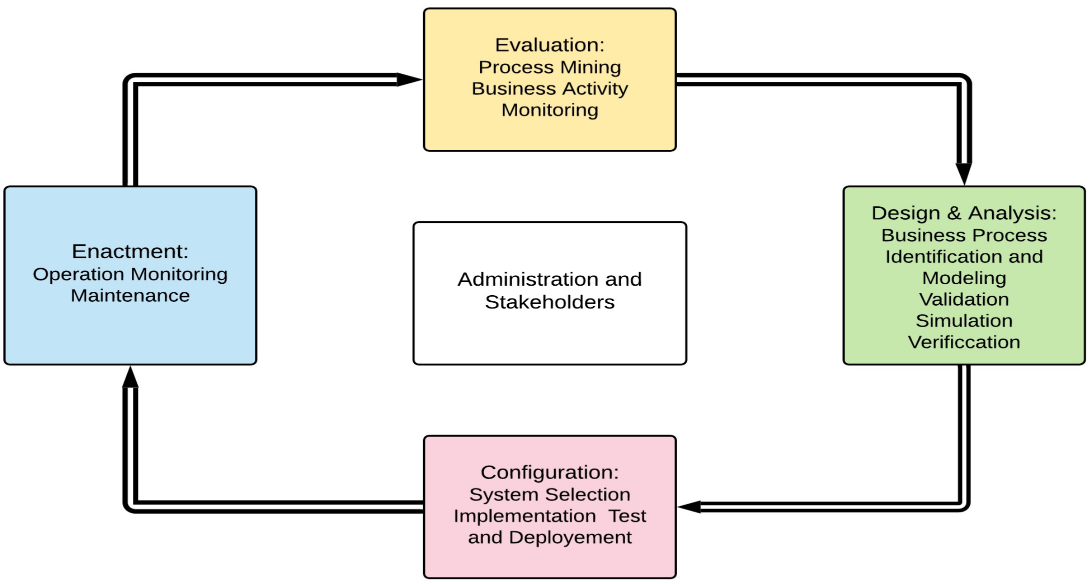

Figure 2.1: BPM life-cycle described by Weske in [WESKE, 2007]

In the design and analysis phase, the processes are identified, (re)designed and validated using for example simulation techniques to verify that the process actually exposes the desired behavior. A Business Process Modeling and Notation (BPMN) is used in this phase. In the configuration phase, BP model is implemented by configuring one or more Information Systems.

The enactment phase incorporates the execution of the BP using the systems configured. Using the monitoring component, the administrator can track and visualize the status of each process instances and other information with the help of Information Systems.

In the evaluation phase, the BP is diagnosed and information is collected to evaluate and improve the BP model and its implementation. The last phase involves the continuous monitoring of processes where many techniques can be used such as Process Mining to analyze the information stored in event data. Process Mining is a collection of techniques which aim to discover, monitor and improve business processes [VAN DER AALST, 2011].

In our work, we focus on all BPM phases of this life-cycle and give specific attention to the selection and the analysis of KPIs, where relevant data are collected in order to determine how the process is performing with respect to its performance objectives.

2.5 Business Process Model and Notation

In BPM, process modeling is a key phase in which the BP model should provide essential concepts to define the whole business. Hence, the designers define business processes or redefine an already existing process with the aim of improving it.

In particular, the Business Process Model and Notation (BPMN) language is a notation proposed in [OMG, 2006] by the Object Management Group (OMG). It is widely adopted as a standard notation for representing business processes. With BPMN, communication between various participants becomes easier and more interactive e.g. moving from the business analysts who create the initial model of the processes, to the technical developers responsible for implementation until coming to the business people who will manage and supervise these processes. In addition, the specification of the BPMN proposes two levels of abstraction [BRIOL, 2008]: A summary level which only consists of essential elements necessary for the business analyst by omitting the details of transcription in the process execution language, and a detailed level completing the fundamental elements of the summary level with technical information intended for the BP execution engines. The BPMN consists of a number of objects, such as flow objects, artifacts, connecting objects and swimlanes.

2.6 Business Process Management System

Business Process Management incorporates Business Process Management Systems (BPMSs) as Information Systems to optimize and automate organization daily procedures. These BPMSs manage the information related to the instances (business data), which in turn are related to the execution of the BP model, and recover the information concerning the process performance (Process Performance Indicators) [PEREZ-ALVAREZ *et al.*, 2016].

At present, there is a wide variety of BPMSs that allow managing BPs to make them more efficient in business environments. According to Briol, these process management technologies generally include many features like BP modeling , collaborative development between participants, BP documentation, BP simulation, integration of internal and external applications to the organization, BP automation, collaboration between company partners, BP deployment, analysis of BP execution, the production of dashboards and reports, and knowledge management of the organization [BRIOL, 2008].

Typically, execution logs generated in the enactment of the BPM phase are used to store information about processes real execution, such as the start or the end of activities. The use of a BPMS facilitates the monitoring of KPIs, and more specically of the Process Performance Indicators (PPIs). BPMSs generate and store information about their performance, such as the number of instances of a BP execution, the duration time of each activity, who has executed each activity, the resources involved, the frequency of each activity, and the number of instances [PEREZ-ALVAREZ *et al.*, 2016].

In order to determine the PPIs values and to obtain information to calculate indicators, process monitoring is fundamental. This monitoring is related to control the process and focuses on supervising process instances. BP monitoring is implemented in most commercial BPMSs [GÖSER *et al.*, 2007]. MEIDAN *et al.* in [MEIDAN *et al.*, 2017], present a detailed evaluation of open BPMSs. In this sense, the evaluation process supports different criteria where authors perform a systematic review of all official documentation provided by each BPMS. Table 2.1 briefly describes each BPMS studied by authors under some criteria.

Table 2 .1 :BPMS description studied in [MEIDAN et al., 2017]

		Bonita BPM	ProcessMaker 2.8.0	YAWL 3.0	Camunda BPM 7.2.0	Activiti 5.17	JBPM 6.2	uEngine BPM 3.6.0
Modeling criteria	**Supported BP Modeling languages**	BPMN 2.0	BPMN 2.0	YAWL	BPMN 2.0	BPMN 2.0	BPMN 2.0	XPDL
	Interoperability	Import jBPM XML 3.2, BPMN 2.0, XPDL 1.0 and Export Only BPMN 2.0 and image file	Only supports ProcessMaker format	Import and export BPMN	Import and export BPMN 2.0	Import and export BPMN 2.0	Import and export BPMN 2.0.	Not supported
	Reuse in BP models	Not supported in the community edition	Supported	Supported	Not supported	Not supported	Supported	Not supported
	Modeling business rules	Partially supported	Partially supported	Partially supported	Partially supported	Partially supported	Partially supported	Use the integrated rule engine
	Modeling of PPIs	Not supported in the community edition	Not supported	Not supported	Partially supported	Not supported	Not supported	Not supported
Design	**Supported programming languages**	Java	JavaScript and PHP	Java	Java and JavaScript	Java and JavaScript	Java	Java

criteria	**Designing the User Interface (UI)**	Supports the automatic generation of UI and supports manual modification in the community edition	Idem (both automatic and manual)	Idem (both automatic and manual)	Idem (both automatic and manual)	Idem (both automatic and manual)	Idem (both automatic and manual)	Idem (both automatic and manual)
Deployment criteria	**Support for distributed execution**	Not supported in the community edition	Not supported	Not supported	Not supported	Partially supported	Supports multi-engine and multi-nodes	Not supported
	Support for integration with other systems and services	It supports more than 80 connectors to allow integration into different systems and services	Support REST API and Web services	Support REST API and Web services	Support REST API and Web services	Support REST API and Web services	Applications can connect to the core engine. It also supports Web service technology	Web services
Execution	**Support for informing users of their tasks, either supporting push** (i.e.,	Both techniques are supported	Both techniques are supported	Partially supported	Both are supported	Partially supported	Partially supported	Partially supported

	BPMS sends a notification to the user about pending tasks) **techniques or pull** (i.e., BPMS allows checking if each user has pending tasks) **techniques**							
	Version management of BP models	Supported	Not supported	Supported	Supported	Not supported	Supported	Supported
Monitoring	**Support for technical monitoring and control**	Supported	Not supported	Not supported	Not supported	Not supported in the community edition	Not Supported	Not supported
	Support for Business Activity Monitoring (BAM)	Partially supported	Partially supported	Supported	Supported	Not supported in the community edition	Supported	Supported
	Support for dashboards and reports	Not supported in the community edition	Basic dashboard and report are supported	Not supported	Supported	Supported	Supported	Supported
	Support for different views of monitoring information	Not supported in the community edition	Not supported	Partially supported	Partially supported	Supported	Supported	Supported

Analysis	**Support for process verification**	Validation of the BP diagram and connectors is available. It also includes debugging mode	Not supported	Supported	Supported	Supported	Supported	Not supported
	Support for process simulation	Supported	Not supported	Supported	Not supported	Supported	Supported	Not supported
	Supported types of historical data available for analysis	Partially supported	Supported	Supported	Supported	Partially supported	Supported	Supported
	Support for improvement suggestions	Partially supported	Not Supported	Not supported	Not supported	Not supported	Not supported	Not supported
	Support for Business Intelligence and Process Mining tools	Partially supported	Partially supported	Partially supported	Partially supported	Partially supported	Provide support to these tools in the history log	Include OLAP tools

In [MEIDAN *et al.*, 2017], the authors evaluate each BPMS consistently by calculating the total support level of every BPMS and sorting evaluated systems according to their level of support for all evaluation criteria. The best rate is provided by jBPM followed by Camunda, YAWL, Bonita, Activity, ProcessMaker, and uEngine.

2.7 Key Performance Indicators in General

The definition of Key Performance Indicators (KPIs) has drawn the attention of many authors in several domains. For instance, in [HORKOFF *et al.*, 2014] HORKOFF *et al.* define an indicator as a metric that evaluates the progress and the performance of the process with respect to some objectives. The authors add later that such metrics can be directly derived from data or can use a formula to combine values.

In [KRITIKOS *et al.*, 2017], Kritikos *et al.* state that KPIs usually include a metric and a threshold imposed on it, thus dening the respective minimum performance level to be sustained. In [VAN LOOY et SHAFAGATOVA, 2016], the authors note that performance indicator should also have a concretization that makes clear how it is measured, and its value should be compared to a target value.

Therefore, according to [POVEDA VILLALÓN *et al.*, 2014], a concrete indicator usually supports some required information for a stakeholder to make decisions and it is referred to a certain attribute of some entity. A performance indicator is also specified in terms of a concrete measure, with a concrete scale and unit of measurement and has a concrete value. Maté *et al.* indicate that KPIs encapsulate knowledge about the degree of performance to be achieved [MATÉ *et al.*, 2017].

Some authors use the term of Process Performance Indicators (PPIs). For example, in [PEREZ-ALVAREZ *et al.*, 2016], the authors state that PPIs tend to be used for the detection of possible deviations of expected behavior and help in the post-mortem analysis and redesign by improving the goals of the processes. Furthermore, they confirm that PPIs are highly related to the process instances that are being executed at any moment, and therefore the description of PPIs implies the description of the data instances. In [DEL-RÍO-ORTEGA, 2012], the author also used the same term and she claimed that PPIs represent process goals that a company wants to achieve on a more operational level. She points out that PPIs are a relevant means to evaluate process performance and can be considered as the first step to carry out continuous process improvement. For [ROSENBERG *et al.*, 2011], the authors define PPIs as quantifiable metrics that allow evaluating the efficiency and effectiveness of business processes. They state that PPIs can be calculated from the generated data within the process flow.

In [BAUMGRASS *et al.*, 2014], the authors indicate that various dimensions have been cataloged concerning KPIs (time, cost, quality, and exibility), that can be referred to as a set of PPIs. In [DEL-RÍO-ORTEGA, 2012], Ortega notes that the terms PPIs and KPIs are used interchangeably. In fact, there is no consensus in the literature regarding the relationships between PPIs and KPIs. Some authors do not present any difference between them, while others classify PPIs as a particular case of KPIs (e.g. process-related KPIs). Finally, there are some other authors who attribute diverse definitions to each one, by placing them at different levels (e.g. while KPIs represent business goals that a company wants to achieve on a strategic level, PPIs are associated to the operational level). The authors in [VAN LOOY et SHAFAGATOVA, 2016] also states that the concepts of performance indicators, measures, and metrics are used interchangeably throughout most of the papers. The concepts are sometimes presented and defined in various ways [VAN LOOY et SHAFAGATOVA, 2016]. In our thesis, we use the term KPIs because it is frequently used, thus allowing it to be applied to all KPIs in every usage case, especially used in a business environment to give a clear picture whether a business is moving towards fulfilling its strategic objectives.

The delivery of BP performance is dependent on both quantitative and qualitative indicators with a variety of information needs. Performance indicators are qualitative or quantitative assessments that are the result of a comparison between an actual value and a target value over specic time periods [MATÉ *et al.*, 2012]. According to [PEREZ-ALVAREZ *et al.*, 2016], a performance indicator is a quantitative or qualitative indicator that reects the state of the processes of an organization.

KPIs are traditionally defined with respect to a business strategy. A very common method based on indicators is the Balanced Scorecard (BSC) [KAPLAN et NORTON, 2005]. It is used to indicate what is to be monitored in different areas of the enterprise. BSC is a strategic tool for measuring an organization's performance [VAN LOOY et SHAFAGATOVA, 2016]. Generally speaking, performance measures enhance processes and procedures which fosters the implementation of the right solutions. These performance measures reflect the progress or degree of fulllment of the organization's goals. They may quantify various aspects of business activities, such as their input, execution, and output, for monitoring purposes [DAVID, 2015].

Based on these definitions, it becomes clear that KPIs act as a set of measures and allow gathering knowledge and exploring the best way to achieve organizational performance.

2.8 Analytic Hierarchy Process Method

When we start searching about techniques used for decision making, in particular, decisions related to ranking various alternatives under the multi-criteria evaluation task, we refer to the most widely used method, Analytic Hierarchy Process (AHP) method. It allows decision-makers to measure the consistency of their decisions [SHAHIN et MAHBOD, 2007]. It was proposed by Saaty in 1980 and designed to develop overall priorities for ranking the alternatives with respect to several criteria. In fact, it can measure and synthesize the preferences for various factors and alternatives.

The application of the AHP method is based on the following three steps:

1- Defining the problem and creating a hierarchical model of decision problems: the method starts with the definition of the main goal to reach the top level. From there, it breaks down this goal into a structured hierarchy of evaluation criteria and sub-criteria through intermediate levels. At the lowest hierarchical level, we find alternatives to evaluate. Figure 2.2 shows an abstract view of such a hierarchy.

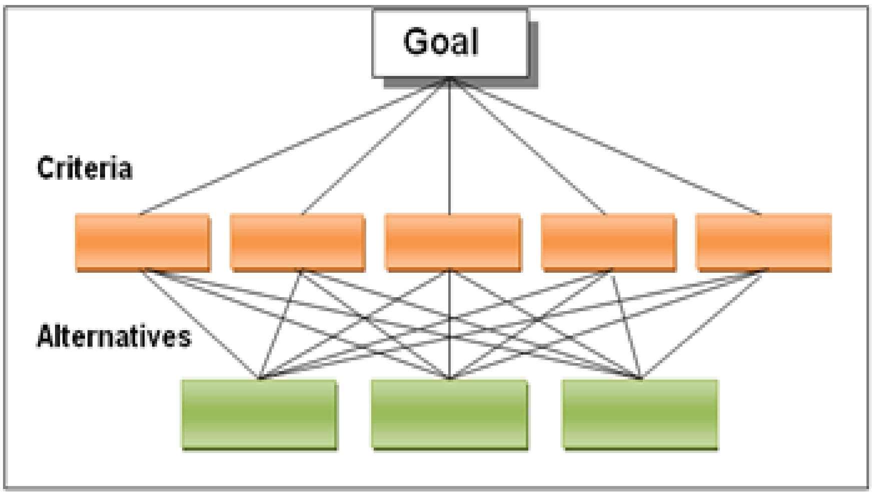

Figure 2.2: An abstract representation of an AHP decision hierarchy

2- Comparing the relative importance of the elements of the hierarchy by making a series of judgments: AHP uses pairwise comparisons based on the Saaty scale. It proceeds by two-to-two combinations of elements of each hierarchical level relative to the elements of the higher level. When we fill a pairwise comparison matrix, we try to answer two main questions: Which criterion/alternative is more important with respect to the goal /criterion? And how important is it? To facilitate decision-maker judgments about the relative importance of criteria and alternatives, there are three judgment elicitation modes (verbal, numerical, or graphical) offered by the AHP method. Hence, a nine-point scale proposed by Saaty that represents how many times one element is more important than another is shown in Table 2.2.

Table 2.2: Ranking scale for criteria and alternatives

Numerical values	Explanation of preferences
1	Equally preferred
3	Moderately preferred
5	Strongly preferred
7	Very strongly preferred
9	Extremely strongly preferred
2,4,6,8	Intermediate values represent preferences halfway between the integers on either side

An element $C_{i,j}$ of the pairwise comparison matrix is the measure of preference of the item in row i when compared to the item in column j. AHP assigns a 1 (equally important) to all elements on the diagonal of the matrix (the comparison of criteria i with itself) and when comparing elements i and j,$C_{j,i}$ must be the reciprocals (inverse) of $C_{i,j}(1/C_{i,j})$ e.g. if an alternative i is twice preferable than alternative j, then, it implies that alternative j must be 1/2 compared to alternative i. AHP method allows decision-makers to refine the relative importance as needed and to evaluate verbally the numerical value of each point of the scale. For example, a judgment of 1 means that both alternatives or criteria are equal, a judgment of 3 means that an alternative is moderately or three times more important than the other alternative.

3- Once the matrix of pairwise comparisons has been developed, we pass to establishing priorities (i.e., weights) for each node of the hierarchy (priority of each alternative under specific criteria, a priority of each criterion under the overall goal) being compared. The mathematical procedure involves the computation of the Eigen Vector; also called the priority vector. It is calculated by two main steps. First, sum the values in each column of the pairwise comparison matrix and then divide each element in the pairwise matrix by the sum of its column. The resulting pairwise comparison matrix is a normalized matrix where all columns in this matrix now have a sum of 1. Second, compute the average of the elements in each row of the normalized matrix. The result is usually represented as the (relative) priority vector.

The AHP method checks the inconsistency in the judgments and provides a way to improve consistency [SAATY *et al.*, 2012]. To handle the consistency question, we check whether the input data satisfies a consistency test related to the quality of the ultimate decision. AHP provides a method for measuring the consistency of judgments that the decision-maker demonstrated during the series of pairwise comparisons. For example, if we judge that an alternative A is twice as preferred as an alternative B and B is three times as preferred as an alternative C, then to be perfectly consistent, A must be six times as preferred as C. The measurement of the consistency is done by computing a consistency ratio (CR). If the value of the CR is greater than 0.10, the inconsistency is high and then the decision-maker should revise the pairwise comparison judgments, else, the decision process can continue. The mathematical computation of the consistency ratio is described in the following step. First, we begin by determining the "weighted sum" vector. This is done by multiplying each value in the first column of the pairwise comparison matrix by the relative priority of the first item considered and then summing the values across the rows. Second, we divide the elements of the vector of the "weighted sum" by the corresponding priority value. Third, we compute the average of the computed values named as $\lambda_{\max}$ obtained in the previous step and then we compute the consistency index (CI) where n is the number of items being compared and finally, we compute the consistency ratio (CR) where the Random Index (RI) is the consistency index of a randomly generated pairwise comparison matrix.

All these steps can be accomplished by using a software package for decision support such as Expert Choice.

2.9 SMART Criteria

The definition of criteria and the calculation of their weight are central in the AHP method to assess the KPIs (alternatives). Each indicator should be based on criteria that make it suitable for further analysis. Reviewing the literature, it is found that SMART (or rather SMARTER) criteria are most often referenced. In fact, they are recommended by many professionals in the domain of performance management systems [PODGÓRSKI, 2015].

The SMART rule was originally developed for establishing meaningful objectives for projects and later adapted to the identification of metrics and KPIs [KERZNER, 2017]. There is no clear consensus about what the ve SMART keywords mean. Table 2.3 presents the meaning of SMART criteria as proposed in the literature.

Table 2.3: The meaning of SMART criteria

SMART Criteria	Meaning of the criteria		
	Ref [KERZNER, 2017]	Ref [KAGANSKI *et al.*, 2016]	Ref [RESINAS *et al.*, 2014]
Specific	The KPI is clear and focused toward performance targets or a business purpose.	Goals should be as specific as possible. Taking into consideration a clear understanding of what KPI measures, should be realized.	It has to be clear what the KPI exactly describes and the context within which it is defined.

Measurable	KPI can be expressed quantitatively.	Each objective, process or KPI should be measurable. The measure itself could be quantitative or qualitative, but measurement shall comply with standards and requirements, depending on the	It has to be possible to measure a current value and to compare it to the target one.
Attainable	It must be aligned with a part of the organization's strategy, something that really affects its performance.	Objectives should be set at right level. Each KPI should have the standard value that should be achieved.	It makes no sense to pursue a goal that will never be met.
Realistic Relevant	KPI is directly pertinent to the work done on the project.	KPIs should provide insight into the performance of the company in obtaining its strategy.	It must be aligned with a part of the organization's strategy, something that really affects its performance.
Time-Based or Time-Specific or Time-Sensitive	KPI is measurable within a given period of time.	Each KPI has meaning if everyone knows the time frames in which it is measured and realized.	A KPI only has a meaning if the time period in which it is measured is known.

Many organizations have applied the SMARTER model considering the fact that two additional criteria are good reminders to managers [KAGANSKI *et al.*, 2016]. The additional letter 'E' represents the "Explainable" or "Evaluated" criterion and the 'R' letter represents the "Relative", "Reviewed" or "Re-evaluate" criterion.

2.10 Ontology Definition

The literature is full of definitions of the term ontology. On the one hand, the term is borrowed from philosophy and on the other, each group adopts its own vision according to the use made of it and the objective sought. We consider, for example, the definition proposed by Guarino: a formal and consensual dictionary of categories and properties of entities of a domain and the relationships that hold among them [GUARINO *et al.*, 2009]. According to Mädche *et al.* [MAEDCHE *et al.*, 2000], the main role of ontologies consists in capturing domain knowledge in a generic way and allowing a commonly agreed-upon understanding of a particular domain. They add later, that the common vocabulary which define the meaning of terms and their relations on the ontology, is usually organized in taxonomy and contains modeling primitives such as relations, classes, axioms, and functions [MAEDCHE *et al.*, 2000].

In computer science, there are various classifications introduced for ontologies. For example, in [GUARINO *et al.*, 2009], the classification of Guarino based on their generality level: (1) the top-level ontologies which describes general knowledge independent of a domain, (2) the domain-level ontologies that describes a particular field, (3) the task-level ontologies which describe concepts related to a generic task, and, (4) the application-level ontologies which presents concepts related to a specific task in a particular domain. In our research, we will be interested in the domain-level ontology.

2.11 Ontology Languages

The ontology representation requires a set of primitives allowing the expression of axioms, instances, entities, and relations that it contains and the necessary operators for their processing. There is a wide range of ontology languages in the semantic web domain. Some of them are based on the XML syntax (Extended Markup Language), such as SHOE (Simple HTML Ontology Extension) that was previously based on HTML, XOL (Ontology Exchange Language), RDF (Resource Description Framework) and RDFS (RDF Schema). We can find other additional data languages established on RDF (S) to improve its characteristics such as OIL (Ontology Inference Layer), DAML+OIL (DARPA Agent Markup Language and Ontology Inference Layer) and the OWL (Web Ontology Language).

Figure 2.3 shows the main relationships between all these languages in the form of a pyramid of semantic Web languages developed in [CORCHO *et al.*, 2003].

Most of today's ontology languages are based on description logic [FANESI *et al.*, 2015]. The description logic used in OWL represents the domain concepts in a form of TBoxes and the assertions as A Boxes [KORCZAK *et al.*, 2017]. The TBox contains the declaration of all concepts or classes. The A-Box or assertional component contains instances of the classes contained in the terminological component. This means that a class cannot be an instance of another class at the same time [DAVID, 2015]. Table 2.4 gives a brief description of the most used languages.

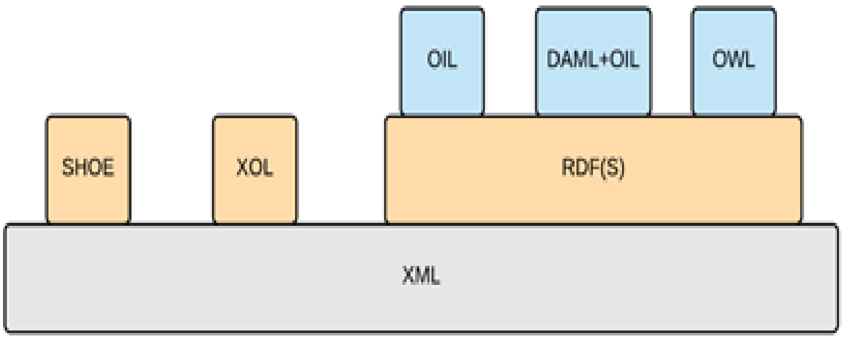

Figure 2.3: Pyramid of semantic web languages adapted from [CORCHO *et al.*, 2003]

Table 2.4: The stack of ontology markup languages.

Language	Description
RDF	Describes resources on the web developed by the World Wide Web Consortium (W3C). It is a standard written in Extensible Markup Language (XML). RDF represents a graph data model for objects ("resources") and relations between them. This graph contains a set of triples, each triple consisting of the subject, predicate (property) and object [CHEN *et al.*, 2009].

RDF Schema(RDFS)	RDFS defines vocabulary (terms) for describing the properties and classes of RDF resources, with semantics for the generalization hierarchies of such properties and classes [CHEN *et al.*, 2009].
OIL	It adds frame-based knowledge representation primitives to RDF(S), and its formal semantics is based on descriptive logic.
DAML+OIL	Developed by the DARPA project DAML. DAML+OIL add descriptive logic to RDF. Both OIL and DAML+OIL allow representing concepts, taxonomies, binary relations, functions, and instances [CORCHO *et al.*, 2003].
OWL	It is a standard ontology language of the W3C. Based on RDFS and inspired by DAML+OIL, OWL provides the engineer with more power to express semantics. OWL is available in three sub-languages: OWL Lite, OWL DL, OWL Full.

2.12 Ontology Editors

Several ontology editors proposed to develop and manage ontologies (e.g. the creation of concepts, properties, axioms, and restrictions). The ontology editors are tools that allow users to visually manipulate, inspect, browse, code ontologies, support the ontology development and maintenance task [ALATRISH, 2013].

Adapted from a comparison of five ontology editors used and experimented by [ALATRISH, 2013], we illustrate in Table 2.5, where the comparison is done by considering different properties of editors.

Table 2.5: Comparison of ontology editors experimented by [ALATRISH, 2013]

	Apollo	**OntoStudio**	**Protégé**	**Swoop**	**TopBraid Composer**
Availability	Open-source	Software Licence	Open-source	Open-source	Software license

Default architecture	Standalone	Client/server	Standalone and client-server	Web-based and Client-server	Standalone
Storage of the ontologies	Files	DBMS	Files and BMS (JDBC)	As HTML Models	DBMS
Imports from languages	Appolo meta language	XML(S), OWL, Excel, RDF(S), UML2.0, database schemas (Oracle) MS-SQL, DB2, MySQL, Outlook E-mails	XML(S), RDF(S), OWL, HTML, (RDF, UML, XML) backend, text file, RDF file, Excel, BioPortal and DataMaster	OWL, XML, RDF and text formats	RDFa, WOL, XML(S), Excel, RDF(S), XHTML, UML, GRD DL, RDB with D2RQ, Microdata and RDFa Web DataSites, SPIN, Spreadsheets, Oracle database, Text File, Rdf file, News Feed, Email

Exports from languages	OCML and CLOS	OWL, RDF(S), RIF, SPARQL, FLogic and Excel	XML(S), RDF(S), OWL, HTML, Java, Clips, FLogic SWRL-IQ, Instance Selection, MetaAnalysis, OwlDoc, Queries and (RDF, UML, XML) backend	RDF(S), OIL and DAML	HTML, UML, XSD, Excel, RDB, Oracle database, RDF File, XML File and Text File

2.13 Association Rule Mining

Data Mining (DM) is part of the Knowledge Discovery in Databases (KDD) process [KAMSU -FOGUEM *et al.*, 2013]. It is an integration of multiple technologies such as statistics, database management and warehousing, decision support systems, machine learning, and visualization. DM offers a new way to look at a set of information/data and provides new information which will prove useful for the user in making decisions/actions. Thus, the Knowledge Discovery in Databases concerns the whole process of data discovering, while DM is related to the application of particular algorithms for extracting data patterns.

DM tools predict future trends and behaviors, allowing managers to make proactive, knowledge-driven decisions [BHAT et BEHAM, 2016]. Association rules mining [AGRAWAL et SRIKANT, 1994] is one of the most essential techniques of DM. The main goal of the association rules is to find and extract all interesting relationships for a given dataset.

The great amount of information captured in the set of association rules can be used to describe the relationships in the database and to classify different kinds of database instances.

Nevertheless, the main problem in association rules mining is its complexity. This is why a mining approach defines an interesting measure to guide the search and prune the search space [MISHRA *et al.*, 2015]. As such, the goal of using associations is to discover regularities in databases under the form of implications if X then Y, denoted as $X \to Y$, where X and Y are named the antecedent and the consequent. This association rule means that transactions including items from set X tend to include items from set Y. In other words, it aims to find common relationships amongst the items, or affinities between existing variables from a collection of records. We can read this implication as follows: if the items in X occur in a transaction, then, it is probable that the items in Y also occur in the same transaction. If a set of items appear frequently together in a transaction dataset, it is named a frequent pattern or frequent itemset. For example, these affinities can be expressed by stating "85% of customers who purchased items X also ended up purchasing Y". Hence, an association rule is defined by two measures which are the support (*sup*) and the confidence (*conf*). In order to obtain a good number of rules, the minimum (*min*) support and the *min* confidence need to be configured before learning. Support means "Both together" and confidence means "If implies then" [YADAV *et al.*, 2016]. The choice of the thresholds *min sup* and *min conf* has a great influence on the resolution and the quality of the rules generated by algorithms. When the value of minimum support is increased, the size of large itemsets and frequent itemsets are decreased. In other words, if set too high, then algorithms generate too few results, discarding valuable information, and if set too low, then algorithms can generate a large number of results and can become very slow [KAMSU-FOGUEM *et al.*, 2013].

There are many well-known algorithms which generate rules from the unsupervised problem. We take the example of the Apriori algorithm. The general idea of this algorithm is to generate frequent itemsets and to scan those frequent itemset to decide which are the most frequent items extracted from the dataset or the database. The generation of frequent itemsets can generate another itemset by joining with previous frequent itemsets. Basic steps for this iterative process are summarized as follows: 1) produce frequent itemsets (length 1); 2) repeat until the count of new frequent itemsets is zero(0): From length n frequent itemsets, produce n+1 candidate itemsets, prune infrequent candidate of length n, count the support of each candidate by scanning the database and retaining the frequent candidate, eliminate the infrequent one; 3) produce Apriori rules based on support and confidence [ALI et XIANG, 2009].

There is another well-known algorithm called Frequent Pattern growth (FP-growth). The mining task adopts a divide and conquer strategy by compressing the database representing frequent items into a structure called the Frequent Pattern tree (FP-tree). This algorithm establishes conditional parameters and uses them to generate a full set of frequent patterns [KAMSU-FOGUEM *et al.*, 2013]. It scans the database only twice. In the first scan, all the frequent items and their support counts are retrieved and sorted in the descending support count order in each transaction. In the second scan, items in each transaction merged into a prefixed tree and items (nodes) that appear in common in different transactions are counted [YADAV *et al.*, 2016].

2.14 Conclusion

In this chapter, we have introduced the main concepts that establish the research context for our main contributions such as the BPM which combines the management discipline and a suite of software technologies, KPIs, the AHP method, some aspects related to the ontology field, and the association rules algorithm.

Chapter 3

State of the art

3.1 Introduction

BPM presents a way to manage organization processes in order to achieve consistently, targeted results aligned with organizational goals. This approach includes many layers. The first one is related to the management level which focuses on creating strategic goals that the organization can move toward. The second layer concerns the process level where companies need to put these processes in place in order to achieve the ideal future state. Finally, the implementation level is related to technological solutions and human resources development for existing and new processes. We conclude that all levels use information related to the BP execution environment. This is a clear indication that we can perform evaluations and improvements over processes. This statement reflects the basic idea to pay particular attention to the possible indicators that need to be considered and selected to get the most from processes. Therefore, many researchers have provided different ideas for determining KPIs in different areas.

This chapter presents a collection of influential approaches to our work. Section 3.2 gives a brief overview of the recent research related to KPIs for BPs. In section 3.3, we investigate related research based on the AHP method. In section 3.4, we explore interesting research work related to the ontology field. In section 3.5, we explore research work using DM techniques. Section 3.6 describes in detail the research questions to address the aforementioned goals. Section 3.7 gives a brief introduction to our main contribution. Finally, section 3.8 summarizes this chapter.

3.2 Related Work Concerning KPIs for BPs

In the literature, the term KPIs is related to many case studies and various domains. In this sense, in [KATTNER *et al.*, 2016], Kattner *et al.* distinguished four major domains in which KPIs are relevant to measure performance (Table 3.1).

Table 3.1: KPIs literature studied in [KATTNER *et al.*, 2016]

	Further domains			
	Corporate Business	**Construction**	**Health sector**	**IT**
Methodology to define KPI	[MATÉ *et al.*, 2012], [WETZSTEIN *et al.*, 2009] [LATORRE *et al.*, 2010] [ECCLES, 1991] [SELMECI *et al.*, 2012] [GHALAYINI et NOBLE, 1996] [XIROGIANNIS et GLYKAS, 2004] [ARIGLIANO *et al.*, 2008] [ANDONOV-ACEV *et al.*, 2008] [ABDULLAH *et al.*, 2008] [DEL-REY-CHAMORRO *et al.*, 2003]	[UGWU et HAUPT, 2007] [COX *et al.*, 2003] [ALWAER et CLEMENTS -CROOME, 2010] [YEUNG *et al.*, 2009] [POSAYANANT et CHAREONNGAM, 2010] [AMRINA *et al.*, 2015] [YUAN *et al.*, 2011] [HAPONAVA et AL-JIBOURI, 2011] [SKIBNIEWSKI et GHOSH, 2009]	[ABUJUDEH *et al.*, 2010] [MURPHY *et al.*, 2016] [BARBER *et al.*, 2015]	[SYCHROVÁ et ŠIMBEROVÁ, 2012] [TARDÍO et PERAL, 2015]

Listing KPIs	[SMITH, 2007] [DEL-REY-CHAMORRO *et al.*, 2003] [WETZSTEIN *et al.*, 2009] [LATORRE *et al.*, 2010]	[UGWU *et al.*, 2007] [COX *et al.*, 2003] [ALWAER et CLEMENTS-CROOME, 2010] [YEUNG *et al.*, 2009] [POSAYANANT et CHAREONNGAM, 2010] [AMRINA et VILSI, 2015] [YUAN *et al.*, 2011]	[ABUJUDEH *et al.*, 2010] [MURPHY *et al.*, 2016] [BARBER *et al.*, 2015]	[SYCHROVÁ *et al.*, 2012]
Use of KPIs	[DEL-REY-CHAMORRO *et al.*, 2003] [MATÉ *et al.*, 2012] [ARIGLIANO *et al.*, 2008]	[COX *et al.*, 2003] [POSAYANANT et CHAREONNGAM, 2010] [YUAN *et al.*, 2011]	[BARBER *et al.*, 2015]	[SYCHROVÁ *et al.*, 2012]

Table 3.1 is the result of the relevant literature review of KPIs and its applications in a variety of domains analyzed by KATTNER *et al.* [KATTNER *et al.*, 2016]. These domains include general business processes, infrastructure management and construction, organizational processes in the health sector, information technology services including website marketing and product creation. We can say that the majority of research works are interested in developing methodologies to define indicators. However, the definition of these indicators is not an end, but a means for KPI management towards improvement.

Another interesting literature review about the BP was elaborated by [VAN LOOY et SHAFAGATOVA, 2016] in which the authors analyzed the current state of BP performance measurement and related performance indicators.

In performance measurement models, authors distinguish between models focusing on the entire business (organizational performance measurement models) and models focusing on a particular BP (business process performance measurement models). On the one hand, organizational performance measurement models provide a holistic view of an organization's performance taking into account different performance perspectives. For example, we can find in this category, BSC which provides four perspectives (financial performance, customer performance, internal BP performance, performance linked to growth and learning). On the other hand, the approach related to BP performance measurement is generally less holistic than the BSC. The performance measurement in this category can also focus on a single business process, such as statistical process control, workflow-based monitoring or process performance measurement systems. For instance, in an established BPM handbook, Dumas *et al.* [DUMAS *et al.*, 2013] note that time, cost, quality, and flexibility are the typical performance perspectives of BP performance measurements. In these two categories, concrete performance measures or indicators should be defined for each process performance perspective. In this review, Table 3.2 gives a brief classification and conclusion.

Table 3.2: Classification of process performance studied in [DUMAS *et al.*, 2013]

	The functionalities of the studies of process performance	
Group	Performance measurement frameworks or systems	Performance indicators and their categorization
Description	Authors suggest concrete stages be followed by particular organizations or discuss the conceptual characteristics and design of a performance measurement system.	Some authors are interested in the process of defining performance indicators by listing requirements or quality characteristics that an indicator should have. Others focus on integrating performance indicators into the process models or the whole architecture of an organization

Conclusion	The second group concentrates more on the categorization of performance indicators into domains (e.g. external/internal, financial/non-financial, BSC dimensions) or levels (strategic, tactical and operational)

Furthermore, it is important to note that several methods are reported in the literature to address this same issue, so we have added some additional relevant papers related to KPIs and other similar concepts used in our thesis in Table 3.3.

Table 3.3: General KPIs literature

Compared approaches	**Main ideas**	**The goal of the approach**	**Context or case study**
[KIBIRA et FENG, 2017]	An approach to systematically rank candidate KPIs. It includes the identification of candidate KPIs, the selection, the ranking, and the composition of a final KPI set	Improve the environmental sustainability of products and manufacturing process	Manufacturing process
[MATÉ *et al.*, 2017]	An approach that offers an integrated view of strategic business objectives	Relating KPIs integrated into the business plan and the Balanced Scorecard with business goals	The Steel Wheels business strategy

[PEREZ-ALVAREZ *et al.*, 2016]	A solution that allows the incorporation of the PPIs into decision tasks, following the Decision Model and Notation (DMN) standard	Enriching the decisions that can be taken during the process execution	A real example of a platform for football bets, called Tutiplay

In [KIBIRA et FENG, 2017], Kibira et Feng indicate that KPI objectives represent activities to achieve identified KPI goals. These goals reflect a normative standard for organizations or industries. In our perspective, we pay more attention to BP objective in order to develop a suitable set of KPIs. Furthermore, the authors developed a method using selection criteria and value functions to rank candidate KPIs so that a final set is selected. They state that the more important the KPI, the more weight it is assigned.

However, the proposed approach does not help the manager to discover other indicators or to improve the definition of existing indicators. Furthermore, there is no guarantee that the final set of KPIs is still valid if we change the period of analysis or when new stakeholders are involved. Also, this final list is very limited and dependent on the choices of criteria definition which has a great consequence in value function development for each criterion. According to the authors, these value functions need experts' assessments of the value of a criterion. The development of a value function starts with the definition of important levels to be assigned to the criterion. But, criteria are not of equal weight during KPI selection which makes this procedure more complicated and time-consuming if we are dealing with many indicators and many criteria. This leads us to raise some questions such as: What happens if we add a new criterion? Do we add new KPI or do we redo all steps?

In [MATÉ *et al.*, 2017], KPIs are defined using a modeling language where decision-makers specify KPIs using business terminology. The main problematic treated in their paper is that the decision-maker lacks an adequate view to verify that the business strategy and the KPIs are consistent with each other. In their work, first, they propose a semi-automatic process to define KPIs. Second, they derive a data warehouse query (in particular (MultiDimensional eXpressions

(MDX)) from the definition of each KPI. Third, they execute this data warehouse query against a target Online Analytical Processing (OLAP) server and load the value of each KPI into a strategic model. Fourth, they allow the user to navigate across the data using a business strategy perspective. Furthermore, some limitations are stated by the authors concerning ambiguity management and the expressivity of their approach. For example, regarding ambiguity management, when the number of concepts increases, the number of synonyms also increases. Consequently, as the complexity of potential mappings across concepts increases, the overhead introduced by ambiguity also rises. Another limitation concerns expressivity, when concepts can be added to the business dictionary to extend the adopted language, the addition of new functions requires more effort. After running an initial test, the author points out that the use of this language to define KPIs by developers led to some wrong definitions and errors due to their lack of experience.

We can say that the work of [MATÉ *et al.*, 2017] gives particular attention to the analysis and assessment of the effectiveness of the strategy model. In our work, we focus on analyzing and assessing the effectiveness of defined KPIs.

The proposal of [PEREZ-ALVAREZ *et al.*, 2016] includes an extension of the decision rule grammar of the Decision Model and Notation (DMN) standard which allows business experts to automatize decision-making processes. To do so, they incorporate the denition and the use of a Process Instance Query Language (PIQL) that offers information about the instances related to the PPIs involved and allows business experts to describe the PPIs. This information, related to the PPIs of the process, is incorporated into the decision knowledge through the Process Instance Query Expressions (PIQEs). The solution proposed by the authors allows the incorporation of process performance indicators into the decision points of the models. The sequence of steps that are executed to evaluate a decision routing and involve the PPIs includes: (1) when a decision needs to be made, the business task calls the engine to communicate the identifier of decision to select the decision rules involved and the required data-flow of the instance, such as the case id; (2) the decision process starts by managing the PIQE contained within the DMN decision table, and evaluates the PIQEs in accordance with the information obtained from the BPMS, if necessary; (3) once the PIQE Engine Module has the PIQEs resolved, (4) the business knowledge is evaluated and the output that represents the decision taken is communicated to the PIQE Engine Module, and finally; (5) to route the execution, these variables are incorporated into the process data-flow. In summary, the extraction of PPIs and the alignment with the process decisions have been completed with the denition of architecture and the implementation of a framework where a set of technologies has been combined to produce a usable solution.

3.3 Related Works Based on the AHP Method and SMART criteria

The state of the art is very rich in work dedicated to the resolution of choice problems in a multi-criteria environment using the AHP method. This section aims to explore how the AHP method is being applied in related research works, and, particularly, how the criteria and indicators are being defined and measured. Linked to our problematic, few works explicitly address the problem of choosing KPIs under SMART criteria. Tables 3.4, 3.5 and 3.6 present some important works that have motivated the development of a new algorithm and capitalization of knowledge to deal with the problem of KPIs selection.

According to Shahin et Mahbod [SHAHIN et MAHBOD, 2007], applying the AHP-SMART method, KPIs can both be prioritized and evaluated to decide which are more "SMART" than others. They suggest an integrated approach to the AHP and SMART criteria for prioritizing KPIs where a case study was conducted in a hotel area.

In [PODGÓRSKI, 2015], the composition of initial sets of PPIs subjected to prioritization was based on a review of selected literature on safety performance indicators, and thus it was a priori assumed that all 109 PPIs being analyzed were relevant to the measurement of Occupational safety and health management systems (OSH MS) operational performance. Moreover, in alternatives comparisons established by the AHP method, the same weight of SMART criteria was applied for the selection of KPIs for all components of OSH MS. However, that hypothesis requires a careful verification, profound analyses, and consultations with experts and managers in the domain of OSH, since certain areas of OSH MS may require more measurable indicators and other more relevant ones, while others require more achievable or specific criterion for a given area.

Table 3.4: Research based on the AHP method and SMART criteria

Compared approaches	Main ideas or steps of the proposed approach	The goal of the approach	Context or case study	AHP method		
				AHP Goal	**Criteria**	**Alternatives**
[SHAHIN et MAHBOD, 2007]	- Define and list all of the KPIs - Build an AHP hierarchy - Undertake a pairwise comparison between alternatives - Calculate composite priority: calculate local weights and global weights - Selection of KPIs that are more relevant to organizational goals	The prioritization of KPI	Hotel case study	Select KPI based on specific organizational goals	SMART goal setting	Qualitative indicator
[PODGÓRSKI, 2015]	- Development of the initial set of PPIs for the measurement of Occupational safety and health management systems - Determination of ranks for individual SMART criteria for the selection of indicators - Prioritization and selection of KPIs for individual components of OSH MS	The selection of a limited number of KPIs for individual components of OSH MS	Occupational safety and health management systems (OSH MSs)	Prioritization of the KPIs for individual components of OSH MS	SMART criteria	109 indicators in total grouped into 20 subsets corresponding to 20 main components of the adopted model of OSH MS
[KAGANSKI *et al.*, 2016]	- KPIs priority calculation and ranking - Data collection from different Small and medium enterprises - Optimization and improvement of Enterprise analysis model process and integration to the production of the monitoring system	The optimization and improvement processes of EAM and KPI selection model	Enterprise analysis model (EAM) process	Sustainable KPIs for the improvement of productivity and effectiveness	SMARTER criteria	13 quantitative KPIs

Table 3.5: Research based on the AHP method and other criteria

Compared approaches	Main ideas or steps of the proposed approach	The goal of the approach	Context or case study	AHP method		
				AHP Goal	Criteria	Alternatives
[YAGHOOBI et HADDADI, 2016]	The application of AHP to rank the five functional units in ITC (a privately-held telecommunications company) involves eight steps as follows : - Step1: entering goals and indicators - Step2: graphical hierarchical representation of the problem - Step3: performing pairwise comparisons - Step4: calculating the local normal weight of each indicator - Step5: calculating the normalized weight of each perspective - Step6: determining the global weight of each performance indicator - Step7: pairwise comparisons of the performance of each functional area in terms of each performance indicator - Step 8: the best performing unit in each perspective	Rank the organizational units and identify the best-performing unit.	A telecommunications industry case	Identifying the top unit	- Criteria: Based on BSC's four performance perspectives - Sub-criteria: 19 Quantitative indicators related to organizational performance measurement	Functional units in ITC: the department of financial and logistical and manpower (unit 1), the department of maintenance and operation (unit 2), the department of development and maintenance (unit 3), the management areas and cities (unit 4) and the Department of IT management (unit 5)
[GHOLAMZADEH NIKJOO *et al.*, 2013]	Identify hospital performance indicators, first from Literature review and then experts panel was used. AHP technique was applied in order to prioritize performance indicators	Identify and select hospitals performance indicators	Health care field	Prioritize hospitals performance indicators	Three areas (Quality-Effectiveness, Efficiency-	Key hospitals performance indicator

					Financing, and Accessibility–Equity)	
[SURYADI, 2007]	The proposed model consists of: - Key Success Factors Identification - KPI Identification - Building KPI Tree - Trend and Comparison based Scoring	Proposes KPIs measurement model based on a combination of the AHP and Trend-Comparative attributes in HEI	Higher education institution	The total score of Higher Educational Institutions (HEI) performance	Three criteria; "academic (teaching)", "research" and "supporting".	KPIs related to each criterion
[AMOLE *et al.*, 2016]	An AHP-based approach to measuring the quality of service rendered by the hospitals from the patient's perspectives involve the following steps: - Identification of service quality dimensions - Identification of alternatives, their ratings and constructing the hierarchical model - Comparison of service quality dimensions and the alternatives in a pairwise fashion to derive their importance and assigning weights for the individual ratings - Derivation of the weights of ratings for the hospital service quality dimension	Estimating determinants of patient satisfaction towards service quality delivery of public teaching hospitals in Southwest Nigeria.	Public teaching hospitals in Southwest Nigeria.	The determinant of patients' satisfaction with service quality dimensions	7 criteria related to the dimension of service quality.	Alternatives were elicited and incorporated into the questionnaire for pairwise comparison by patients

Table 3.6: Research based on other methods and SMART criteria

Compared approaches	Main ideas or steps of the proposed approach	The goal of the approach	Context or case study	Criteria	Indicators
[DEL-RÍO-ORTEGA, 2012]	Describes the template for the definition of PPIs. This template has been defined in order to fulfill the SMART criteria.	Definition of good PPIs	BP	SMART	Quantitative indicator
[RESINAS *et al.*, 2014]	Present KPIshare for KPI definition. First Enterprise business professionals document their situation, the process they want to measure and the strategic or operational goal they want to achieve and leave blank the fields for which they are looking for an answer. Second, process measurement specialists; contribute to them by completing some or all of the fields of the KPI structure left blank by the KPI challenger. they can also comment on resolved KPIs, vote for the community answers they find valuable and report all wrong or inadequate answers.	Provide the BPM community with the knowledge base of well-defined, mature KPIs and a place where they can discuss, collaborate and create process-related KPIs that are applicable in real business situations	BP	SMART	Business-applicable process-related KPIs

In [KAGANSKI *et al.*, 2016], Kaganski *et al.* apply the Fuzzy AHP method to reduce the time and eliminate confusion in the case of large matrixes. They build a Fuzzy AHP hierarchy based on SMARTER criteria and combined with 13 KPIs. But in this work, they do not provide the final results corresponding to the KPIs prioritization because the comparison matrixes would be completed by experts and they lack more details according to the choice of KPIs.

Many works focus on integrating Balanced Scorecard (BSc). As an example, we can cite the work of Yaakoubi [YAGHOOBI et HADDADI, 2016]. The results presented in [YAGHOOBI et HADDADI, 2016] can help the organization to evaluate and revise its strategy (not revise the KPI). In addition, this method ignores the contributions of employees, suppliers, and stakeholders in achieving the company's objectives. In other words, the model determines the customer perspective indicators from the management's point of view instead of the external stakeholders and customers' points of view. Also, the weights of perspectives (organizational performance) and KPIs are important from a managerial viewpoint and specific to the case studied.

In [GHOLAMZADEH NIKJOO *et al.*, 2013], during the study of articles and internal/ external expert panel, many indicators of hospitals were obtained. The selected performance indicators were included in the AHP questionnaire and completed by experts. So, we can conclude that the list is limited regarding the areas and based on expert's ideas.

KPI Scoring in [SURYADI, 2007] is based on decision rule. In fact, KPIs are measured based on principles of trends and comparison dimensions. However, the Total HEI Performance score formula and KPI pairwise comparison under each criterion are not clear.

The Wheel model, too, for HEI Performance and its KPIs are not clear. Authors state that the performance of HEI is due to the growth of organization results which are determined by the actual level compared to historical performances. Besides, it is reflected by a comparison between the current level and the competitor performances or benchmarks. As we can see, it depends on the available data.

In [AMOLE *et al.*, 2016], the authors investigate the use of AHP in estimating determinants of patients' satisfaction towards the service quality of public teaching hospitals in Southwest Nigeria. They use an AHP-based approach to measure the quality of service (e.g. effective communication and waiting time) offered in the hospitals from the patients' perspectives. The questionnaire used in this paper revealed that the majority of respondents (patients) were females. As a consequence, if we change the Socio-demographic component like age, gender, marital status, and education, or change the medical and paramedical staff availability or team, all these aspects related to the relationships between patients' expectations and experiences of the received treatment will also change. Moreover, there was a significant association between patients' satisfaction (e.g. for the cleanliness of the hospital, up-to-date medical equipment and for waiting time alternatives) and the period of investigation (record patient satisfaction during the afternoon,night or weekend). This can have an influence on the determination of the priority weight for service quality dimensions and the ranking of KPIs.

In [DEL-RÍO-ORTEGA, 2012], all indicators are previously supposed SMART and the author just filled, in a very simple way, all necessary fields in the template. For example, for the field "Goals" related to the "Relevant" characteristic, there is no guarantee that this KPI really contributes to evaluating the process performance. So, the relevance of KPIs should be evaluated from the experts' point of view.

The goal of a KPI challenge in [RESINAS *et al.*, 2014] is to complete the description of a KPI that fulfills some operational and/or strategic goals set by the user that raise the challenge. KPI challenge provides these SMART predefined fields as a structure that frames the process measurement questions and solutions. These fields are defined so that the user is encouraged to follow the SMART criteria and include the measurement definition and units of measure. The target of the KPI and the filter, which specifies the process instances that must be considered to compute the KPI value, are defined. However, a KPI challenge presents some limitations that need to be addressed, such as dealing with a potentially unclear or conflicting understanding of KPIs and the way they are defined. Such different views can occur when KPIs are interpreted by different people in different business situations. As a consequence, a misunderstanding of the questions or a wrong implication from the answers are probable. This template is applied only for the quantitative indicator, where the qualitative indicators are not supported. In these two works, it is not clear whether the template is related to the definition of a KPI goal or a BP goal.

3.4 Related Works Based on Ontologies

The state of the art is very rich in work related to semantic representation where various ontologies in various domains are proposed, and it has been applied in many fields, such as semantic web and information retrieval. We need to look at other approaches which use ontologies with concepts similar to BPM, BP or indicators. Some of these approaches are shown in Tables 3.7 and 3.8.

Regarding the work of [JUNIOR *et al.*, 2016], the authors demonstrate the usefulness of the proposed ontology for the given company in the proposed scenario which needs to analyze its fleet fuel consumption and needs this to be done car by car. However, in the ontology, there are many missing details and they do not say how to choose indicators related to a specific company purpose. For example, the model contains two indicators "car A average consumption" and "car B average consumption" with many details (e.g. seven classes "attribute" related to the same indicators and two data property under each attribute). This lets us raise several questions about the visibility of information under each indicator, and how to choose the KPI pair comparison if we have many indicators defined in the same model: how can we do that? And in the case where it is not possible to compare indicators? And what about the 'hasWeight' property? Is it changed after KPIs comparison? In the case scenario, to establish an accurate comparison, variables must be defined by domain specialists or according to company interests. Authors state that their proposed ontology allows these modifications to adapt to each situation. Thus, all of these variables must be analyzed to determine if both indicators are equivalent and could be fairly compared. However, Junior *et al.* do not specify how they analyze them. They only represent the ontology model giving improved comprehension of the background of the measurements.

For [POVEDA VILLALÓN *et al.*, 2014] Poveda Villalón *et al.* present a methodology designed for ontology development in which there is already some data available and it has to be annotated by means of a domain ontology describing such data. This data should be properly contextualized when interchanging KPI data across systems.

Table 3.7: Research based on ontology and indicators or BP

Compared approaches	Main ideas of the proposed approach	The goal of the approach	Context or case study
[JUNIOR *et al.*, 2016]	Presents a knowledge model based on an ontology that may be used to represent indicators semantically and generically	Increases semantic representation of indicators, in particular specifying background information about measurements, and thereby reducing vagueness and imprecision	Car consumption ontology
[POVEDA VILLALÓN *et al.*, 2014]	Proposes a methodological approach to the process of developing an ontology to represent data about KPIs and their context	Allows for meaningful use of KPI data	The energy domain
[BISTARELLI *et al.*, 2017]	Describes a prototype system able to discover business processes from an event log and classifies them with a suitable level of abstraction by referring to a business ontology	Discovers patterns, structures, and operations based on event logs analysis and BP knowledge	Logs provided by an Italian company, Corvallis S.P.A. for "Corvallis 3.0 " project
[NGUYEN *et al.*, 2017]	Presents the CPN Ontology which is defined for business processes modeled with Coloured Petri Nets (CPNs)	Makes BP models easily shareable and reusable	A set of workflow templates relating to the fromOrdertoDelivery (fOtD) process.
[GÓMEZ *et al.*, 2017]	Presents the Strategic Decision Making (SDM) ontology to support different strategic decision-making processes and extended the ontology to cover the context of managing quality in Rapid Software Development (RSD) projects	Identifies the concepts of strategic decision making, and maps those concepts to the context of quality requirements in RSD	Q-Rapids European project

Table 3.8: Research based on ontology and BPM

Compared approaches	Main ideas or steps of the proposed approach	The goal of the approach	Context or case study
[ROSPOCHER *et al.*, 2014]	Describes a formal ontological description of the Business Process Model and Notation (BPMN Ontology)	Provide an OWL-DL formalization of all the elements, attributes, and properties of the language, and allow the description of any BPMN model as an instantiation of the ontology where all structural aspects related to the process model are encoded in it	Can be exploited in (Semantic Web) applications, in frameworks where workflows encoded in BPMN have to be translated in a different process model formalism and vice versa
[DEL-RÍO-ORTEGA, 2012]	Formalizes the definition of PPIs using DL to automate the analysis operations by means of DL reasoners	Maps both the BP model and the PPI model into a DL KB serialized in OWL	Many case studies such as the IT Department of the Andalusian Health Service
[FANESI *et al.*, 2015]	Enables metamodeling representations based on a multilayer semantic description of BPMN models on an OWL-FA ontology	Enhance the mechanization level of BPM activities based on a queryable system.	The student admission process
[KORCZAK *et al.*, 2017]	Integrates BP knowledge of Decision Support Systems	The automation of the process of decision making support	Processes of financial data analysis
[SAIDANI *et al.*, 2015]	Proposes a meta-model for the context representation in the field of BPM called: CM4BPM (Context Meta-Model)	Identifies and formalizes the contextual knowledge relevant to business processes in order to be able to adapt business processes according to the context	Loan request management business domain

In [BISTARELLI *et al.*, 2017], the authors represent a prototype system 'PrOnto' which takes as input an event log file represented on comma-separated values (CSV) format and produces a Unified Modeling Language (UML)-based Activity Diagram. The 'PrOnto' represents ontology-driven support for process monitoring and analysis. The ontology includes activity and resource classes which refer to agents or roles related to the process's activities.

The main goal of the author's prototype is to discover business processes from an event log and an appropriate level of abstraction from the business ontology. 'PrOnto' reads process's activities by mining the event log file and extracting a model of the process described in a UML Activity Diagram model.

In [NGUYEN *et al.*, 2017], the authors deal with the problem of modeling business processes and reusing them. The ontology provides adequate information about the workflow templates for workflow modelers to determine whether a workflow template can be reused. The scope of this research is different because we deal with the problem of the improvement of business processes and KPIs.

In [GÓMEZ *et al.*, 2017], the proposed ontology 'SDM ontology' identifies the key terms from a glossary and their relationships from a conceptual model, defined with a UML class diagram and related integrity constraints. The main goal of authors is to represent an integrated ontology constituting relationships among different concepts of strategic decision making. Authors refer to the Q-Rapids European project which aims to develop a highly informative dashboard to assist the manager in making strategic decisions in rapid cycles. In this sense, the intended dashboard is based on the SDM ontology to support decision making. In other words, these concepts are used to model and measure strategic indicators.

A strategic indicator has a name (e.g. customer satisfaction), an optional description and may refine other strategic indicators forming a graph (e.g. customer satisfaction may be refined as time-to-market, product value, and product quality). The strategic indicator may be measured by a KPI (e.g. time-to-market may be measured as the time it takes from defining a product to its delivery) and it is related to one or more factors (e.g. customer satisfaction may be linked to usability factor). To evaluate a KPI, authors use metrics and evaluations connected to each strategic indicator factor at diverse time points. As we can see, just one strategic indicator is measured by one KPI. However, we can have many metrics that measure the degree of achievement of a strategic indicator. Also, it is not clear how to get the relation between the two KPIs.

In [ROSPOCHER *et al.*, 2014], the authors present the Business Process Model and Notation Ontology, an ontological formalization of the BPMN specification in the Description Logics fragment of OWL (OWL-DL) to present how the elements are combined to get a BPMN process model compliant with the BPMN Specification. In particular, the BPMN Ontology encodes the classification of all BPMN elements with the formal representation of BPMN attributes and conditions.

The BPMN Ontology is not intended to model the dynamic behavior (behavioral semantics) of a BPMN process, but it may be used, for example, to verify that a given process has been correctly specified according to the BPMN guidelines, or to express additional guidelines as formal constraints on top of the ontology to guarantee process readability.

In [DEL-RÍO-ORTEGA, 2012], the author presents the automated analysis of PPIs at design-time by means of analysis operations that allow investigating properties of their definitions. She uses Description Logics (DL) which are reasoners (software tools) that implement several operations on the ontologies in an efficient manner by using several heuristics and techniques. Concretely, she has presented two families of analysis operations: those that provide information about the relationships between PPIs and BP elements; and those that give information about the relationships among PPIs themselves. In order to facilitate this automated analysis, she has also proposed a formalization of the PPINOT meta-model using DL. For example, the relationship "measured by" is formalized in DL by defining a new role in the Knowledge Base (KB) (measuredBy), whose domain is "BPElement" and whose range is PPI so that "measuredBy" (e, p) means that a BP element e is measured by PPI.

According to [FANESI *et al.*, 2015], BPM lacks mechanization and requires a lot of human intervention. Many researchers analyzed this problem and one of its main causes is the lack of an appropriate formal semantic representation of the company's process space. Having a unified ontology that includes the process model and the execution data is one requirement to solve this problem. This will allow to run queries on an automated system in order to make a business analysis. In [FANESI *et al.*, 2015], authors describe OWL-FA which is a multilayer OWL-DL ontology. This ontology requires tagging every class with the layer it belongs to. They point out that the execution data produced by a workflow engine are previously well organized and represented in the proposed ontology. Some proposed queries in their work provide interesting data for the management. For example, query 2: finds all tasks that take more than 40 minutes to be performed. this query may be similar to our proposed indicator.

In [KORCZAK *et al.*, 2017], Korczak *et al.* propose an approach that integrates financial knowledge, analytical models, and business reasoning i.e., the formalization of processes, the reuse of a domain ontology, and the analysis of economic and financial information. they use Business Process Abstract Language (BPAL) to specify procedural knowledge in processes of the data analysis. The purpose of the authors is to focus on the improvement of the financial situation as a dominant objective of any manager. In the use case, the analytical process of emergency policy is presented and illustrated by the real data from financial information systems. BPAL was considered by the authors as an abstract level since it relies on BPMN for its concrete diagrammatic representation and on BPEL for its actual execution. The formally written BPAL specifications can then be automatically translated into executable programs using the Business Process Execution Language (BPEL) and perform the reasoning and interpretation of financial information. The purpose of the authors is a bit different; they enrich the financial knowledge by presenting formally specified business processes.

In [SAIDANI *et al.*, 2015], Saidani *et al.* focus on the adaptation of business processes since knowledge related to the context is an essential resource for adapting business processes. The main goal of the proposed model is to support contextual factors which are related to BP and representing dependency situations in the context. The orientation of [SAIDANI *et al.*, 2015] is a little different because the authors use ontologies in a modeling context. They chose ontology because it allows specifying concepts and relationships between different components and allows to add semantics to contextual elements. The definition proposed by authors regarding the contextual information is the following: information that is recognized by the analyst or the business engineer as having an impact on the BP model, and whose values are not necessarily constant and may vary throughout the BP life-cycle. Authors emphasize that it is not possible to enumerate exhaustively the entire relevant context elements even in a particular business domain. For example, they propose a “process” context entity; this context entity is only represented by a set of context attributes (atomic characteristic): duration and deadline.

3.5 Related Works Based on Association Rules

There has been considerable research on DM problems where many organizations in various industries and various domains are taking advantages of DM to increase their business efficiency such as in marketing and manufacturing. In this part, we especially focus on some interesting works presented in Table 3.9 that use concepts similar to those of association rules, business processes, and indicators.

In [LIAO et HSIAO, 2013], the authors focus especially on integrated KPIs, because they provide a complete vision on different sectors coordination and work progress. The main idea is that the authors identify integrated KPIs for the case of the company's problems and then look for interactions that are associated with the KPIs. However, the association between factors and indicators is not very clear.

In [PERAL *et al.*, 2017], the authors focus on finding an adequate KPI to associate with each business objective. They analyzed the candidate KPIs to make sure that they reflect the relationships defined during the business strategy modeling.
The use of the DM technique is summarized on five processes: preprocessing, potential anomalies detection, difference series calculation, analysis of pair-wise relationships between series (e.g. correlation, time series analysis, and linear regression), and analysis of compound relationships (e.g. classification DM technique). In the second illustrated case study (Open Data extracted from the University of Alicante), the authors concluded that there were no significant correlations. Therefore, they have analyzed the existence of compound relationships and explored the data using DM algorithms provided by Weka [PERAL *et al.*, 2017].

We can state that the work of [PERAL *et al.*, 2017] requires detailed knowledge of data dimensions, attributes in each specific use case, and poses a serious comprehension obstacle for a DM nonspecialist user. Furthermore, there is no indication about the quality of the model (e.g. visualization and interpretation). Moreover, when the authors define KPIs and the multidimensional model, they elaborate a set of candidate KPIs for each objective listed during the first step. However, there is no indication when we have the same KPI related to many objectives in the same organization. The goal of using DM is to extract and determine relevant KPIs and to check the relationships/correlations between the KPIs.

Table 3.9: Research based on Association Rules and indicators

Compared approaches	Main ideas or steps of the proposed approach	The goal of the approach	Context or case study
[LIAO et HSIAO, 2013]	Use BI and the DMtool of SPSSClementine, and explore the integrated KPIs that affect moulds in E optical company, in a specific period of time.	Achieve better leverage in controlling to success factors that affect optical mould industry.	Optical mould industry
[PERAL *et al.*, 2017]	Create a multidimensional model to support KPIs calculation and provide additional analytical capabilities.	Obtain specific KPIs for business objectives in a semi-automated way	Massive Open Online Courses (MOOCs) and Open Data extracted from the University of Alicante
[GIRALDO *et al.*, 2015]	Integrate process management, analytical processing, and DM to guide the improvement of processes	Improve the process as well as the efficient achievement of organizational goals.	Information Systems Management Process in Organization "Fundación Clínica del Norte (FCN)"
[KAMSU-FOGUEM *et al.*, 2013]	Propose a rule mining approach based on Rule Growth to build association rule mining facilities	Reach effective manufacturing process quality monitoring combined and sustainable operation and continuous improvement processes.	Industrial case (manufacturing example)

In [GIRALDO *et al.*, 2015], Giraldo *et al.* propose an integrated model based on three components. One of them is for managing processes in any organization. That is,the organization data, processes, sub-processes, activities and variables are set up correspondingly. Process indicators are obtained at this stage from a data warehouse through an (Online Analytical Processing Server) OLAP cube. Then, there is an optimization module of the KPIs obtained through DM. In [GIRALDO *et al.*, 2015], the authors deal only with quantitative data but they don't provide any information about the quality of those indicators (any selection criteria of KPI). Also, the application of association rules of KPIs is not clear (which algorithm, which parameter *min conf, min sup*). They present some details of some KPIs in relation to the dimensions of the organization, association of KPIs and variables of the sub-process monitoring database. The author concludes that the organization model shows how to improve KPI's through the improvement plan.

In [KAMSU-FOGUEM *et al.*, 2013], the authors use 'RuleGrowth' that mines sequential rules common to several sequences by FP-Growth (frequent pattern growth). Their approach is divided into two steps: first inductive reasoning where knowledge is extracted through the DM procedure. Then, deductive reasoning is based on the extracted knowledge which is associated with the system goals and is linked to the obtained rules.

3.6 Research Challenges

First, many companies are working with wrong measures, many of which are incorrectly named KPIs. Furthermore, very few organizations really use and monitor their adequate KPIs. That is because only a few organizations, business leaders, writers, accountants, and consultants explored and knew what a KPI actually is [BADAWY *et al.*, 2016]. Thus, indicators are defined inconsistently since every company, and indeed every opportunity for measured performance has its own set of indicators. For instance, indicators useful in department A may be inappropriate for department B. At this level, we try to answer some questions such as: how can we be sure that we have the appropriate set of indicators? on which basis (criteria) can we make such a judgment? According to which criteria should the indicators be improved, added or deleted?

Second, the decision-maker may consider KPIs with a very wide scope and with various perspectives/semantics. For example, they may be basic or aggregated indicator, quantitative or qualitative indicator, indicator related to internal actors or external actors. Hence, this step is one of the most important steps because it is based on a deeper understanding of how KPIs are linked to work in particular contexts including who will use them and what decision they support. At this level, we try to answer questions such as: what semantics should be included in the KPIs description? i.e., which BP activities are related to each KPI? How does this affect other indicators?

Third, they are too much data-oriented from the point of view of business decision-makers. According to [KORCZAK *et al.*, 2017], business data usually contain a lot of explicit and hidden relationships, which makes their use difficult. As a consequence, these raw data should be interpreted and linked back to their performance measurement. At this level, we try to answer questions such as: how can we discover and extract the possible interdependencies between indicators based on real data log for a given period of analysis?

Fourth, to monitor KPIs, organizations rely on reports and dashboards presenting one or more KPIs together in order to help decision-makers identify opportunities for the improvement or the re-engineering of the desired process [DAVID, 2015]. However, this practice presents several drawbacks. First, most BPMSs are closely linked to the structure of available data, providing many reports that may be hard to understand with respect to overall business strategy. Second, this provides partial information to decision-makers, without taking into account which activity in the BP is involved and which inter-relationships between KPIs are considered. At this level, we try to answer the following question: how can we analyze, present and extract all valuable data?

3.7 Contribution Intentions

For the first point, we can conclude that choosing the appropriate indicators is based on a good understanding of what is important to the organization. In fact, the selection of the right performance measures depends on a number of criteria, including who will use them and what decision they support. It is necessary to identify and clarify the criteria which influence the choice of these indicators. If the wrong KPI is measured, or if it is measured in the wrong way, the information may be misleading and the quality of decisions could be affected. Human judgments about selecting the appropriate choices are still the basis for making good decisions. A new approach is, therefore, needed to facilitate the structuring, measurement, and/or synthesis of KPIs. In this sense, it is recommended that KPIs satisfy the SMART criteria [GEORGE, 1981] [MEYER, 2003] [SHAHIN et MAHBOD, 2007] and it is crucial to use one of the most popular methods for multiple criteria decision making, such as the Analytic Hierarchy Process method (AHP) [JABLONSKY, 2015] [SAATY *et al.*, 2012]. The purpose of using the AHP method in this research refers to extracting the larger meaning of KPIs and providing a way of thinking while defining KPIs. In addition, before measuring KPIs, it is essential that we identify important criteria that should be taken into consideration when developing them. The aim of this step is to identify the quality of indicators for comparison and to set priority areas for additional KPI development or improvement. The improvement in performance comes from an efficient definition and selection of appropriate measurement.

For the second point, the effective and intelligent use of ontologies and knowledge bases will contribute to accomplishing significant results particularly in the first and last stages of our approach. In fact, the ontology representation will help the business analyst to have a good understanding of particular elements meaning as well as their relationships, leading to much better comprehension and analysis. In particular, our ontology will support the identification of SMART indicators as well as the knowledge of domain experts aiming at establishing meaningful relations among indicators of business processes in real organizations.

For the third point, we can conclude that DM techniques are widely used and have an increasing acceptance in many science and business areas. In our context, by combining BP data and BP knowledge, decision-makers can analyze data and discover trends that could not be otherwise found. Semantically, enriching advantages derived from the previous point and association rules technique can successfully open a new perspective of analysis on business processes. In our work, the proposal of applying DM techniques, mainly association rule mining, will complement the definition of SMART KPI relationships and will correctly assess if the ontology model reflects reality and risking unrealistic results to the further updates. The usage of an ontology being populated by DM results is an interesting point that can advance the field, solving the problem of lack of precise semantics in KPI.

For the fourth point, BP analysis and evaluation based on KPIs constitute the proactive part towards the BP improvement. Hence the data retained from KPIs is a stimulus for analysis and for change. Therefore, the capture of KPIs and the modeling of semantic links between them is not an end in itself, but the data captured from logs and the interpretation of the most relevant rules must serve a purpose: that of better selecting KPIs and, thus, being able to access and improve the corresponding BP. In our work, to make any decision, it is important to analyze all the relevant information related to our KPIs. At this level, we aim to extract knowledge using the Process Mining tool and to develop a global framework as a tool for retrieving all KPIs valuable data.

3.8 Conclusion

In this chapter we describe the main related works, putting special emphasis on the way KPIs are exploited in them. We also detail the research problem and introduce our research intentions. To sum up, the majority of works thoroughly review concepts such as BP and KPI and use different tools and methods to fulfill their research purpose. We can state that Ortega thesis [DEL-RÍO-ORTEGA, 2012] is the most similar work to ours because it measures an organization's performance from a Business Process Management perspective.

Part III

Proposed Approach and Experimental Results

Chapter 4

New Approach for Key Performance Indicators Management: KPIMgtAssist

4.1 Introduction

Supporting our approach's research goals introduced in Chapter 1 requires a set of methods and techniques explained in Chapter 2. All of them are exploited to construct our approach steps on the basis of BPM fundamental steps.

During our research work, we identified some of the challenges in integrating KPI management into the BPM life-cycle. Ortega in [DEL-RÍO-ORTEGA, 2012] stated that it is desirable to define a life-cycle for the performance indicators management and to integrate it into the BPM life-cycle for several reasons. First of all, process performance indicators management (PPIM) needs are quite similar to those of BPs. Secondly, though Process Performance Indicators (PPIs) are closely related to BPs, they are not intrinsic to their definition and management. So, this PPIM life-cycle must be independent. Finally, the main benefit of integrating this PPIM life-cycle into the BPM life-cycle is that process performance indicators become the first-class citizen in process-oriented organizations, enabling, thus, proper evaluation and optimization of BPs.

While Ortega focuses on the definition of the PPIs and particularly focuses only on the design and instrumentation of BPM phases, in our work we focus on the improvement of KPI in all BPM phases. In section 4.2, we explain the motivation behind the use of each method or technique related to our research. In section 4.3, we present our proposed approach. In section

4.4, we present the framework functioning and others means to support our proposed approach. In section 4.5, we analyze and discuss the current solutions by relating them to our research goals. Finally, section 4.6 ends this chapter.

4.2 The Usefulness of Each Method or Technique

Before discussing a collection of authors' proposals in detail, we explain the usefulness of each method or technique.

4.2.1 The AHP Method

The AHP method is used successfully in many areas, including multi-criteria decision and seems very suitable to our selection problem for the following reasons: first, it permits reaching an agreement on a coherent set of KPIs that do not conflict but ideally support BP goals, and that meet the needs of as many stakeholders as possible (requiring, of course, as inputs, subjective judgments from a decision-maker or an expert). Second, a low number of criteria (SMART) seemed appropriate to structure the decision maker's mind in order to provide a systematic prioritization of sustainable performance indicators. Third, we do not need an absolute scale which requires much domain experience but relative values (e.g. less/more, somewhat, very) because it is easy to elicit and to decide for example, which indicator is more important in opposition to classical measurement. Fourth, the AHP method allows us to keep a logical consistency of the judgments used in detecting when KPIs preference is inconsistent. Fifth, we refer to the main point offered by the AHP method related to the relative priority of each criterion to obtain the best KPI according to the identified BP goal. The synthesis provides a general assessment of the desirability of each KPI. By adopting the AHP method with SMART criteria, all of which are combined to move from a first KPI list to an advanced SMART KPI list. In addition, we are not only enhancing process measurement definition; but also ensuring that KPIs fulfill the requirements of the BP and then eliminate inappropriate KPIs or discover other indicators. In turn, the use of this method in the KPI life-cycle offers more consistent indicators tailored to our BP.

4.2.2 The Semantic Technique

We emphasize that the ontology allows effective use of information, making it understandable. Our purpose is not to represent the whole BPM specifications in a semantic way. Instead, we aim to define a simple ontology. For this reason, a well-defined KPI ontology enables business analysts to describe business activities with their full measurements. In fact, we are motivated by the following factors. First, we need to model the most important concept in a meta-model because each concept has a meaning for the purpose of the model in which it is defined. For example, we need concepts that reflect a practical knowledge of the field rather than having a full model that has the ambition to cover all aspects of BPM. Consequently, regarding our general problem in the BP improvement context, we focus our vision essentially on two basic concepts which are Activities and KPIs. However, the concepts defined in a conceptual meta-model are not reusable outside this meta-model. Therefore, we need an ontological model where classes and properties are associated with universal identifiers allowing them to be referenced in a unique way from any structure. As a result, these concepts are reusable whenever needed. Second, it makes knowledge explicit and allows for knowledge sharing among domain experts and people engaged in the BP design phase and BP improvement phase. Third, it serves as a requirement specification from which a number of recommendations or guidelines can be generated.

The proposed ontology is a conceptualization validated by a community. Therefore it is somehow a valuable cognitive representation of their thoughts and is under full control of the people who have the right to access it, meaning that it can be changed and extended as required. Fourth, since knowledge bases can be changed and other KPIs can be discovered in the life of a BP, business analysts find themselves obliged to do a rapid evaluation of the current BP. On such basis, the business analyst can easily get a sense of the practical usefulness of the last ontology. As such, early evaluation and comprehension of concepts effectively help before the execution phase and also a later validation using DM. For example, we identify the specific indicator that is expected to have an effect on other KPI measures. In other words, we need to evaluate whether a semantic representation is correct and cognitively adequate.

4.2.3 The Data Mining Technique

Regarding the use of DM techniques in our context, at least five reasons can be stated. First, the association rules technique is very simple and comprehensible for a DM non-specialist user. The reason is that implications are the core of human thinking. Second, the technique extracts the complete set of association rules without the need of an important user implication during the process and uses support and confidence as a constraint to generate interesting rules e.g. to extract the most relevant KPI that can be used to characterize the situation of the BP. To be more concrete, we need to select the more frequent KPI values in a specific BP and analyze the rules that are considered relevant to help BP analysts in the improvement phase. Third, regarding our problem, in this part we address three main issues: the integration of user knowledge in the discovery of KPIs, the interactivity with the user to validate the ontology and the improvement of KPI/BP. More precisely, the interactivity with the user allows a more iterative mining process where the user can successively focus on KPI data and interesting rules to validate the previous ontology. Moreover, we believe that taking into account KPI links driven from ontology and association rules has a considerable impact on the performance of BP since knowledge related to the KPI is an essential resource for the improvement of business processes.

4.3 Key Performance Indicators' Management Assistance Approach: KPIMgtAssist

Jeston states that process management and analysis are basic to BPM, where there is no limit for improvement [JESTON, 2014]. Hence, we know that it is through measurement that we can be sure that improvements are being made. In this section, we present the life-cycle of KPI from the design to the improvement. Thus, we take as a starting point the BPM life-cycle (with grey color) to define a KPI life-cycle showed in Figure 4.1 (in the colored parts). We give therefore our main contribution under each KPI life-cycle phase. The global proposed approach is titled "KPIMgtAssist".

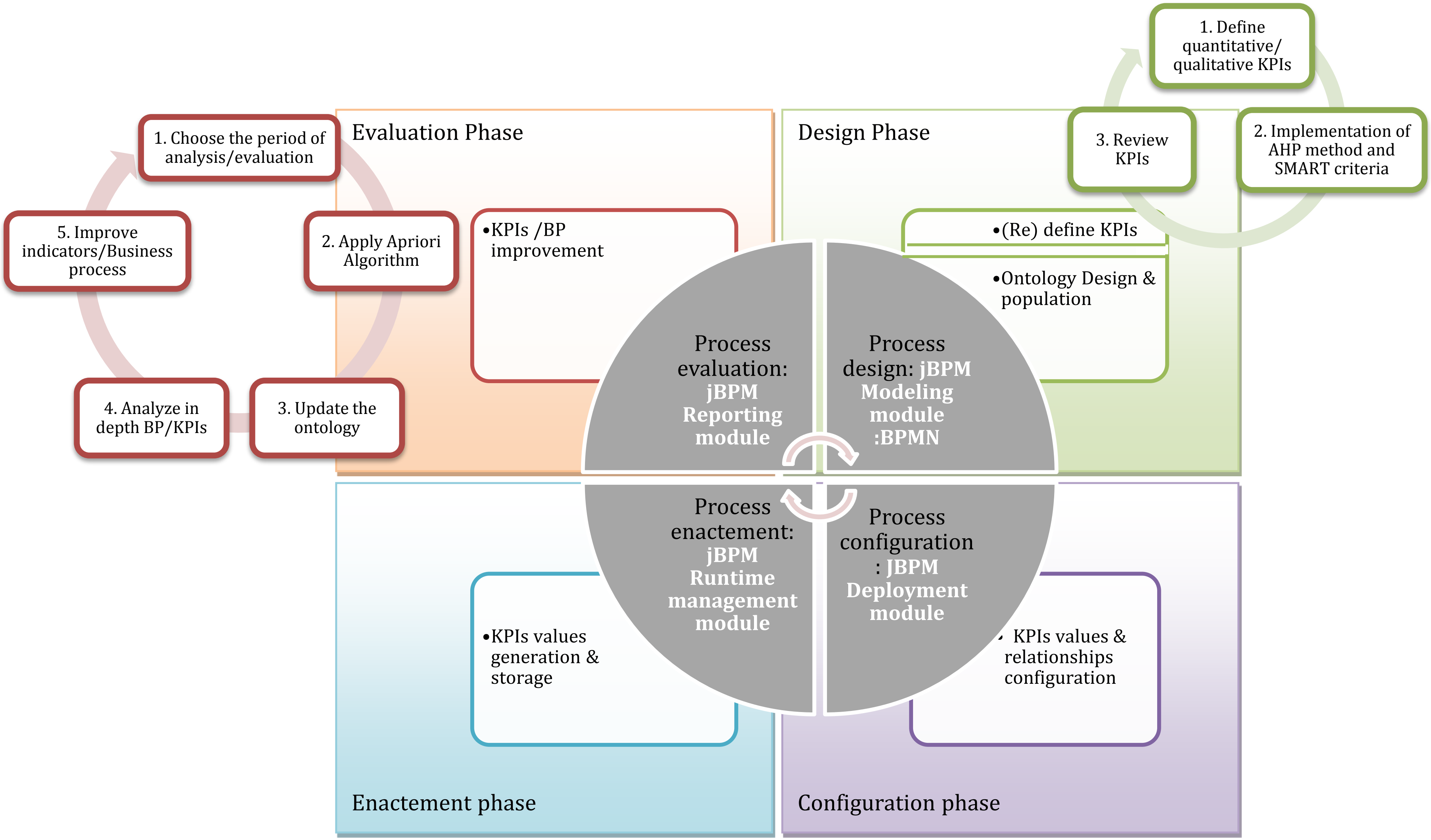

Figure 4.1: Proposed KPIMgtAssist approach

4.3.1 Design Phase

In this section, we provide a description of the first phase in BPM life-cycle and present its corresponding phase in KPIMgtAssist approach.

4.3.1.1 Process Design

The first step involves the modeling of BP with a clear purpose in mind. After BP design already included in the BPM cycle, we add in this phase specific sub-phases dedicated to KPIs definition and ontology design.

4.3.1.2 KPIs Definition

The BP model should respond to the BP goals. It is essential to note that the goals of the process can depend on either internal or external actors that will have an impact on the KPI selection process. In this phase, we analyze KPIs currently in use and identify if it is necessary to define new KPIs for the defined BP goals.

After that we move on to the definition of KPIs, these steps respect business-level knowledge and may include qualitative and quantitative indicators. Furthermore, the use of qualitative defined measurement is essential for the evaluation and improvement.

On the one hand, the qualitative indicators are a broad field which is neither simple to define nor measure. In fact, we focus especially on improving satisfaction which has become an integral component of effective BP delivery. On the other hand, quantitative indicators facilitate the capture of BP as a quantitative measure of the activities involved. The development of the two aspects offers a powerful vision to business managers and process analysts as well.

In this sub-phase, we essentially adopt the AHP method and SMART criteria. In the proposed life-cycle described in Figure 4.2, we essentially deal with various measurements related to the BPs. We will also deal with two different aspects: qualitative and quantitative. In each aspect, we define and validate the appropriate indicators with different stakeholders of the BP, these measures are based on their intensive knowledge, experience, and preferences and should have a significant impact on the organization. There are two hierarchical decision models, one for the quantitative indicators and the other for qualitative indicators.

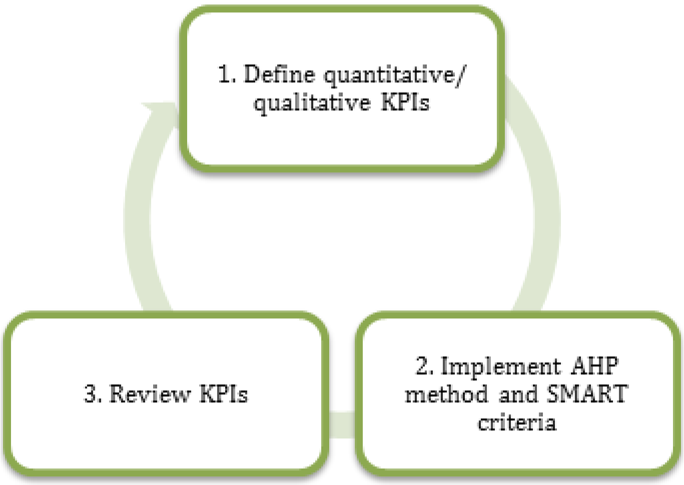

Figure 4.2: The proposed approach in the first phase

In the second and the third phases of our proposed life-cycle (Figure 4.2) related to the KPIs definition sub-phase, we develop a new algorithm. The use of this algorithm for KPI definition and improvement is crucial prior to their actual implementation.

The proposed algorithm enables users to refine their definition of a problem and to improve their judgment and understanding through repetition and thereby makes a positive contribution not only to the ranking but also to get an optimum SMART definition for KPIs. Variables and methods used in this algorithm are defined in Listing 1.

We create two functions named Compare_SMART_Criteria and Compare_KPI _alternative (Listings 2 and 3). In the first function, the comparison matrix is formed by repeating the process for each criterion. In the second function, the comparison matrix is formed by repeating the process for each alternative. Responses to the pair-wise comparison question use the nine-point scale (Saaty scale).

We create two functions named Check_SMART_Matrix_Consistency and Check_KPI _Matrix_Consistency (Listings 4 and 5). These functions verify if the judgment matrix (under goal or under particular criteria) is inconsistent and the entries that are given by the decision-maker have to be revised until a satisfactory consistency ratio is obtained.

We create a procedure named Improve_KPI (Listing 6). In this procedure, the user can fulfill the alternative matrix with respect to the criteria, check the consistency of his judgments and based on the synthesis he can improve KPIs under a particular criterion.

The algorithm (Listing 7) starts after constructing the hierarchy and enriches pair-wise comparison.

```
SMART_criteria:  a set of criteria
KPI_alternatives:  a set of alternatives
NK: the number of KPI alternatives
NC: the number of criteria
i, j: a pair of alternatives
M: pairwise-comparison  matrix (n×n matrix) (reciprocal matrix)
Cij: the value obtained by comparing criterion ci compared to
criterion cj.
KPIij: the value obtained by comparing KPIi relative to KPIj.
CR: Consistency Ratio measured by AHP method and displayed in pair-
wise comparison using Expetchoice tool to see the overall
consistency of judgment
Update_KPI_set:  a predefined method where the user can delete an
existing KPI or add a new KPI to KPI alternative set.
Display_criteria_synthesis_under   the _goal and
Display_particular_alternative_synthesis_under_particular_criteria:
predefined methods which used the eigenvalue method to calculate the
relative weights of elements in each pair-wise comparison matrix.
Diplay_synthesis_under_all_criteria:   the predefined method referring
to the aggregation of relative weights of decision elements to
obtain an overall rating for the alternatives.
```

Listing 1- Variables and methods definition

```
Function Compare_SMART_Criteria (var cij: double): double
Var
K: double
i, j: integer
Begin
FOR (i =1; i<= NC ; i++)
      SET cii to 1
        {   FOR (j =1; j<= NC ; j++)
                  PRINT "How important is criterion ci relatively to
criterion cj"
                  READ(k)
                  SET cij to k
                  SET cji to 1/k
            ENDFOR
          }
ENDFOR
End
```

Listing 2- Compare_SMART_Criteria function

```
Function Compare_KPI_alternative  (var C: SMART criteria,  KPIij :
double ) : double
Var
K: double
i, j: integer
Begin
FOR (i =1; i<= NK ; i++)
      SET KPIii to 1
            {
            FOR (j =1; j<= NK ; j++)
    CASE c OF
                Relevant    : Print "According to your experience, how
important (that really affects the performance of BP) do you
consider the indicator KPIi compared to the indicator KPIj?)"
                Time_based  : Print "According to your experience, how
important (is it really time-sensitive and does its completion on
time really affect the performance of the BP) do you consider the
indicator KPIi compared to the indicator KPIj? "
                Attainable  : Print "According to your experience, how
important (that the respect or not of its tolerant target value
really affect the other indicators value) do you consider the
indicator KPIi compared to the indicator KPIj?"
                Specific    : Print "According to your experience, how
important (is it sufficiently clear and focused toward BP purpose)
do you consider the indicator KPIi compared to the indicator KPIj?"
                Measurable  : Print "According to your experience, how
important (is it clearly quantifiable using an available tool or
data?)do you consider the indicator KPIi compared to the indicator
KPIj?"
     ENDCASE
                  READ (k)
                  SET KPIij to k
                  SET KPIji to 1/k
            ENDFOR
            }
ENDFOR
End
```

Listing 3- Compare_KPI_alternative function

```
Function  Check_SMART_Matrix_Consistency (M: pairwise comparison
matrix, cij: double): Boolean
Begin
READ (CR)
```

```
      IF CR >= 0.1 THEN
            SET Check_SMART_Matrix_Consistency to false
            Compare_SMART_Criteria (cij)
      Else skip
      END IF
End
```

Listing 4- Check_SMART_Matrix_Consistency function

```
Function  Check_KPI_Matrix_Consistency  (M: pairwise comparison
matrix, C: SMART criteria): boolean
Begin
READ (CR)
      IF CR >= 0.1  THEN
            SET Check_KPI_Matrix_Consistency to false
    Compare_KPI_alternative (C,KPIij)
  END IF
End
```

Listing 5- Check_KPI_Matrix_Consistency function

```
Procedure Improve_KPI (var KPIij alternatives )
Var
Response: string
Response_Criteria: string
Begin
SET Response_Criteria to ""
      Repeat
            PRINT "enter  the name of  criteria to fulfill
alternative pairwise matrix with respect to this criterion or enter
a space to skip"
            READ (Response_Criteria)
            IF Response_Criteria <> "" THEN
            //fulfill alternative pairwise matrix for the initial KPI
alternative set
                  Compare_KPI_alternative (Response_Criteria, KPIij)
                  Check_KPI_Matrix_Consistency (M, Response_Criteria,)
      Display_particular_alternative_synthesis_under_particular_crite
ria ()
      //fulfill alternative pairwise matrix after a change of KPI
alternative set
                  PRINT "Type "yes" if would you like to improve KPIs
```

```
(alternatives) under this criterion or "no" to skip"
                READ (Response)
                CASE  Response  OF
                                "yes"    : Update_KPI_set (KPI
alternatives)

Compare_KPI_alternative (Response_Criteria, KPIij)

Check_KPI_Matrix_Consistency (M, Response_Criteria)
Display_particular_alternative_synthesis_under_particular_criteria()
                                "no"     : Skip
                ENDCASE
           Else
                skip
           END IF
      UNTIL Response_Criteria = ""
End
```

Listing 6- Improve_KPI procedure

```
                                Algorithm
Var
Response: string
i, j: integer
Begin
Compare_SMART_Criteria (cij)
Check_SMART_Matrix_Consistency (M)
Display_criteria_synthesis_under_goal ();
Repeat
      PRINT "do you think that you set and evaluate the final list
of SMART KPIs"
      READ (Response)
      CASE  Response  OF
                                "yes"    : skip
                                "no"     : Improve_KPI (KPI
alternatives)
      ENDCASE
Until response= "yes"
Display_synthesis_under_all_criteria ()
End
```

Listing 7- Proposed algorithm

4.3.1.3 Ontology design and population

In this section, we are going to present the second contribution under the design phase. First, we need a comprehensive conceptual model of the necessary components coupled with the capacity to navigate through different levels of abstraction across the process, activities, and KPIs, and the ability to appropriately deal with quantitative and qualitative aspects.

Regarding the modeling objective, the first step consists in defining a meta-model. In practical terms, this task is very similar to creating an object-oriented class diagram. Concepts are represented by classes, whereas each class may have several properties to describe the various features and attributes of a concept. The meta-model prescribes the information that must be defined in a way that suits the domain expert, the requirements engineer and the BP modeler, who may not be an expert. Based on the classes defined in the meta-model presented in Figure 4.3, we construct our abstract ontology model presented in Figure 4.4. In the ontology, we define a glossary of classes, which serves as a central repository for both domain experts and software engineers.

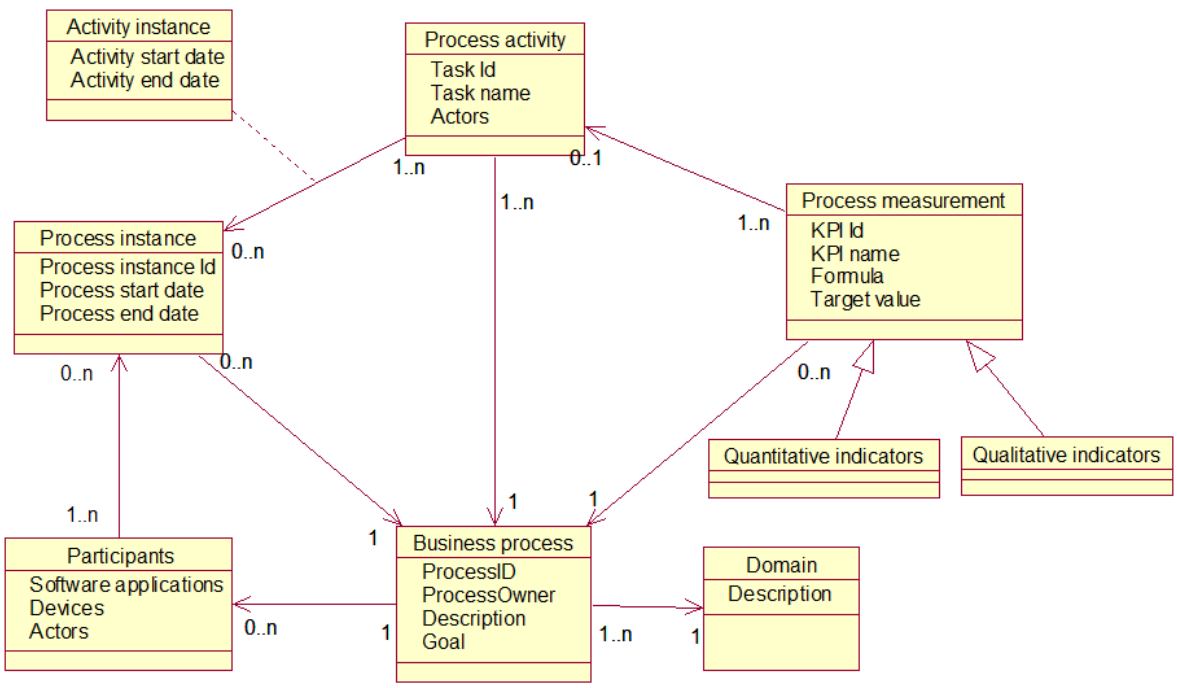

Figure 4.3: The proposed meta-model

We essentially focused on process tasks and qualitative and quantitative indicators. More precisely, we define a set of individuals for specifying KPIs and activities regarding the contextual characteristic of KPIs (what can be considered as a KPI within a particular domain might not be as relevant for another). Although the activities can be related to data and resources in the ontology, they won't be detailed in our current research work but they will be considered in further other works. In this work, on one hand, we extract relevant quantitative information from the event logs produced during the BPM execution, and, on the other hand, we extract relevant qualitative information related to a specific domain by addressing actor queries.

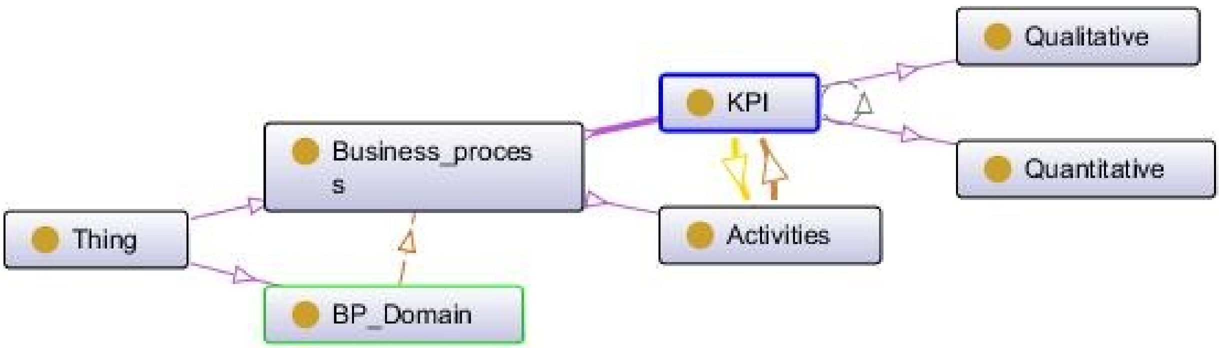

Figure 4.4: Ontology model

The second step focuses on the creation of instances from concepts (i.e., classes) taking into account the organizational aims. In addition, the business analyst can instantiate classes and create instances, by populating, for instance, KPI classes from the SMART KPIs validated from the AHP phase and fulfilling the suitable activities related to a specific BP. This step will help to understand all involved concepts by the BP analysts before BP gets implemented. Thereafter, the inputs in this phase are process tasks and qualitative and quantitative indicators, thus facilitating their future improvement.

So, in order to make more informed decisions, we represent, on one hand, the relationships between an activity and the attached KPIs, and on the other hand, the relationships between indicators. Those definitions of relationships and the relative individuals need to be highlighted and modeled in order to aid the monitoring of KPIs that contribute to performance improvement. As well, we envision a collection of datatype properties to describe relationships between individuals and data values. Attributes are represented in OWL using properties: Datatype Property. The Datatype Property is a relationship between value or a data and a class instance. KPI relationships are represented by properties in OWL with ObjectProperty properties type. Object Property is defined between two individuals of a class or several OWL classes. We collect as much data as possible about the possible relationships and we define a set of properties in Table 4.1.

Table 4.1: Description of object properties and data types properties

Name	**Description**
Has_link	Link possible KPI individuals either from the same category (qualitative class or quantitative class) or indicate the links between different KPI categories (quantitative and qualitative). This object property is symmetric.
Related_to	Link the defined BP to the domain field.
Has_name	The name of the indicator.
Has_activity	The related activity in the BP.
Has_formula	The associate KPI formula.
Has_target	The target KPI value.
Has_ok	The number of KPI occurrences which has an acceptable "ok" value.
Has_not_ok	The number of KPI occurrences which has an unacceptable "not ok" value.

4.3.2 Configuration Phase

In this phase, we essentially persist the historical data and we prepare the Knowledge Database (KDB) dedicated to storing all important information related to the BPs. More details are given in section 4.3.6.

4.3.3 Enactment Phase

In this section, we explain the process enactment phase and the main reason behind the development of the KPIs values generation and storage phase.

4.3.3.1 Process Enactment

Once KPIs have been developed, it is necessary to determine which data needs to be collected for each KPI used to measure performance. The most efficient way is to collect data from BPMS to ensure the required information which is already being recorded for operational purposes. It is necessary to select PPIs from BPMS to ensure that data is collected consistently. Based on our SMART KPI defined in the first phase, we can also need to review administrative documents or statistics. In fact, when we check other qualitative evaluation through a questionnaire, we find that qualitative indicators may create value for actors by closely matching some aspects in the BP to their necessities. The incorporation of KPI data regarding knowledge, attitudes, and behaviors.is intuitive to both business managers and process analysts as well.

4.3.3.2 KPIs values generation and storage

After analyzing the available data in the BPMS logs, we conclude that not all KPIs can be directly retrieved from these logs and that the representation of KPI values, especially in the calculation of waiting time and duration in milliseconds, can be misunderstandable for the decision-maker. In this sense, the proposed framework is motivated by the following factors:

- The limited representation of KPI values especially in the calculation of waiting times and durations (in milliseconds and seconds).

- There is no indication in the history logs if KPIs met desired target values.

- The data related to quantitative and qualitative indicators are treated separately.

- The need to query semantically the activities and KPI established in the OWL file.

KPI covers SMART measurement that can be directly driven from the execution of a process (BPMS logs, or logs from any other data source), and from additional information on the internal or external environment (e.g. interview and administrative file, and questionnaire in order to cover qualitative aspect and missing quantitative indicators (not derived from a BPMS)) of an organization that impacts the business process. The integration of external sources of information and qualitative KPI aspect with the quantitative KPI data is a way of reducing uncertainty in the decision process.

4.3.4 Evaluation Phase

In this section, we present the evaluation phase where we focus essentially in the proposed KPI life-cycle in the KPIs/BP improvement.

4.3.4.1 Process Dashboards

Dashboards provide a detailed view of certain KPIs and enable some level of analysis. However, many other indicators are missing and this is explained by the availability of possible indicators driven from the BPMS log. As a consequence, this conducts a semantic gap between the decision-makers' knowledge and the BPMS system. We conclude that it is still needed to enrich these phases with other techniques and methods that help stakeholders for concrete actions with the purpose of improving KPIs and as a result BP performance.

4.3.4.2 KPIs/BP improvement

After analyzing a BP based on process dashboards which can be provided by a BPMS, we move on to the corresponding KPIs improvement step in this phase (Figure 4.5).

The proposed KPI life-cycle related to the KPIs/BP improvement sub-phase, started by choosing the period of analysis and the preparation of the data set. The period of analysis in which business processes are executed is of great interest to evaluate our KPI in reaching a BP objective.

After the decision-makers choose the period of analysis, our approach proposes to apply the Apriori algorithm and to select discovered rules. The BP model and the ontology model represent what the company does in general, where the BP execution and the DM association rules show what the company did in every specific case and what possible rules exist.

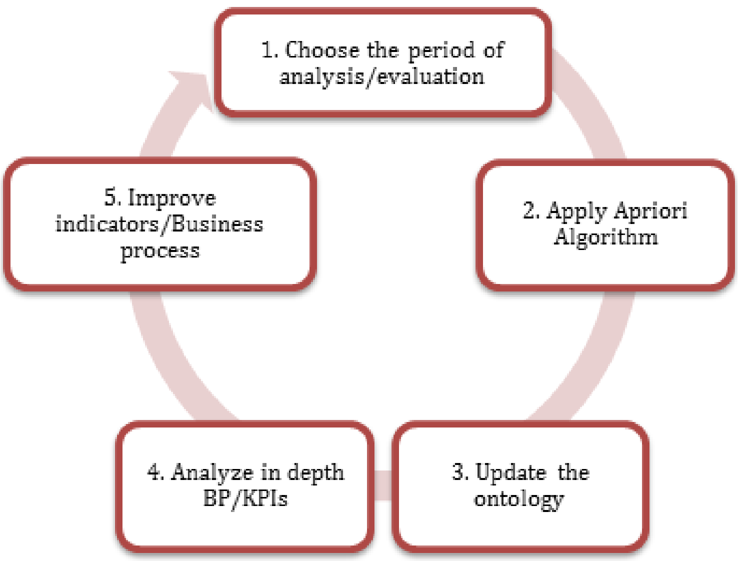

Figure 4.5: KPI life-cycle in the evaluation phase

The DM is in charge of analyzing huge data from different perspectives and summarizing them into useful information. During the discovery of the KPI process, all experimental results should be analyzed and interpreted in order to enrich domain ontology with newly discovered rules. When doing DM, we are faced with significant amounts of association rules with some inconsistencies that may contain novel knowledge. By using the Apriori algorithm we aim to find frequent associations and correlations among sets of items. If a KPI value is not frequent, no association rules related to the KPIs are generated. So, we refer to the expert of the domain to validate these rules. For instance, this will allow analyzing what other KPIs should be taken into account to support high satisfaction with a given selected KPI. This analysis of frequent KPIs helps managers to find all interesting rules that correlate the presence of one indicator with another one. The major advantage of using association rules in our BP improvement approach is the ability to use information from the BP execution and the information-driven from KPI ontology to evaluate and improve the process. Our aim is to identify the KPIs whose variations require a change in the process execution. All this information can be converted into knowledge to improve KPI or BP if necessary.

Next, the ontology can be updated (step 3 in the proposed KPI life-cycle) by adding or removing classes, individuals (in our case, KPIs), object properties and data properties. Furthermore, up to this point, we are not sure if the ontology built in the design-time really reflects the reality of the possible interaction between indicators and if it is still up to date and if BP decisions are still consistent. For instance, we focus especially on analyzing possible KPI instances related with each other by "Has_link" object property either from the same category (qualitative class or quantitative class) or indicate the links between KPI with different categories (quantitative and qualitative). After that, the proposed ontology aims at taking into account interesting rules which are explicitly related to BPs and representing dependency situations between indicators.

We use knowledge retained from association rules. In fact, first, it helps to find inconsistencies in the first designed ontology. Second, it helps to enrich its previous properties with the newly discovered links, and third, it guarantees that the ontology is still up to date. This step consists on updating a new object or data properties. The explicit visualization of the first designed ontology, not only makes the interpretation of indicators found by association rules easier, but it also contributes to finding explanations and validating the current relation between indicators.

After updating the ontology, we add new data properties for each KPI to describe the importance of the indicator. In fact, we distinguish two new data properties described in Table 4.2.

Table 4.2: Data properties related to KPI class represented in KPI Ontology

Data property	**Description**
Has_ok	The value of this data property for each KPI is the number of occurrences of the same KPI in the KDB (as consequent or antecedent which takes an ok value).
Has_not_ok	The value of this data property under each KPI is the number of occurrences of the same KPI in the KDB (as consequent or antecedent which takes not ok value).

Let us move on to analyzing in-depth process data inspired from Process Mining. Typically, a BP is based on the workflow of activities which depend on the events that initiate the process, the participants in the process and process measurements.
Event data can be analyzed according to different perspectives [REBUGE et FERREIRA, 2012], including the control-flow perspective, the organizational perspective, the data perspective and the performance perspective. The control- flow perspective is concerned with the process behavior, namely the activities in the process and their order of execution. The organizational perspective focuses on the relationships between the users who performed the activities, such as whether they belong to the same or to different groups or organizational units. The performance perspective aims at detecting bottlenecks or calculating performance indicators, such as throughput times and sojourn times. The data perspective is related to the data objects that serve as input and output for the activities.

In our work, the analysis is based essentially on the completed process instances. In this way, the decision-maker can see how the process has been actually performed, the most frequent completed paths and also can analyze the distribution of all cases over the different paths through the process. If we have more complicated BP and more BP traces we can see for example which process steps happened multiple times? Which activity takes a lot of time before starting? How many actors are involved in a specific case? In this way, it becomes easy to detect paths or activities that cause a bottleneck. The more data attributes we have in the logs, the more additional statistic we get. These data are very important for the process analysis because they hold relevant context information such as: By which actor the activity was handled and in which department the process was performed. We can find out more information when we inspect the log. For example, we can inspect the process instances and browse the set of cases in the log.

After all process flows are investigated and all interesting KPIs are analyzed, the decision-maker can set additional questions or goals based on possible observations to summarize the existing inefficiencies and thus it becomes possible to indicate points to be improved.

The last step in this evaluation phase concerns the improvement of KPIs/BP. Human intervention at this level is essential to remove the ambiguity and to make an effective decision. Based on KPI improvement, different possibilities of BP improvement become possible. More precisely, various BP perspectives may be concerned. For example, organizational, behavioral or informational perspectives may be concerned by such improvement. In fact, based on the most important retained KPIs and their corresponding values, BP improvement may concern the assignment of tasks to actors, the order in which tasks have to be fulfilled or input data that will be taken into account for specific tasks.

4.4 Framework and Other Adopted Means for Supporting KPIMgtAssist Approach

In Figure 4.6, we identify the corresponding means used to support our KPIMgtAssist approah. The main means are jBPM BPMS for BPM life-cycle, Expert choice tool synthesis for the AHP method, Protegé editor for ontology design, ProM for logs analysis and our proposed framework.

4.4.1 Design Phase

In this section, we provide a description of means support in the first phase in BPM life-cycle and present its corresponding phase in KPIMgtAssist approach.

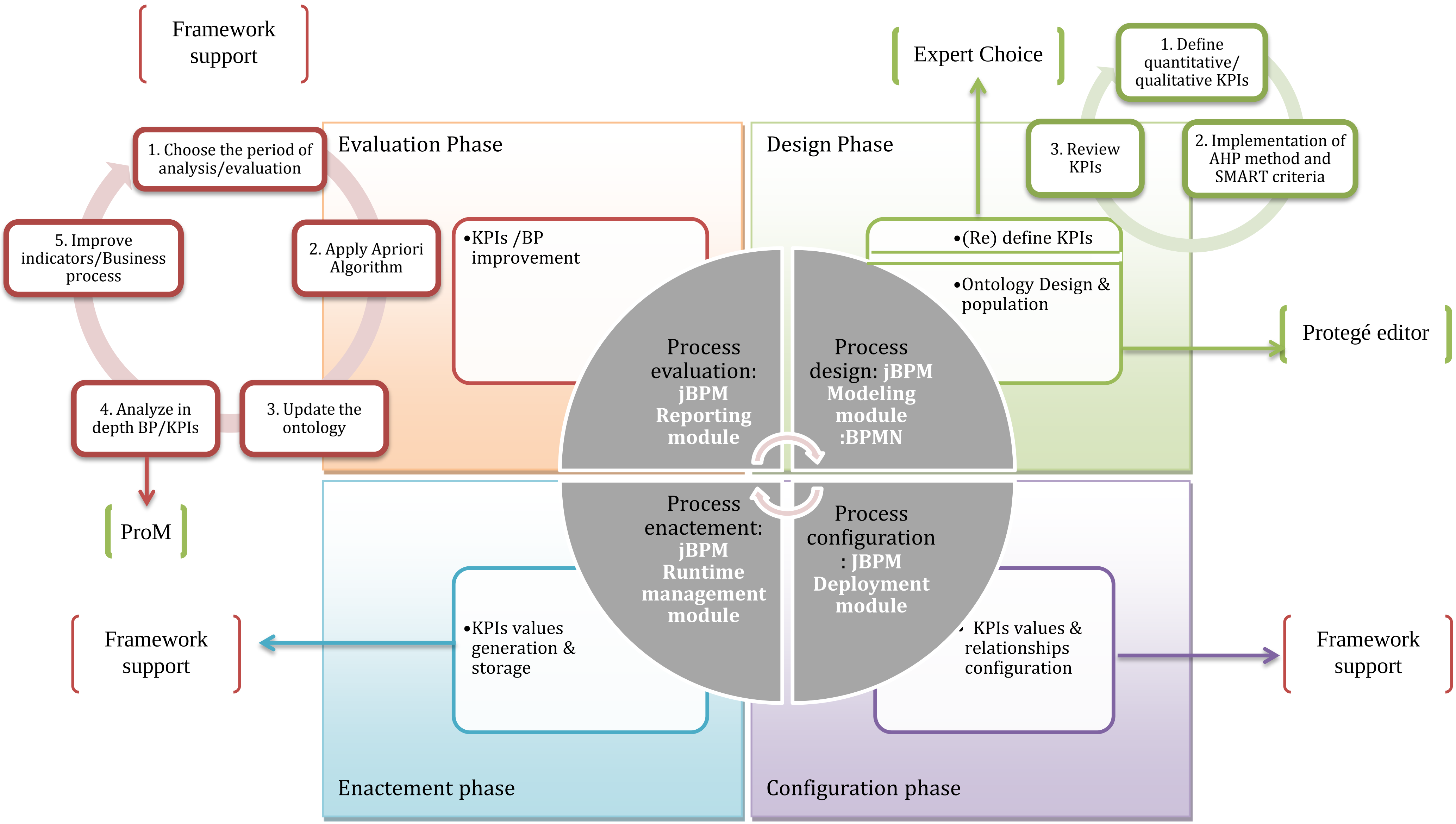

Figure 4.6: Framework and complementary means adopted to support KPIMgtAssist

4.4.1.1 Process Design

For the first phase in BPM life-cycle, we use the Business Process Model and Notation 2.0 language (BPMN) and we use jBPM module. Our choice of jBPM is motivated by its capability in answering performance measurement needs, such as the availability of history logs of all process instances as the data source of measurement. The data related to process execution can be stored in relational databases such as MySQL, PostgreSQL or Oracle. We persist this execution data since it will be used as the data source for performance measurement in two stages. First, to develop a process dashboard in the reporting module which provides BAM capability using SQL query from jBPM database. Second, to develop some features in the supported framework to help the user retrieve the major process indicator stored in this database.

4.4.1.2 KPIs Definition

In this sub-phase, we follow the main instructions in our proposed algorithm to get a SMART KPIs list. After all responses are recorded, the priorities of alternatives with respect to each criterion are automatically computed. The Expert Choice tool synthesizes the priorities of the objectives, data, and ratings to determine the overall priorities of the alternatives. These priorities are a corporate perception of what is important.

4.4.1.3 Ontology design and population

In this step, we chose to use the Protégé tool which is frequently used and offers a simple and understandable graphical interface. Thanks to the richness of its functionalities and its extensibility via plug-ins, it is accepted by relatively large semantic web communities. According to Escórcio et Cardoso, the significant advantage of Protégé is its scalability and extensibility [ESCÓRCIO et CARDOSO, 2007]. Protégé allows building ontologies in an efficient manner. Through its extensibility, this free open source platform might be customized to suit users' requirements. Others say that the great success of this editor is due to its support by a strong community of developers and academics in various fields [ESCÓRCIO et CARDOSO, 2007].

4.4.2 Configuration Phase

In this phase, we focus on the process configuration and KPIs values determination and relationships configuration.

4.4.2.1 Process Configuration

The configuration in the BPM phase consists essentially in persisting the jBPM historical data. In this phase, we configure also process participants (the actors involved in the BP) to the Knowledge is Everything (Kie) workbench runtime. We specify a role for the users and the authentication password in the appropriate files.

4.4.2.2 KPIs values determination and relationships configuration

In this section, we present the main features of the framework related to the KPI values determination and relationships configuration. At this stage and before BP execution, the proposed framework supports the import of all SMART indicators defined in the ontology that respect the class hierarchy mentioned in section 4.3.1.3 ontology design and population.

The process engineer develops all the code behind the framework. To do that, the user is invited to open the ontology feature included in the framework and selects the appropriate OWL file designed for the case study. S/he obtains a success message after loading the ontology file (Figure 4.7). All classes are displayed in a table. When the user clicks on any class or subclass name displayed in this table, s/he gets all individuals related to this class. The ontology features display all information related to a specific KPI (e.g. the name of the indicator, the name of the activity belonging to it, all other KPI names linked to it). It also displays all information (e.g. class names, data properties, and object properties) (Figure 4.8).

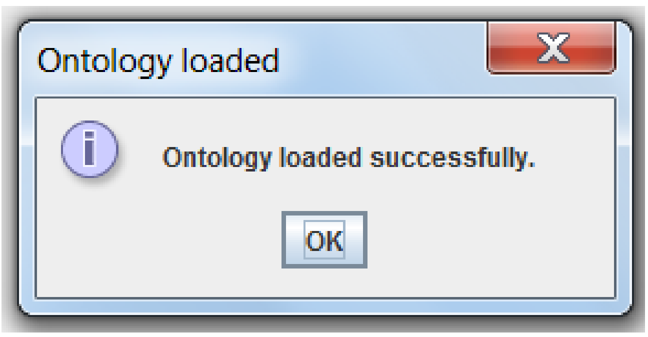

Figure 4.7: Load ontology message

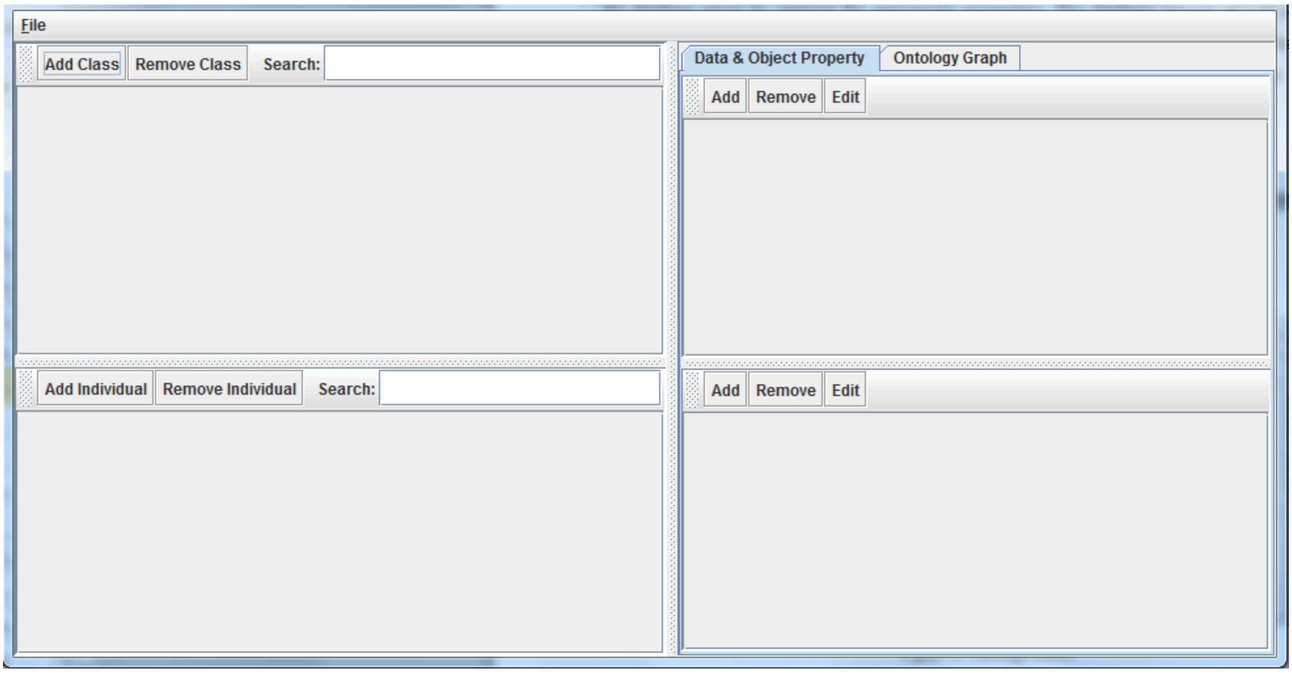

Figure 4.8: Ontology feature

The user uses this ontology feature for two main purposes. On the one hand, it serves as an output of KPI ontology where each concept (e.g. activity, indicator) and its corresponding data property and object properties are stored in a KPI file (a CSV file). This file will later serve as an input to provide the necessary knowledge for the corresponding database table. On the other hand, the ontology feature will be used to update the ontology after applying the Apriori algorithm.

To persist our Knowledge Database (KDB), we adopt the WAMP server which uses MySQL database for storing user's data. The first step before the creation of the KDB is to connect to the database server by entering the appropriate parameters. This database consists of a set of tables. Each table is characterized by its name, the list of its attributes and a list of its records.

After connecting to the database server, the user enters the name of the KDB.Then, the system checks if this database already exists or not (Figure 4.9). When the user clicks on the "ok" button, s/he gets a confirmation of the creation of the KDB.

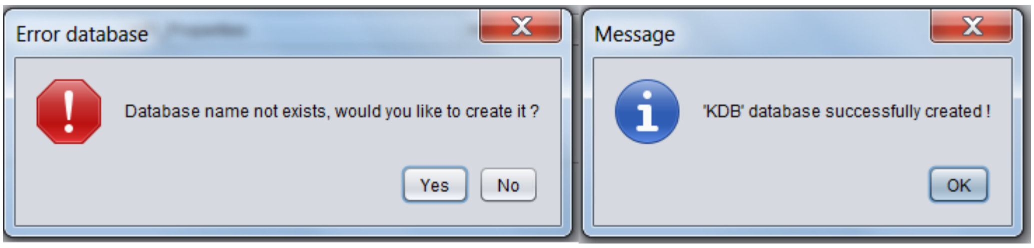

Figure 4.9: Knowledge Database creation and checking

The user can select the corresponding KPI file generated from the framework and the table will show file content (Figure 4.10). After that, the user enters the Knowledge Database name and then, clicks the button to generate the KDB.

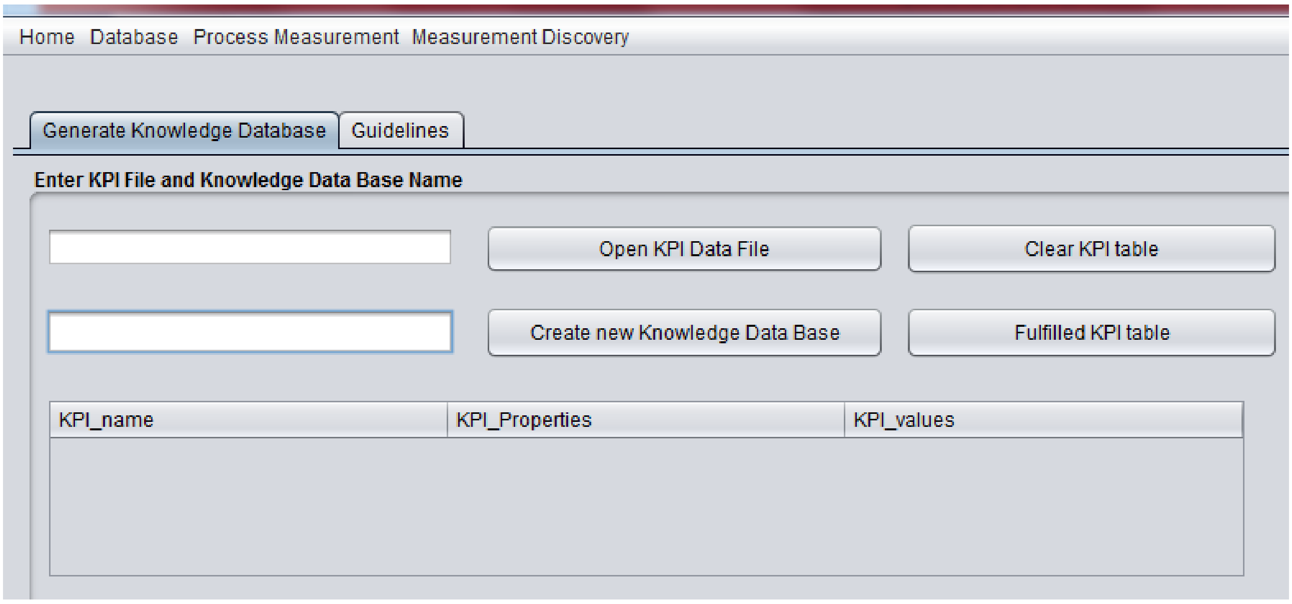

Figure 4.10: Knowledge Database form

The creation of a new KDB involves the creation of three tables in this database. The first table named *KPI* contains three columns (KPI_Name, KPI_Properties, and KPI_Values). This table stores all inserted information (e.g. data properties names and values, object properties names and values for each individual related to quantitative or qualitative KPI subclass). To fill this table automatically, the user must select the corresponding KPI file. Second, a table named *Rules_Data* will later store the association rules after applying the Apriori algorithm into specific KPI data set with specific parameters. Finally, a table named *Temporal_relationships* will be filled automatically with user guidelines.

4.4.3 Enactment Phase

In this section, we track KPIs data retrieved from the BPMS and we explain the KPIs values generation and storage phase.

4.4.3.1 4.4.3.1 Process Enactment

To formulate a query for retrieving KPI values, we usually pass the SELECT query to the appropriate data source. After analyzing the available data in jBPM logs, we mainly focus on three tables:

- *Processinstancelog* table which contains the basic log information about each process instance. For example the start date, the end date, the duration of the process instance. Every process instance has an identifier.

- *Bamtasksummary* table which contains summarized information about each process task such as the created date, start date, end date, duration and the name of tasks.

- *Variableinstancelog* table which stores the data element values i.e., values obtained from tasks during process executions.

These tables retrieve the data needed for general KPIs like the calculation of execution time of an activity, the waiting time before specific activity or also the calculation of the number of instances in the BP.

4.4.3.2 KPIs values generation and storage

In this work, it is necessary to clarify what are the possible KPIs that can be gathered from a BPMS. To do that, we mainly develop two features.

The first one presents the most popular and general KPI values retrieved from the BPMS logs produced during the BP execution, which enable the user to select the appropriate BP and to track KPI values. In addition, the user selects the corresponding BP name and clicks on the "Load related Activities". After that, s/he can select any activity to obtain the available KPIs retrieved by a select query from the generated jBPM logs.

The second one is divided into panels:

- The first panel extracts all indicators from the KDB generated from the ontology file and gives the option to the user to complete all necessary KPI real values. For automatic evaluation (supported in the second panel) of KPI real values, the user must follow a specific procedure while filling the KPI real values table. First, the user enters the values under each indicator (column) (if it's necessary, s/he can refer to the previous form which contains the general KPIs information or by referring to other data sources such as administrative files, questionnaire evaluation files and so on). Second, the user must set the threshold or the target KPI bound to evaluate later each cell value under each indicator. In this way, targets are essential for evaluating KPIs in order to inform analysts on progress towards an acceptable level of performance and also to challenge BP to improve.

The activity of evaluating KPIs assists organizations in identifying targets or expectations. Interviews with decision-makers can assist in identifying their information needs, and elicit what data they can provide. It can include different stakeholders (experts with experience) to ensure that the data collection and the analysis methodology are reliable and valid. To estimate what targets are reasonable, the organization should consider a couple of items, such as programs, or procedures. It is essential to incorporate this feature into the supported framework and get another KPI data file where each row contains a KPI evaluated by decision-makers. The final KPI real data file ensures that the quantitative and qualitative real data are clearly defined and values are stored. After filling all KPI real values, the user can save this table content in a CSV file.

- The second panel is dedicated to KPI evaluation based on the judgment and consensus of the decision-makers. To do that, the user selects the KPI CSV file and the framework will evaluate all KPI real values entered by the user in the previous panel. All data in this panel will be checked and evaluated to detect if KPI values reached the desired results. Next the user can save the obtained result into a CSV file

The main advantage of this estimated KPI file is that it provides the basic information to the decision-maker to execute corrective actions in the case of important deviations. It will also serve as an input for mining in phase 4.

To summarize, the supported framework must edit and save KPI data which can be classified into two categories "real values" and "estimated values" reflecting the nature of the information observed and treated. The input file built from a unified view on process measurement evaluation (quantitative and qualitative) is based on each real process instance data.In the case of basic KPIs, the value is determined from each process instance, and in the case of aggregated KPIs, the values determined from an aggregated formula like *sum*,*avg*, or *max*. While the KPI file "real values" contains all observed data, the KPI file "estimated values" contains all evaluated data after comparing the real value with the target value or tolerant value set by the decision-maker. This contains two values: "ok" codes the KPI value which is considered by the organization as acceptable and "not ok" corresponds to the fact that the KPI value is not acceptable.

4.4.4 Evaluation Phase

In this section, we present the evaluation phase supported by our framework and other adopted means. On one hand, this evaluation phase includes the presentation of some dashboards offered by jBPM. On the other hand, it includes a proposed KPI life-cycle where some steps are supported by our framework and some other steps are supported by other adopted means.

4.4.4.1 Process Dashboards

The log information represents an input to build reports in business dashboard module. In addition, the jBPM core engine stores the process and task history and provides Application Programming Interface (APIs) to perform the Business Activity Monitoring (BAM) operations. Further, the jBPM functionalities include the dashboard builder, which enables its users to create custom dashboards from the BP history. In the dashboard, the data can be retrieved from both relational jBPM databases using SQL query and CSV files. Measuring performance indicators is basically passing through queries to the data source for retrieving the query result. In jBPM dashboard, they are defined as data providers. In any case study, we started with this data provider and we created the necessary data provider queries. For example, we can create a new data provider query, to define KPIs related to the waiting time and then we can create a new dashboard panel and set the relevant details.

4.4.4.2 KPIs /BP improvement

After analyzing a BP based on process dashboards which can be provided by a BPMS, we move on to the corresponding KPIs improvement step in this phase.

Applying the Apriori algorithm and updating the ontology steps are supported by our proposed framework.
While the ontology helps with the early validation and verification of KPIs relationships, the association rules help to find incoherences and inconsistencies after BP execution. In fact, the inclusion of expert knowledge in event logs, expert knowledge in the ontology and association rules results, facilitate new types of analysis. For example, we can consider KPI relationship knowledge through the use of the ontology, for time delays identification in BP requiring special attention. All necessary information will be saved in a KDB.

The importance of the KDB gains increasing interest, mainly because it allows recording meaningful data about KPIs. Data can be considered and used for analyzing processes, providing real knowledge about their execution and facilitating the identification of improvement opportunities. This KDB serves as an input to examine the BP performance, and challenges. The main benefits of this KDB are as follows: First, it exploits the strengths of a SQL database such as the access speed, and mass storage, to store large information derived from the ontology defined by decision-maker related to any domain. On the other hand, it provides the user with the necessary KPIs in a dynamic way (e.g. if an indicator or any further links are added, removed or modified in the ontology). Third, it records KPI association rules. In fact according to our experience, when we use software tools such Weka or Tangara tools, the association rules results are not saved in Weka (only displayed for the user) or in Tangara (displayed and only the opportunity to copy the results to other files). Furthermore, in our framework, KPI relationships stored in the KDB where each KPI couple has its specific *min* support and *min* confidence configured before running the algorithm. Fourth, in KDB, we record the occurrence of KPI for further analysis. In addition, this feature helps the decision makers to explain why an indicator has a bad/good value, what other depending indicators exist, and how we can improve the model of a process.

With the aim of extracting knowledge from event logs that are recorded by BPMS and mining KPI content associated with process instances data, the ProM software was used. ProM is one of the most omnipresent Process Mining tools [Kalenkova *et al.*, 2014]. It was chosen because it allows automatically constructing process visualization.

First, we start with the data that should be analyzed. Our data comes essentially from the BPMS database system and estimated KPI files. Before we apply Process Mining we should prepare and clean the log to answer some questions related to the data we are interested in. For example, how many process instances/tasks/resources are in the log? What are the most frequent paths in the process? Are there any loop paths in the process? Thus, in this step, we are based essentially on *Bamtasksummary* table because it contains information about the dates and times on which tasks were executed. To do that we import to ProM the corresponding event log which contains essentially activities that happened, the process instance identifier, and the start/end date timestamp.

An event log can have many more attributes such as actors and department. The essential thing is to carefully prepare which data can help the decision-maker to firstly focus on the root cause analysis and the value-adding process improvement activities. Secondly, such data can also help to get some conclusions about indicators toward process enhancement.
With ProM, we can also inspect activities' occurrences from the event logs. In this view, the user will get overview information about the number of different classes of registered execution scenarios. We can consider the role of this log view like the dash builder module provided by jBPM because both of them provide some performance information view about the process.

Second, using Process Mining tools, we can construct a more critical vision based on process discovery in order to suggest a process redesign or to analyze gaps in the process. The Process Mining software supports various actions to mine the control-flow perspective of process models in order to see how cases are actually being executed in the organization. For example, the "α -algorithm" plug-in allows to visualize a Petri Net graph and then we can convert this graph to a BPMN diagram. In this way, we obtain the process model that summarizes the sequences of activities followed by most/all cases in the log.

Third, in order to improve BPs and KPIs, we consider the mining of KPIs as an explorative and highly interactive task where the decision-makers learn to understand the data in two ways. First by understanding KPI relationships retrieved from the KDB and second by using some data retrieved from KPI estimated file and *processinstancelog* table in order to look at the process from multiple views using ProM software.

Framework functionalities and Process Mining features are the key element of KPI/BP improvement, as they offer a global vision on KPIs relationships and impact on other indicators which will enable early identification of KPIs that are not moving in the expected directions, and, thus, inform any needed mid-course improvement in KPI or BP.

4.5 Discussion

After studying several research papers described in Chapter 3, in Table 4.3, we try to set some different points regarding some compared authors' proposals. According to the scope of research, many works use similar concepts, methods or techniques for various purposes. Regarding our research questions, we try to set several points related to previous research.

Table 4.3: Authors approach differences

Authors approach	**Main difference points**
[MATÉ *et al.*, 2017]	The definition of KPIs according to the author requires a highly qualified expert in language and tools. However, we define all pertinent indicators in the first phase (when modeling BP and by using AHP proposed cycle).
[PEREZ-ALVAREZ *et al.*, 2016]	The common point between our works is that both of us focus on the BPMS to extract process indicators. However, in our approach, we also use other indicators (from administrative documentation and qualitative inquiry) to evaluate the performance of the BP.
[SHAHIN et MAHBOD, 2007]	The author's approach is only used for prioritization and therefore it is supposed that the selected KPIs are already relevant.
[JUNIOR *et al.*, 2016]	The author's approach uses an ontology to establish the importance of an indicator in an instantiated set of indicators. In our work, this property is already accomplished by using the AHP method. The main difference when we use the semantic technology is that we not only represent performance measurement indicators, based on ontology like them but also we improve and validate this ontology.
[POVEDA VILLALÓN *et al.*, 2014]	In our approach, the data was retrieved from the BPM system and other administrative files.
[BISTARELLI *et al.*, 2017]	Regarding our proposed ontology, the main difference is that the ontology proposed by authors focus on resources and activities of the processes and our ontology presents KPIs and activities.
[ROSPOCHER *et al.*, 2014]	The main difference is in the use of an ontology. The authors aim to support process modeling activities. However, in our work, we focus more on the modeling and analysis of KPIs behavior. Because based on the understanding and modeling of the correct "link" between indicators we can expect the good health of the BP.

[DEL-RÍO-ORTEGA, 2012]	The main difference is that the analysis of performance measurement is in the design time and in our work we focus on both times: the design time based on our proposed ontology and in the execution time based on DM technique.
[FANESI *et al.*, 2015]	The main difference is that we are be based on jBPM logs which contain full data about the BP, and we will base on KPI to evaluate the BP.
[KORCZAK *et al.*, 2017]	In our work, we do not need an abstract specification. We just refer to our activities designed in BPMN and our SMART KPI.
[SAIDANI *et al.*, 2015]	The main difference with this work is that it focuses on contextual information, however, in our work, we focus on KPI.
[PERAL *et al.*, 2017]	The major difference between their work and our work is that in our work the KPIs relationships are established through the first designed ontology and the DM technique was used to discover and validate existing relationships between the KPIs.
[GIRALDO *et al.*, 2015]	In the authors' approach, they don't mention how to improve indicators or how BP is updated. Maybe this can be the main difference because we aim to improve KPI by focusing on the sensible link approved by DM technique.
[KAMSU-FOGUEM *et al.*, 2013]	The main difference is that the continuous improvement program proposed by this author is based on the analysis of completed projects. However, in our work, we are based on completed process instances from BPMS and other data sources. Regarding our objective, we extract knowledge from the obtained rules and we exploit them to improve the proposed ontology.

Regarding related works that apply AHP method, SMART criteria, and KPIs, the common point between our proposed approach and some previous approaches is summarized by the validation of our KPI with an expert. Some works such as [RESINAS *et al.*, 2014] [YAGHOOBI et HADDADI, 2016] use the interview method which forms a very effective way to capture the real attitude, ideas, or opinions of interviewees. Some other works based on literature reviews such as [PODGÓRSKI, 2015], [GHOLAMZADEH NIKJOO *et al.*, 2013] or preliminary studies (e.g. Trend-Comparative attributes in [SURYADI, 2007]) collect KPIs or the appropriate criteria for the selection. This method is suitable in case it covers a generic concept of the topic studied. However, since it is one of the most initial steps in data collection, it might not emphasize the exact issue that is being studied and also this method wastes time due to the consideration of irrelevant information to the main scope of research. In [RESINAS *et al.*, 2014] the authors confirm that the most cited process best practices or reference frameworks such as Information Technology Infrastructure Library (ITIL) encourage and even provide KPIs for the processes defined in them. However, those KPIs are defined at a high level of abstraction and they must be customized to the specific processes implemented in the organization. The same problem is found in web platforms such as KPILibrary, in which KPIs are also defined at a very high level of abstraction.

There are two points which make minor differences between our work and the mentioned works are summarized in the following two questions:

- Does the methodology guarantee that the predefined indicators are SMART?

This aspect is partially dealt with in the works [DEL-RÍO-ORTEGA, 2012] and [RESINAS et al., 2014] when using the template for KPI definition. Other works are based on an expert panel or literature review. In this way, it is assumed that the selected KPIs are already relevant (e.g. in the works [SHAHIN et MAHBOD, 2007] and [PODGÓRSKI, 2015]).

In our work, this is obtained when applying the AHP methodology by evaluating KPIs alternatives with respect to previously determined criteria. Therefore, it is necessary to consider all relevant criteria and make judgments according to professional experience so that results give the adequate answers.

- Does the methodology cover quantitative and qualitative aspects in the evaluation of performance?

The majority of works usually cover one side quantitative or qualitative indicators and maybe this is justified by the context of their research. However, very often, KPIs have been defined without an understanding of their purpose and the whole process. For this reason, managers, process measurement specialists or BP analysts, as in our case study, need to ensure that everyone involved in the improvement of the BP is aware of goals. We can conclude that the variation in the views of the people participating in the judgemental process might lead to different results. As a consequence, in some cases, it involves the definition of qualitative indicators.

Two main points make the major differences between our work and the mentioned works. Those points are summarized in the following two questions:

- Does the methodology help to improve the definition of existing KPIs?

This question is partially solved in [RESINAS *et al.*, 2014] by introducing the collaborative KPIshare platform which provides a place for the BPM community where they can discuss, collaborate and create process-related KPIs. Furthermore, many methodologies founded in literature do not help to improve the definition of existing KPIs because the main goal when using AHP method is the prioritization. However, in some cases, we can detect indicators which have a higher score with respect to the relevance criterion and have a lower score for other criteria (e.g. an indicator might have a high-weight under relevant criteria but a low weight under other criteria). In the synthesis phase, AHP combines the criteria weights and the KPIs scores, thus determining a global score for each KPI, and a consequent ranking. The global score for a given KPI is a weighted sum of the scores obtained with respect to all considered criteria. As a consequence, this relevant indicator can have "bad" ranking in the final phase. For this reason, this aspect is covered when we calculate the local weight under each criterion.

In our work, we aim to improve the definition of KPIs by proposing a new approach in which we guarantee that all indicators are specific and measurable and just the other criteria make the difference in calculating priorities. In summary, the aim when using AHP method is to find the most relevant KPIs and to guarantee that the ranking criteria and alternatives are up to date, as a consequence the prioritization acts as an enabler rather than the ultimate goal.

- Does the methodology help to discover KPIs?

This aspect is not supported by any of the aforementioned works. In fact, to be more effective, after reviewing the synthesis (the improvement phase) we can discover another indicator not mentioned before. This step helps us to ensure that our KPIs are sufficient regarding our goal and to check our KPI requirements for ambiguities or completeness. Also in defining the first list of KPIs, the discussion and collaboration between different stakeholders in the BP concerning the definition of KPIs form an innovative way to discover another indicator (e.g. the open questions in the qualitative inquiry).

Regarding related work that use semantic techniques and KPIs, the common point between our proposed approach and some previous approaches is summarized in the following points. First, the need for a formal aspect provided by ontology allows the machine to verify automatically certain properties of consistency and/or make certain automatic reasonings on the ontologies and their instances. Second, the need for the explicit aspect offered by ontology where categories of concepts (of the domain) and their various properties are explicitly described. Third, the need for a consensus where the ontology presents an agreement on a shared conceptualization. And finally, the reusable aspect because the ontology is a component which can be reused for various tasks.

The main point which makes the major differences between our work and the mentioned work is summarized in these three questions:

- Does the ontology cover all necessary concepts involved in the BP field?

We remark that many works focus on the formalization of processes or indicators and present an extensive ontology that covers all aspects of the business. For example, Ortega focuses on the definition of PPIs, their representation, and their automated analysis [DEL-RÍOORTEGA, 2012]. In fact, the PPINOT meta-model allows to define all the PPIs found in the literature review. After that, she details two relationships between PPIs and BP elements. Under each relationship, there are many analysis operations that can be defined for each of them. The mapping of both the BP model and the PPI model (PPINOTmeta-model) involves defining a Description Logics Knowledge Base (KB) serialized in OWL, that includes the classes and relations of the meta-model as axioms of its TBox. In particular, they create one DL concept for each class of the meta-model. Some other works such as [FANESI *et al.*, 2015] cover the extensive set of BPM or BPMN elements, attributes, and properties, formalized in ontology. In [KORCZAK *et al.*, 2017], the authors use the abstract language of process specification to provide a declarative and procedural semantics that can be interpreted, processed and executed as a BPEL. The process model respects a number of constraints related to the representation of activities, events, conditions, and exception handling.

- Can the ontology design be validated by experts and real BP execution?

The majority of previous work expresses the semantics of processes in a formal way and demonstrates the proposed approach with several cases studies. As a consequence, we can say that they are validated by domain experts because they provide a concise and comprehensive description of BPM (in some cases BPs or BPMN or KPIs).

In our work, to describe the business activity in a semantical rich way, it was proven helpful to use the real execution data. The use of real BP execution is partially invoked in [FANESI et al., 2015], the authors provided some examples of possible queries that usually provide interesting data for the management. To do that, they write the SPARQL queries, run into the ontology and show some results.

The original difference between our work and the previous work is that we use real values of KPIs (not only from logs) to validate the relations (object property) between concepts involved in our proposed ontology and to enrich the description of KPI (datatype property for each KPI). In fact, to be more effective, domain experts can help to define relationships in terms of describing behavior from a business viewpoint. Properties and behavior may be added later while discovering rules since each object property needs to be consistent with the discovered rules. So this led us to concentrate more on the most critical links with positive or negative impact.

- Does the ontology help to continuously improve KPI and BP?

This question was partially addressed in [SAIDANI *et al.*, 2015] when using the contextual information. According to the authors, reasoning on the context consists in using contextual information in an intelligent way by using techniques of interpretation and knowledge inference. It is clear that a BP engineering approach that supports context-awareness process approach must have methods of reasoning to interpret contextual information and derive new knowledge. To do that, the authors propose using inference rules to perform the reasoning in order to deduce contextual information and to define new contextual information.

In our work, we pay particular attention to the logical relation between our KPIs presented in the ontology. In fact, we develop and validate our ontology in two phases: The first is based on expert knowledge domain in a specific field. Because the "link" designed between two KPIs for process A cannot necessarily be the same for process B. Second, we offer to the expert, the most important association rules based on DM techniques. In this way, the ontology can be easily adapted to meet changing requirements. The two last properties are concerned with building an ontology correctly by involving the appropriate users, while ontology validation, on the other hand, is concerned by building a correct ontology and by using DM technique.

The majority of existing approaches deal with the improvement of BPs using the DM technique in different ways and with different methods and tools. Whereas, to make the difference, we especially focus on our problematic context, and we set two main points summarized as follows:

- Does the association rules help to continuously improve the proposed ontology?
To the best of our knowledge, there is no approach which addressed exactly this aspect. For example in [FANESI *et al.*, 2015], the authors point that having a unified ontology that includes the process model and the execution data is one requirement to resolve this problem. This allows to run queries on an automated system in order to make a business analysis. In our work, we are based on association rules to complete the knowledge expressed in the first proposed ontology. In addition, association rules play a significant role in knowledge acquisition to improve and enrich the proposed ontology. Therefore, the decision-maker is invited to set association rules parameters in each KPI links to analyze interesting ones. The definition of the term is interesting, however, it depends on the application.

In our work, we propose to enrich the KPI ontology to bridge the business measurement understanding of the enterprise with its representations in real scenarios based on association rules. Each decision-making related to a specific BP should be decomposed to SMART (Specific, Measurable, Attainable, Relevant and Time-bounded) KPIs and activities, and associated with relevant information. This would not be possible without the use of knowledge possessed by experienced managers (modeled in the ontology) and real association rules extracted from real data.

- Does the association rules help to continuously improve KPIs and BPs?
Authors in [PERAL *et al.*, 2017] [GIRALDO *et al.*, 2015] use DM software as one of numerous analytical tools for analyzing data. In fact, it allows authors to analyze data from different dimensions and conclude the relationships identified. Based on the proposed question, we can say that this purpose is addressed partially in their work. For example, in [PERAL *et*

al., 2017], the authors use DM to extract relevant KPIs which provide insights into potential predicted attributes on which companies and organizations can focus to improve their results. Especially, the authors analyze KPIs through DM techniques to guarantee that they reflect the relationships established during the business strategy modeling. In their work, Peral *et al.* [PERAL *et al.*, 2017] discarded some indicators for which data is unavailable, or their values do not change at all for a period of time. Furthermore, during pre-processing, they determine whether they are working with pure time series or panel data. However, discarding an indicator which was judged pertinent to the stakeholders during the requirement analysis can have a big influence on evaluation and improvement.

In our work, we focus on BPMS logs where quantitative indicators are available and we enrich the data file with other qualitative indicators (this aspect is not handled in [PERAL et al., 2017]). And the most important thing in this stage is that we do not discard any indicators that previously were judged SMART and required from the point of view of stakeholders. After giving the stakeholder all necessary data and analysis, they have the right to update the KPI list for further evaluation and improvement.

4.6 Conclusion

This chapter introduced a new approach fostering the improvement of BPs and KPIs. Usually, the first problem is the selection of influential KPIs for BPs. For this reason, the AHP method and SMART criteria were used to detect appropriate KPIs. Then we introduced an algorithm to help the user to get an optimum SMART definition for KPIs. Furthermore, a well-defined KPI ontology was built and association rules were used to discover KPIs relationships.

Chapter 5

KPIMgtAssist Application in Healthcare Case Study

5.1 Introduction

In this chapter, we explicitly describe the way in which each step of our KPIMgtAssist approach was conducted in healthcare case study. In section 5.2, we present our application domain. In sections 5.3, 5.4, 5.5 and 5.6 we illustrate the main results from our framework and other means used in each phase in KPIMgtAssist approach. In section 5.7, we conclude this chapter.

5.2 Healthcare Application Field

Health institutions' processes are the basis for decision making which is focused on achieving their objective of ensuring high quality and safe service. However, healthcare processes generate huge volumes of data every day. Therefore it is imperative before managing that information in the most effective possible way, to set appropriate KPIs. Performing BP analysis in healthcare organizations is particularly difficult due to the highly dynamic, complex, ad-hoc, and multi-disciplinary nature of healthcare processes [REBUGE et FERREIRA, 2012].
In this context, we especially focus on the Emergency Care (EC) processes in "Farhat hached" Emergency Department (ED). In fact, the development of the right KPIs is challenging for process improvement in hospitals. In addition, it is crucial not only to understand the actual situation in the ED and to remodel the business processes if necessary but also to continue the improvement of EC Business Processes based on comprehensive measurement of organizations' performance.

5.3 Design of Emergency Care BP

Qe first phase in BPM life-cycle and present its corresponding phase in KPIMgtAssist approach for the emergency care BP.

5.3.1 Emergency Care Process Design

Healthcare providers are constantly striving to improve the quality of the care they provide, and patients are becoming increasingly interested in the quality of care provided by various departments and individuals. As it is not possible to exhaustively monitor every aspect of performance (e.g. quality of care, safety, risk management), priority should be given to specific BP goals for which there is evidence to support sufficient indicators for improvement. The definition of KPIs in the "Farhat hached" ED is not intended to replace the currently running quality improvement activities. With the current state of the art of indicators being mere "flags" to indicate potential problems or areas where improvement could occur.

The main activities in "Farhat hachad" ED are as follow: First, at the beginning of this process, every patient has to go through the Registration activity. After that, in order to arrive at a preliminary conclusion about the status of the patient, sorting activity represents the second task in the BP and the first point of contact with medical staff. This activity consists in recording the preliminary observations and prioritizing the patients, according to their degree of urgency. The following tasks depend on the status of the patient. We find various cases of consultations such as consultation in the delayed emergency sectors in the case of non-urgent patients, or consultation in the box. It can be a simple consultation or surgical consultation. Finally, it can also be a consultation in the crash room if the patient is of serious harm which requires immediate medical attention or consultation in the supervision room if the condition of the patient is not stable. At the end of this process, three possible cases exist: the patient is treated and leaves the emergency department, the patient is referred to another service (hospitalization or specialized consultation) to ensure continuity of care or the situation of the patient requires long treatments.

We will rely on the simplified version of the EC process (Figure 5.1) which aims to better satisfy the patients and to offer faster services with better quality. We have validated it in our current case study, using observations and interviews with the main actors of the process. In addition, we better understand the process and its main activities. For this process, we focus on a particular goal which is the evaluation of BP activities.

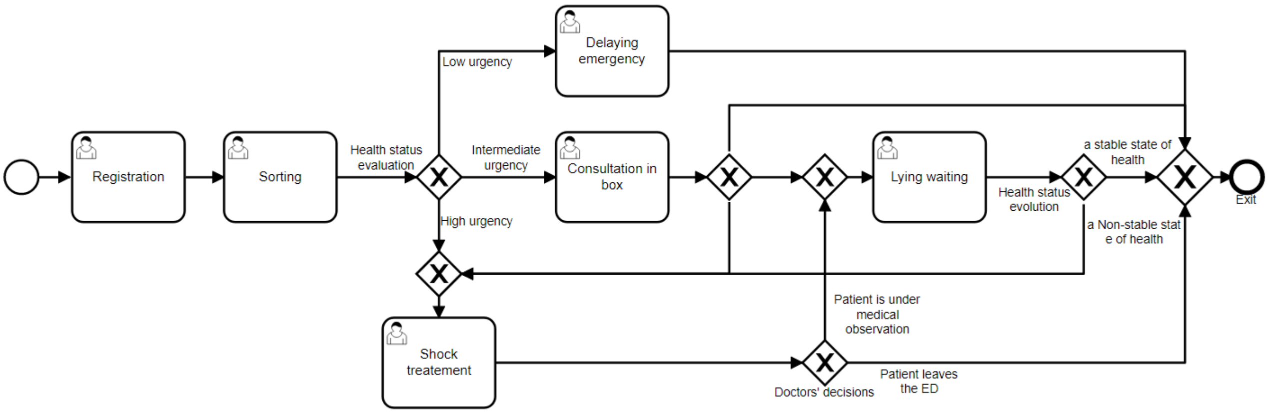

Figure 5.1: A simplified version of the EC process

5.3.2 KPIs Definition for Emergency Care BP

This healthcare process requires a good understanding of what is important to the Emergency Department. First, we started by adopting the AHP method and SMART criteria for quantitative indicators. To do that, we applied AHP steps as follows:

A. Graphical hierarchical representation of the problem

The hierarchical structure design starts from the top level, which set up the main problem and continues through the main SMART criteria to the bottom level that usually suggests KPIs for that particular problem.

B. Pairwise comparison of each SMART criterion under the goal

The first criteria pairwise comparison matrix will be used to establish the relative importance of five main criteria. In this step, the decision-maker needs to define the most important criteria for quantitative indicators and for qualitative indicators. Figure 5.2 shows that all the judgments are considered consistent and accepted for analysis (Incon: 0.00).

	Specific	Mesurable	Attainable	Realistic	Time-Based
Specific		2,0	2,0	2,0	2,0
Mesurable			1,0	3,0	1,0
Attainable				3,0	1,0
Realistic					3,0
Time-Based	Incon: 0,00				

Figure 5.2: Pairwise comparison under the goal

C. Pairwise comparison and revision of quantitative KPI under each criterion
The first list of KPIs contains many indicators which are intended to stimulate a culture of improvement. In this case regarding the BP goal, we can set two categories of KPIs. The first one contains all aggregated indicators which can be used to assess the overall performance and the second one reserved for all indicators related to a patient instance.

Comparing them pairwise with respect to how much one is better than the other is a difficult task and sometimes can lead to a confusion decision. For example, it is really important to have indicators related to the maximum waiting time by all patients or to have an indicator related to the waiting time per patient. After discussion with experts, we retained only the second list because it may contain very useful information in the evaluation of the EC process in the specified time frame and we eliminated some other indicators.

Based on the alternative retained from "Relevant" criterion, we compared two indicators. We found that some indicators are not clear enough in the synthesis. So we focused on those indicators to refine their definitions. For example, we retained the previous indicator related to the waiting time per patient. We discovered that the definition of this indicator is incomplete and it is not clear enough about the result. For example, does it mean the waiting time in a specific activity of the BP or is it related to the waiting time in all activities? After discussion with experts, we developed additional indicators related to the waiting time. As a consequence, we returned to check and set up the previous comparison matrix under relevant indicators. We also checked the ratio of consistency before moving to the next pairwise criteria. The ratio of consistency has a great impact on setting the right value in the pairwise matrix.

For "Relevant" criterion, the decision-maker preferred to classify indicators related to the waiting time before each activity as the most relevant group. The reason is that the evaluation of the waiting time reflects the main goal of the BP which is reducing the waiting time. After that, they also wanted to evaluate the occupation time in each activity because of the duration sometimes depends on the status of the patient, the availability of expert consultation or specific equipment.

For "Specific" criterion, after improvement of some indicators, all indicators were equally important. All indicators improved in the previous criteria were precisely defined and their measurement is not unambiguous. So, as a consequence, they were considered equally important under "Measurable" criterion.

For "Attainable" and "Time based" criteria, all indicators related to the time occupation were considered moderately more important than other indicators related to the waiting time. So when the target values of those indicators are respected or not, it really affects and has a direct impact on the other indicators values. The total time spent in the ED is the last ranked indicator because it depends on the indicators related to the duration and the indicators related to the waiting time. Both criteria have the same ranking results because all defined indicators are time-sensitive (related to the task duration, waiting time and process duration). The AHP synthesis for this case is given in Figure 5.3.

Next, we moved on to the integration of the AHP method and SMART criteria for qualitative indicators. In what follows, we describe some steps adopted from AHP method and the proposed algorithm.

D. Pairwise comparison and revision of qualitative KPI under each criterion

Qualitative KPIs reflect the qualitative aspects of care in the ED. The first list of KPIs contains many measurements which are intended to evaluate the satisfaction of patients toward the ED .

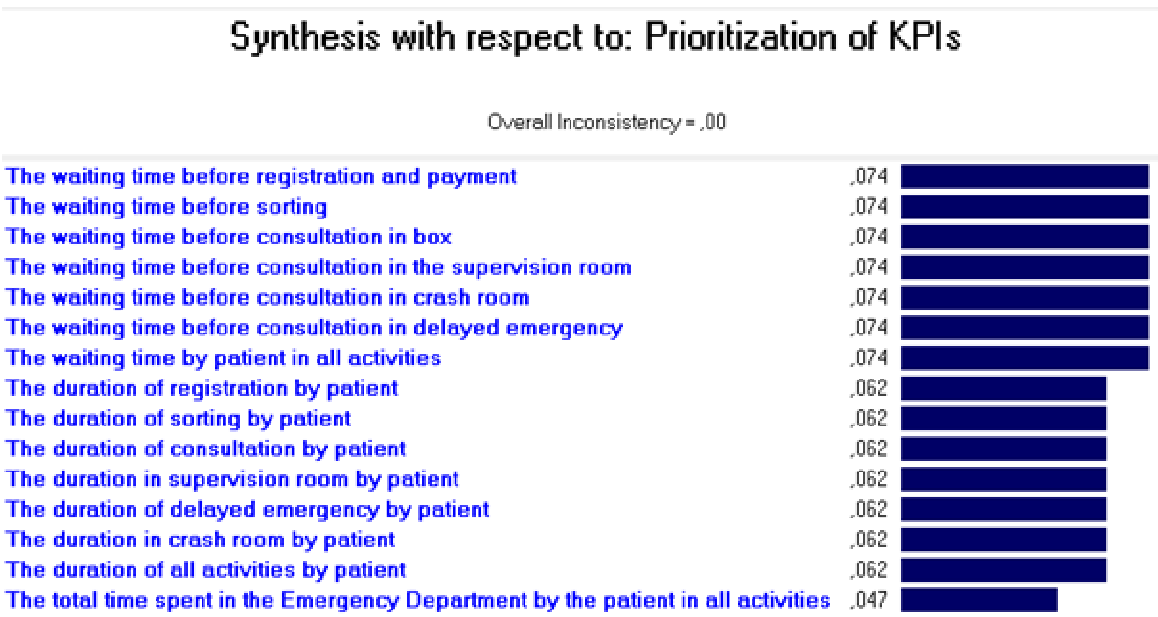

Figure 5.3: AHP synthesis

Comparing them pairwise under the "Relevant" criterion becomes a difficult task and sometimes can lead them to a confusing decision. For example, is it really important to have indicators related to the quality of care supported by medical staff or paramedical staff? Is it really important to ask patients about some quantitative aspects such as paramedical staff availability and the overall waiting time before treatment by paramedical personnel? This is due to the fact that for example sometimes the nurse is available but the patients who are in less urgent situations are not given sufficient attention by nursing staff. So, in order to provide a higher level of quality and consistency with quantitative measurement and with the processes in place, we record the patients' level of satisfaction with those indicators.

After discussion with experts, we concluded that they give more importance to the indicators related to some quantitative aspects such as the availability of personal and medical equipment and the hospital staff clothing because it reflects the image of health care. After that, they prefer indicators related to staff attitudes towards patients and the final rank is reserved to the installation of patients in the waiting room.

Based on the alternatives retained from "Relevant" criterion, we compared two indicators and found that some indicators are not clear enough in the synthesis. So we focused on those indicators and refine their definition. For example, we retain the previous indicator related to the regularity of doctor visit. We discovered that the definition of this indicator is incomplete and it is not clear enough about which activity. For example, does it mean the regularity of doctor visiting the supervision room or the crash room? Another example regarding the installation in the waiting room, which may include many aspects such as comfort, cleanliness, and hygiene. Does it concern the waiting room before the consultation in box or concern the waiting room before registration task? After discussion with experts, we developed additional indicators retained to specify the place and the assigned personnel group. As a consequence, we returned to checking and setting up the previous comparison matrix under relevant indicators. We also checked the ratio of consistency before moving to the next pairwise criteria.

Comparing qualitative indicators under "Measurable" criterion is not a simple task. The first rank concerns qualitative indicators which include some quantitative aspects that are moderately more important than others. Qualitative indicators related to the installation of the patient can also be approximately measurable if we count the number of chairs and the regularity of personnel staff to keep the room clean. However, according to patient perception for some qualitative indicators, they are in the last rank because they are rather related to the behavior, attitudes, and practices of the staff.

For "Attainable" criterion, we can divide the qualitative indicators into 4 groups. First, decision-maker gives more attention to the fact that hospital staff is well dressed and available and also the availability of medical equipment (first ranked group), because if we expect that these indicators meet the desired target value, then all other indicators can be accomplished. Second, if the attention, the quality of care and the clarity of information supported by hospital staff (the second group) reflect the desired target value, then automatically it will have an effect on the regularity of hospital staff visit and the overall waiting time (the thirdranked group). The last group is reserved to the patient installation in the waiting room.

For "Time based" criterion, all indicators related to the time occupation are equally important because all defined indicators are important to evaluate in the same time frame related to the same patient instance. The AHP synthesis for this case study is given in Figure 5.4.

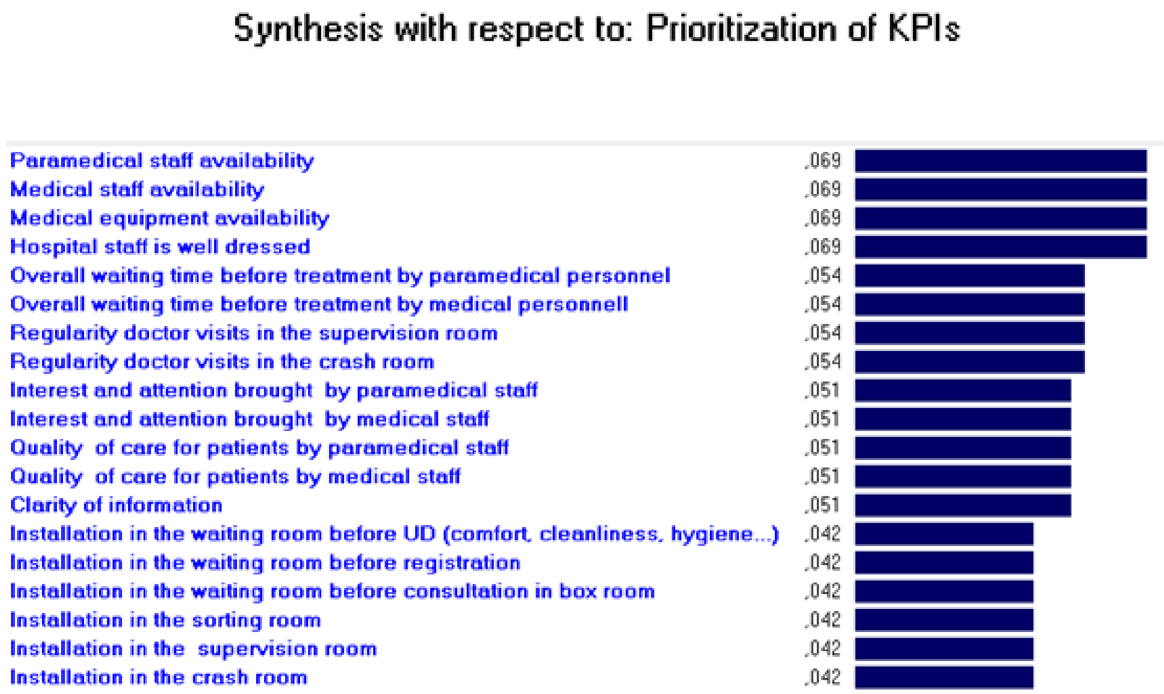

Figure 5.4: AHP synthesis

5.3.3 Ontology Design and Population for Emergency Care BP

Using the Protegé editor, first we define the BP domain of the ontology which covers the healthcare domain. In particular, we take the health care process. Business analysts are our target audience. They will use and maintain the ontology to obtain good BP guidelines or recommendations. Two prerequisites must be met before the BP ontology can be created. The first step provides the definition of the class hierarchy. For the first level, we have the process related to a specific domain (in this case the healthcare field). For the second level, we have two big lines (activities and KPIs). The second step focuses on the creation of instances from concepts (i.e., individuals). The emergency care ontology is given in Figure 5.5.

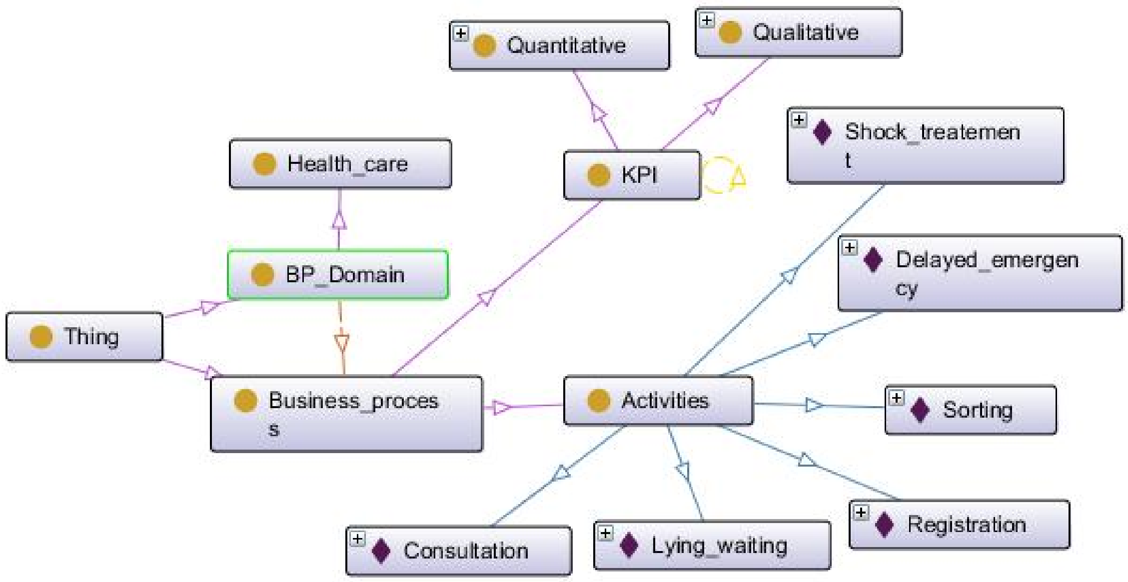

Figure 5.5: Emergency care ontology

The activity can belong to any activity modeled in the BP. We come then to our KPIs which incorporate the SMART qualitative and quantitative KPIs of the healthcare process. After that, we specify a set of properties of data type, and a set of object properties, to describe relationships among indicators in which we can define some restrictions of properties. For example, Figures 5.6 and 5.7 present data and object properties related to *Quanti_ KPI6* and *Quanti_ KPI9*.

Quanti_ KPI6 has the name "Duration of delayed emergency by the patient" which can be calculated as *the start date of consultation in the "Delayed emergency" activity – end date of "Sorting" activity*. The value of this indicator must be less than ten minutes to be classified as *"acceptable value (ok)"*. Furthermore, this indicator is related to many qualitative indicators such as *Quali_ KPI1* concerning the interest and attention brought by paramedical staff, *Quali_ KPI8* concerning the quality of care for patients by medical staff, *Quali_ KPI9* related to the clarity of information, *Quali_ KPI2* related to interest and attention brought by medical staff (doctor), *Quali_ KPI7* assessing the quality of care for patients by paramedical staff, *Quali_ KPI5* assessing medical equipment availability and *Quali_ KPI6* for checking if hospital staff are well dressed.

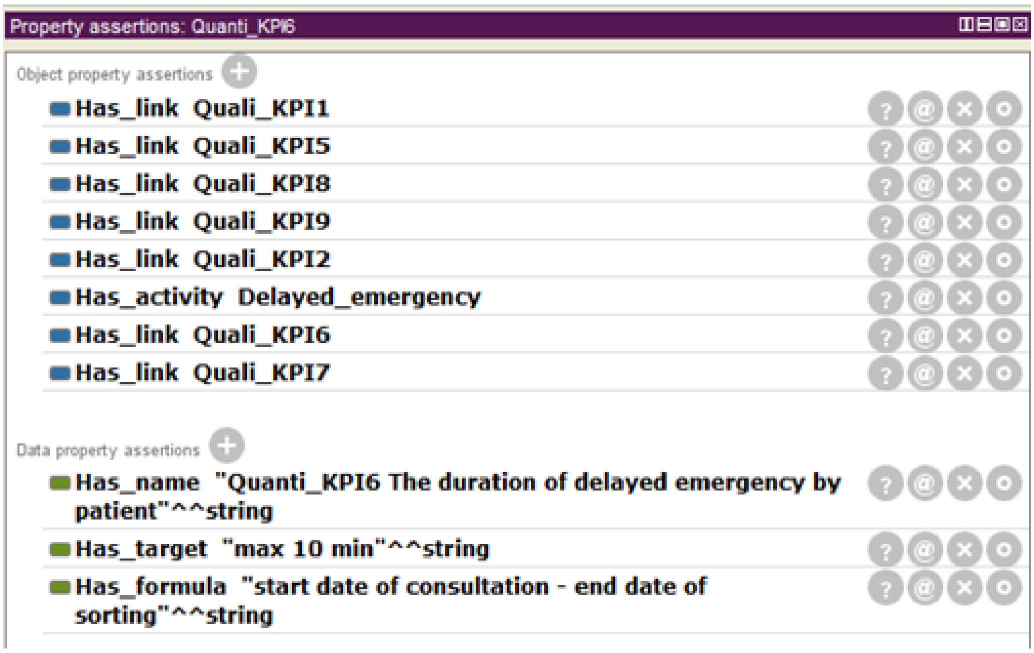

Figure 5.6: Properties related to Quanti_KPI6

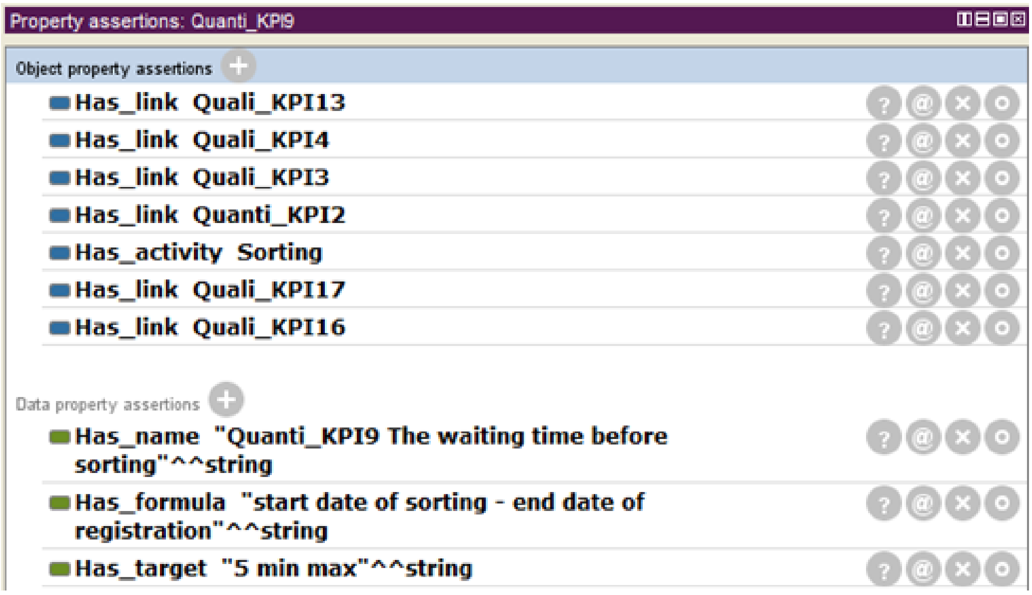

Figure 5.7: Properties related to Quanti_KPI9

Quanti_KPI9 measures the waiting time before sorting. This indicator is calculated as *the start date of sorting activity – the end date of the registration activity*. Tolerated values of this indicator must not exceed five minutes. Many indicators are linked to these indicators which are *Quanti_KPI2* corresponding to the duration of sorting and *Quali_KPI13* corresponding to installation in the sorting room, *Quali_KPI3* for paramedical staff availability, *Quali_KPI4* for medical staff availability, *Quali_KPI16* related to the overall waiting time before treatment by paramedical personnel and *Quali_KPI17* corresponding to the overall waiting time before treatment by medical staff. After discussion with the decision-maker, we built all necessary properties related to all individuals included in the ontology.

Tables 5.1, 5.2 and 5.3 summarize the main links between indicators.

Table 5.1: Links between quantitative indicators

Quantitative KPI name	**Related Quantitative KPI**	**Related Activity**
Quanti_KPI8 The waiting time before registration	Quanti_KPI1 The duration of registration by the patient	Registration
Quanti_KPI9 The waiting time before sorting	Quanti_KPI2 The duration of sorting by patient	Sorting
Quanti_KPI15 The waiting time before consultation by the patient	Quanti_KPI3 The duration of consultation by the patient	Consultation in Box
Quanti_KPI12 The waiting the time before the consultation in the crash room	Quanti_KPI5 The duration in the crash room by a patient	Shock Treatment
Quanti_KPI11 The waiting time before the consultation in the supervision room	Quanti_KPI4 The duration in supervision room by a patient	Lying Waiting
Quanti_KPI10 The waiting time before the consultation in delaying emergency	Quanti_KPI6 The duration of delaying emergency by the patient	Delaying Emergency
Quanti_KPI13 The waiting time per patient in all activities	Quanti_KPI8, Quanti_KPI15, Quanti_KPI9, Quanti_KPI12, Quanti_KPI11, Quanti_KPI10	All activities
Quanti_KPI7 The duration of all activities by patient	Quanti_KPI6, Quanti_KPI5, Quanti_KPI4, Quanti_KPI3, Quanti_KPI2, Quanti_KPI1	All activities

Quanti_KPI14 The total time spent in the ED by the patient in all activities	Quanti_KPI7, Quanti_KPI13	All activities

Table 5.2: Links between quantitative and qualitative indicators

Quantitative KPI name	**Related Quanlitative KPI**	**Related Activity**
Quanti_KPI8 The waiting time before registration	Quali_KPI11 Installation in the waiting room before registration	Registration
Quanti_KPI9 The waiting time before sorting	Quali_KPI13 Installation in the sorting room, Quali_KPI3 Paramedical staff availability, Quali_KPI4 Medical staff availability, Quali_KPI16 The overall waiting time before treatment by paramedical personnel, Quali_KPI17 The overall waiting time before treatment by medical staff	Sorting
Quanti_KPI2 The duration of sorting by patient	Quali_KPI1, Quali_KPI2, Quali_KPI5, Quali_KPI6, Quali_KPI7, Quali_KPI8, Quali_KPI9	Sorting
Quanti_KPI15 The waiting time before consultation by patient	Quali_KPI12 Installation in the waiting room before consultation in box room, Quali_KPI3, Quali_KPI4, Quali_KPI16, Quali_KPI17	Consultation in Box

Quanti_KPI3 The duration of consultation by patient	Quali_KPI1, Quali_KPI2, Quali_KPI5, Quali_KPI6, Quali_KPI7, Quali_KPI8, Quali_KPI9	Consultation in Box
Quanti_KPI12 The waiting time before consultation in crash room	Quali_KPI14 Installation in the supervision room, Quali_KPI3, Quali_KPI4, Quali_KPI16, Quali_KPI17	Shock Treatment
Quanti_KPI5 The duration in crash room by patient	Quali_KPI1, Quali_KPI2, Quali_KPI5 Medical equipment availability, Quali_KPI6, Quali_KPI7, Quali_KPI8, Quali_KPI9, Quali_KPI15 Installation in the crash room,Quali_KPI19 The regularity doctor visits in the crash room	Shock Treatment
Quanti_KPI11 The waiting time before consultation in the supervision room	Quali_KPI14, Quali_KPI3, Quali_KPI4, Quali_KPI16, Quali_KPI17	Lying Waiting
Quanti_KPI4 The duration in supervision room by patient	Quali_KPI1, Quali_KPI2, Quali_KPI5, Quali_KPI6, Quali_KPI7, Quali_KPI8, Quali_KPI9, Quali_KPI18 The regularity doctor visits in the supervision room	Lying Waiting

Quanti_KPI10 The waiting time before consultation in delaying emergency	Quali_KPI10 Installation in the waiting room before Delaying Emergency, Quali_KPI3, Quali_KPI4, Quali_KPI16, Quali_KPI17	Delaying Emergency
Quanti_KPI6 The duration of delaying emergency by patient	Quali_KPI1, Quali_KPI2, Quali_KPI5, Quali_KPI6, Quali_KPI7, Quali_KPI8, Quali_KPI9	Delaying Emergency
Quanti_KPI13 The waiting time per patient in all activities	Quali_KPI11, Quali_KPI13, Quali_KPI12, Quali_KPI14, Quali_KPI3, Quali_KPI4, Quali_KPI16, Quali_KPI17	All activities
Quanti_KPI7 The duration of all activities by patient	Quali_KPI1, Quali_KPI2, Quali_KPI5, Quali_KPI6, Quali_KPI7, Quali_KPI8, Quali_KPI9, Quali_KPI19, Quali_KPI18	All activities
Quanti_KPI14 The total time spent in the ED by the patient in all activities	Quali_KPI11, Quali_KPI13, Quali_KPI12, Quali_KPI14, Quali_KPI3, Quali_KPI4, Quali_KPI16, Quali_KPI17, Quali_KPI1, Quali_KPI2, Quali_KPI5, Quali_KPI6, Quali_KPI7, Quali_KPI8, Quali_KPI9, Quali_KPI19, Quali_KPI18	All activities

Table 5.3: Links between qualitative indicators

Quanlitative KPI name	**Related Quanlitative KPI**	**Related Activity**
Quali_KPI1 Interest and attention brought by paramedical staff, Quali_KPI2 Interest and attention brought by medical staff (doctor)	Quali_KPI3, Quali_KPI4, Quali_KPI5, Quali_KPI6	All activities
Quali_KPI7 The quality of care for patients by paramedical staff, Quali_KPI8 The quality of care for patients by medical staff, Quali_KPI9 The clarity of information	Quali_KPI1, Quali_KPI2	All activities
Quali_KPI10 Installation in the waiting room before delaying emergency	Quali_KPI16, Quali_KPI17	Delaying Emergency
Quali_KPI11 Installation in the waiting room before registration	Quali_KPI16, Quali_KPI17	Registration
Quali_KPI12 Installation in the waiting room before the consultation in the box room	Quali_KPI16, Quali_KPI17	Consultation in Box
Quali_KPI13 Installation in the sorting room	Quali_KPI16, Quali_KPI17	Sorting
Quali_KPI14 Installation in the supervision room	Quali_KPI16, Quali_KPI17, Quali_KPI18, Quali_KPI19	Lying Waiting or Shock Treatment

5.4 Configuration Phase

In this phase, the KPI values determination and relationships configuration were done in the same way for both case studies. For this reason, we present only the main features of the framework related to the selection candidate case study (Chapter 6).

5.5 Enactment of the Emergency Care BP

The proposed BP model was deployed with the use of jBPM software, where 100 instances have been created through the execution of the process. KPIs data mainly contained all the quantitative and qualitative indicators regarding patients. The storage of such type of data varies depending on the period of analysis and the evaluation of organization performance. The study was conducted over 10 days (20 to 30 May 2016) at the University Hospital Center (UHC) Farhat Hached, Sousse.

5.5.1 BP Enactment

In this study, we have faced some challenges. The first one concerns the fact that we must get close enough to the patient pathway. In fact, since a patient represents a process instance, we must record the start date and the end date of all activities from the arrival of the patient to his/her discharge. If the patient leaves the healthcare process before treatment, we redo the recording of our KPIs with a new patient. Second, we must record common attributes for consistency purpose between quantitative and qualitative indicators such as the name of the patient, the number of medical fields and the birth date. These data are stored later when executing the BP in the Variableinstancelog table. Third, not all patients accept to respond to the questionnaire because of their critical health status or if the patient is overall not satisfied with the quality of care provided by the ED.

After the deployment of the BP, we entered the different process instances related to the emergency care process. Figure 5.8 displays a screenshot of *TaskEvent* table. An overview of the process execution instances for some tables is shown in Appendix A.
By addressing patient queries, the qualitative aspect will be in a better position to improve satisfaction toward the healthcare processes.

id [PK] bigint	logtime timestamp without time zone	taskid bigint	type character varying(255)
1428	2016-05-26 11:34:39.562	464	ADDED
1429	2016-05-26 11:34:47.901	464	STARTED
1430	2016-05-26 11:35:17.053	464	EXITED
1431	2016-05-26 11:35:21.401	465	ADDED
1432	2016-05-26 11:36:06.58	465	EXITED
1433	2016-05-26 11:33:49.075	466	ADDED
1434	2016-05-26 11:34:05.604	466	STARTED
1435	2016-05-26 11:35:11.887	466	EXITED
1436	2016-05-26 11:39:57.506	467	ADDED

Figure 5.8: Screenshot of TaskEvent table

A qualitative inquiry is necessary to get close enough to the patient and capture the level of his/her satisfaction. Hence, at the end of the process, each patient was invited to provide feedback about his/her satisfaction. These indicators, such as staff attitudes toward patients concern not only the qualitative aspects of care in the ED but also they concern some quantitative aspects such us paramedical staff availability and the overall waiting time before treatment by paramedical personnel. This is due for example to the fact that sometimes the nurse is available but the patients who are in a less urgent state are not given sufficient attention by the nursing staff.

So, in order to provide higher quality and consistency with quantitative KPIs and with the processes in place, we record the patient's level of satisfaction with those KPIs through a questionnaire. The aim of this questionnaire is to determine why patients are unsatisfied and what we can do to improve their satisfaction. The proposed questionnaire is in Appendix C. Based on this questionnaire, we add "notes" space which supports open questions that encourage the respondent to speak freely, yet keeping the conversation focused on the question being asked. In this way, we have reliable information on current performance and desired improvement of the healthcare process. Table 5.4 provides a synthesis about each level of satisfaction under each question.

Table 5.4: Responses synthesis for qualitative indicators

Indicator	**Very satisfied**	**Satisfied**	**Neutral**	**Dissatisfied**	**Very dissatisfied**
KPI1 Interest and attention brought by paramedical staff	56	12	9	11	12
KPI2 Interest and attention brought by medical staff	60	14	7	8	11
KPI3 Paramedical staff availability	72	3	11	10	4
KPI4 Medical staff availability	74	2	11	10	3
KPI5 The availability of medical equipment	73	2	15	5	5
KPI6 Hospital staff is well dressed	84	3	12	0	1
KPI7 The quality of care by paramedical staff	63	4	12	8 1	3
KPI8 The quality of care by medical staff	65	5	13	7	10
KPI9 The clarity of information	53	9	12	6	20
KPI10 Installation in the waiting room before delayed emergency (comfort, cleanliness, hygiene...)	2	0	89	6	3
KPI11 Installation in the waiting room before registration	29	17	20	19	15

KPI12 Installation in the waiting room before the consultation in the box room	27	9	50	10	30
KPI13 Installation in the sorting room	46	19	19	9	7
KPI14 Installation in the supervision room	6	2	88	2	2
KPI15 Installation in the crash room	1	0	98	0	1
KPI16 The overall waiting time before the intervention of paramedical personnel	43	20	17	6	14
KPI17 The overall waiting time before the intervention of medical staff	43	20	17	6	14
KPI18 The regularity of doctor visits in the supervision room	50	18	14	7	11
KPI19 The regularity of doctor visits in the crash room	4	1	93	0	2

5.5.2 KPIs values generation storage

In the healthcare process, we try to record our KPI in different periods of the day (in the morning, in the afternoon and by night) with various patients (male and female in different ages) with different emergency status (immediately life-threatening, potentially serious and less urgent).

Quantitative KPIs are derived from a close look at the activities involved in the BP. For more details, we define six indicators: the duration of registration by patient, the duration of sorting by patient, the duration of consultation by patient, the duration in supervision room by patient, the duration of delayed emergency by patient, the duration in crash room by patient) related to the time that the process actor actually spends doing each activity. We also define another indicator related to the duration of all the activities by the patient (the sum of all previous activities duration). The value of this indicator corresponds to the duration column in the bamtasksummary table. We also define six indicators related to the time the process waits for the activity in question to be done, from the initial request to the eventual delivery. The values corresponding to these indicators represent the waiting time of different activities. Thus, such indicators are important to consider, for example, how long a patient waits for a consultation, which is defined as the time difference between the created date of a consultation task and its actual start date. In jBPM logs, we do not have a column for this duration, so we need to create SQL queries to retrieve this value. Another interesting value that can be derived from this measure is the waiting time per patient in all activities, which represent the sum of waiting time per patient in all activities. Finally, we define the total time spent in the Emergency Department by the patient in all activities. Its value is retrieved from the duration column in the *processinstancelog* table.

As previously mentioned not all KPIs can be retrieved from these logs (e.g. additional data source or administrative files are necessary to retrieve and calculate specific KPIs). For example, for qualitative indicators, we are based on the responses of the patient, and consequently, a set of qualitative results is recorded by using a Likert scale. Since the exactly followed paths in the process are different from an instance to another, the number of questions asked to each specific patient varies and then some columns in the table have a null value. The framework helps the user to find the major KPI real values related to the appropriate process identifier deployed in jBPM and later to evaluate them against a target value. Figures 5.9, 5.10 and 5.11 give on overview of some quantitative indicators. Figure 5.12 displays some qualitative KPIs real values. At this stage, we track the healthcare process and we identify and extract the appropriate KPI. The data collected during the BP execution is used for deriving the KPIs. In addition, we record and evaluate all real values of indicators of both quantitative and qualitative aspects, which offer a better comprehension of the situation. The final files contain all information related to quantitative process indicators and qualitative indicators related to the same process instance id.

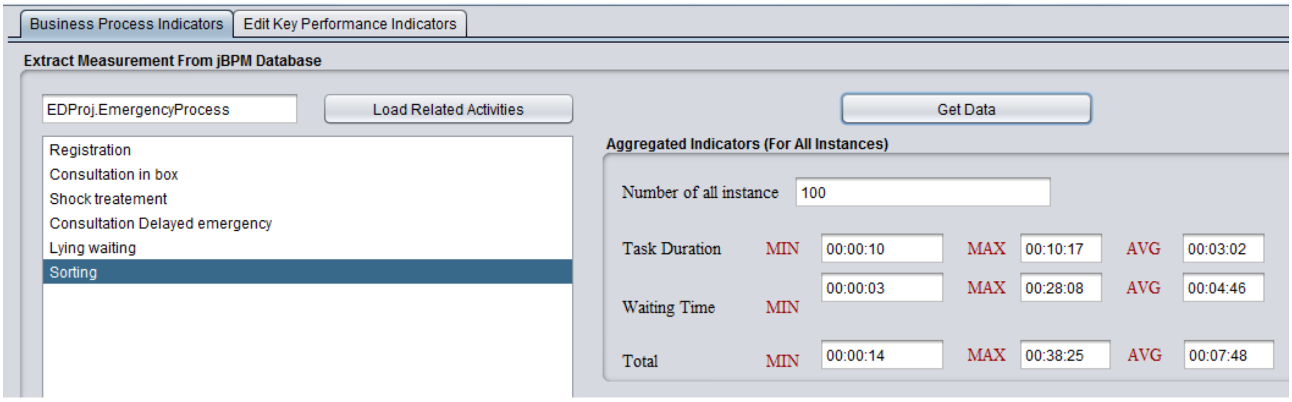

Figure 5.9: Screenshot of some aggregated KPIs

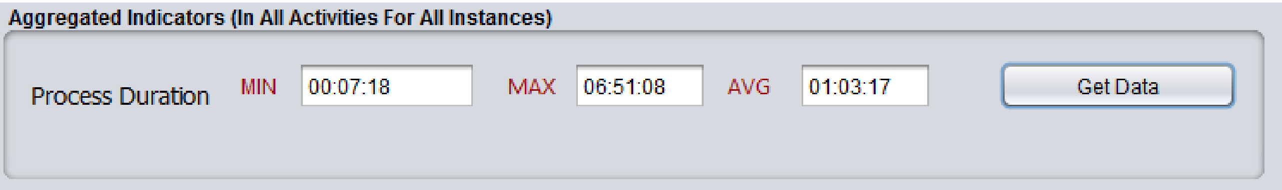

Figure 5.10: Screenshot of some aggregated KPIs

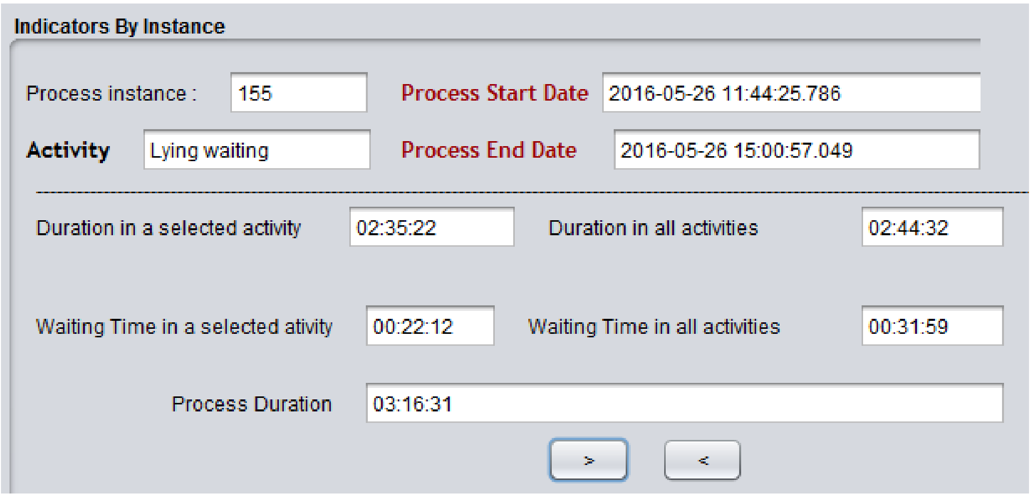

Figure 5.11: Screenshot of a process instance data

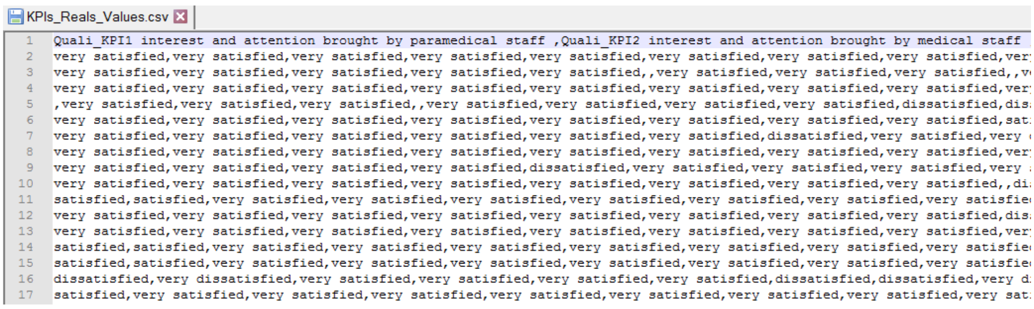

Figure 5.12: Screenshot of some qualitative KPI real values

5.6 Evaluation of Emergency Care BP

In this section we present some emergency care BP dashboards and we illustrate the proposed KPI life-cycle in this phase.

5.6.1 Process Dashboards

In this case study, we are based on 100 rows referring to patient data since an instance of BP represents a patient. For example, Figure 5.13 represents a graphical representation of KPIs in the workbench environment.

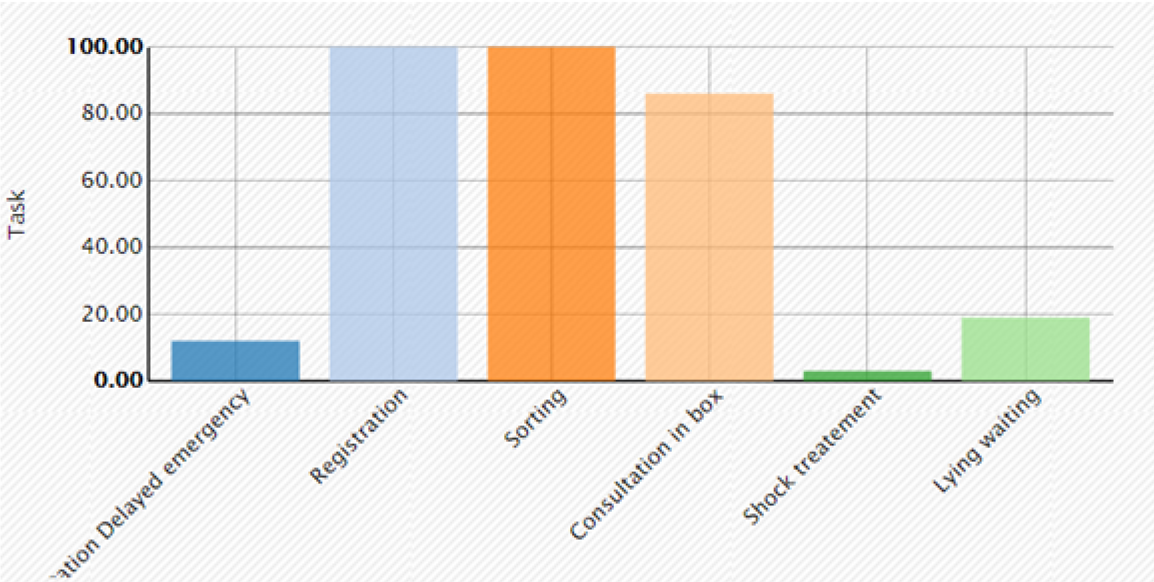

Figure 5.13: Number of patients in each activity

In Figure 5.14, we can find all quantitative indicators' values related to task duration details. This dashboard shows all tasks that have been executed.

process_id	start_date	end_date	taskname	createddate	enddate	status	task dura
211	05/21/16 10:50	05/21/16 11:50	Consultation Del	05/21/16 11:29	05/21/16 11:50	Completed	0h 5m 25s
212	05/21/16 10:28	05/21/16 11:15	Registration	05/21/16 10:28	05/21/16 10:32	Completed	0h 1m 40s
212	05/21/16 10:28	05/21/16 11:15	Sorting	05/21/16 10:32	05/21/16 10:46	Completed	0h 3m 12s
212	05/21/16 10:28	05/21/16 11:15	Consultation Del	05/21/16 10:46	05/21/16 11:15	Completed	0h 5m 11s
448	05/26/16 11:35	05/26/16 5:35 P	Registration	05/26/16 11:35	05/26/16 11:37	Completed	0h 1m 40s
213	05/22/16 11:45	05/22/16 12:08	Registration	05/22/16 11:45	05/22/16 11:46	Completed	0h 1m 10s
213	05/22/16 11:45	05/22/16 12:08	Sorting	05/22/16 11:46	05/22/16 11:50	Completed	0h 2m 20s
213	05/22/16 11:45	05/22/16 12:08	Consultation in b	05/22/16 11:50	05/22/16 12:08	Completed	0h 18m 32s
214	05/22/16 11:42	05/22/16 12:17	Registration	05/22/16 11:42	05/22/16 11:43	Completed	0h 1m 8s
214	05/22/16 11:42	05/22/16 12:17	Sorting	05/22/16 11:43	05/22/16 11:46	Completed	0h 1m 3s

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Figure 5.14: Task duration details

5.6.2 KPIs /BP improvement

The running of the Apriori algorithm in the proposed framework starts by entering a dataset which contains all indicators (see Figure 5.15). A screenshot of the content of this file is shown in Figure 5.16.

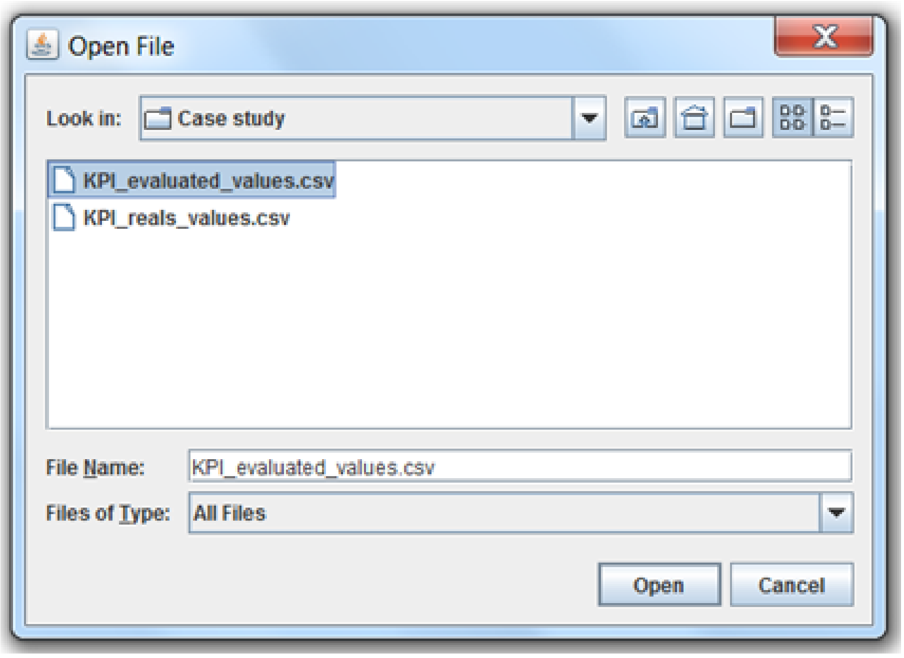
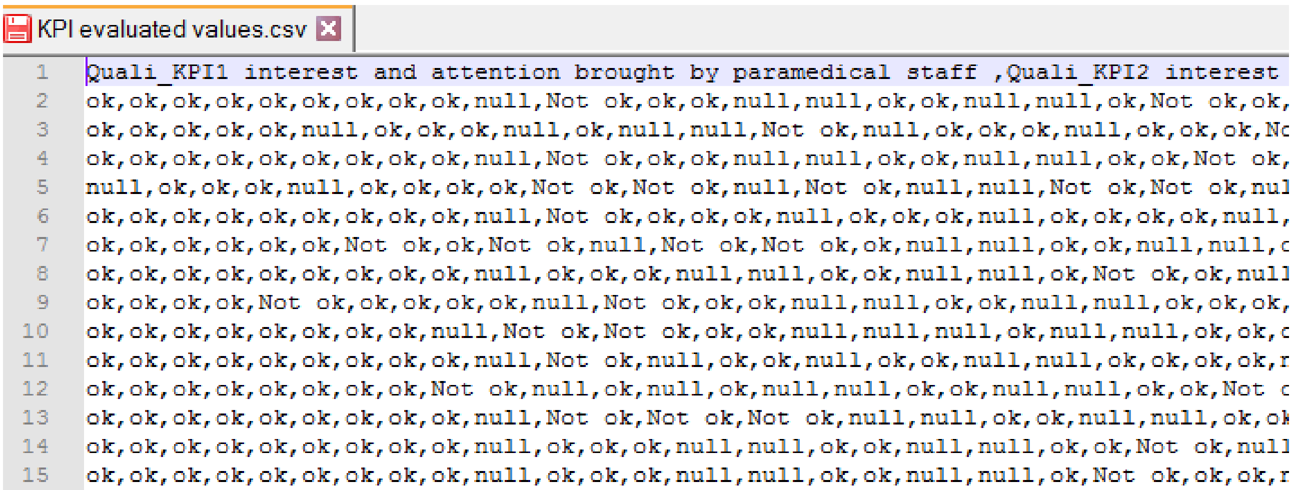


Figure 5.15: Opening form for the KPI evaluated values file



KPI evaluated values.csv

```
Quali_KPI1 interest and attention brought by paramedical staff ,Quali_KPI2 interest
ok,ok,ok,ok,ok,ok,ok,ok,ok,null,Not ok,ok,ok,null,null,ok,ok,null,null,ok,Not ok,ok,
ok,ok,ok,ok,ok,null,ok,ok,ok,null,ok,null,null,Not ok,null,ok,ok,ok,null,ok,ok,ok,Nc
ok,ok,ok,ok,ok,ok,ok,ok,ok,null,Not ok,ok,ok,null,null,ok,ok,null,null,ok,ok,Not ok,
null,ok,ok,ok,null,ok,ok,ok,ok,Not ok,Not ok,null,Not ok,null,null,Not ok,Not ok,nul
ok,ok,ok,ok,ok,ok,ok,ok,ok,null,Not ok,ok,ok,ok,null,ok,ok,ok,null,ok,ok,ok,ok,null,
ok,ok,ok,ok,ok,ok,Not ok,ok,Not ok,null,Not ok,Not ok,ok,null,null,ok,ok,null,null,c
ok,ok,ok,ok,ok,ok,ok,ok,ok,null,ok,ok,ok,null,null,ok,ok,null,null,ok,Not ok,ok,null
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ok,ok,ok,ok,ok,ok,ok,ok,null,Not ok,Not ok,ok,ok,null,null,null,ok,null,null,ok,ok,c
ok,ok,ok,ok,ok,ok,ok,ok,ok,null,Not ok,null,ok,ok,null,ok,ok,null,null,ok,ok,ok,ok,r
ok,ok,ok,ok,ok,ok,ok,ok,Not ok,null,ok,null,ok,null,null,ok,ok,null,null,ok,ok,Not c
ok,ok,ok,ok,ok,ok,ok,ok,ok,null,Not ok,Not ok,Not ok,null,null,ok,ok,null,null,ok,ok
ok,ok,ok,ok,ok,ok,ok,ok,ok,null,ok,ok,ok,null,null,ok,ok,null,null,ok,ok,Not ok,null
ok,ok,ok,ok,ok,ok,ok,ok,ok,null,ok,ok,ok,null,null,ok,ok,null,null,ok,Not ok,ok,ok,r
```

Figure 5.16: A screenshot of the KPI evaluated values file content

Figure 5.17 shows various functionalities supported by the framework applied to this case study. First, the user was able to load the KPI names list from the opened evaluated KPI file. Next, the user could select which two indicators are involved in Apriori learning (for example it contains *Quali_KPI1* and *Quali_KPI2*. And then, s/he clicked on the pre-process button to display these two itemsets in the table. After that, s/he saved the KPI data set in another CSV file. Next, the user clicks on the Run Algo button which shows results if the user wants to see possible rules related to these two KPIs. Figure 5.18 shows the Apriori algorithm result for the previous data set. We set 50 instances as *min* support (minimum 50% patients) and 0.5 as *min* confidence.

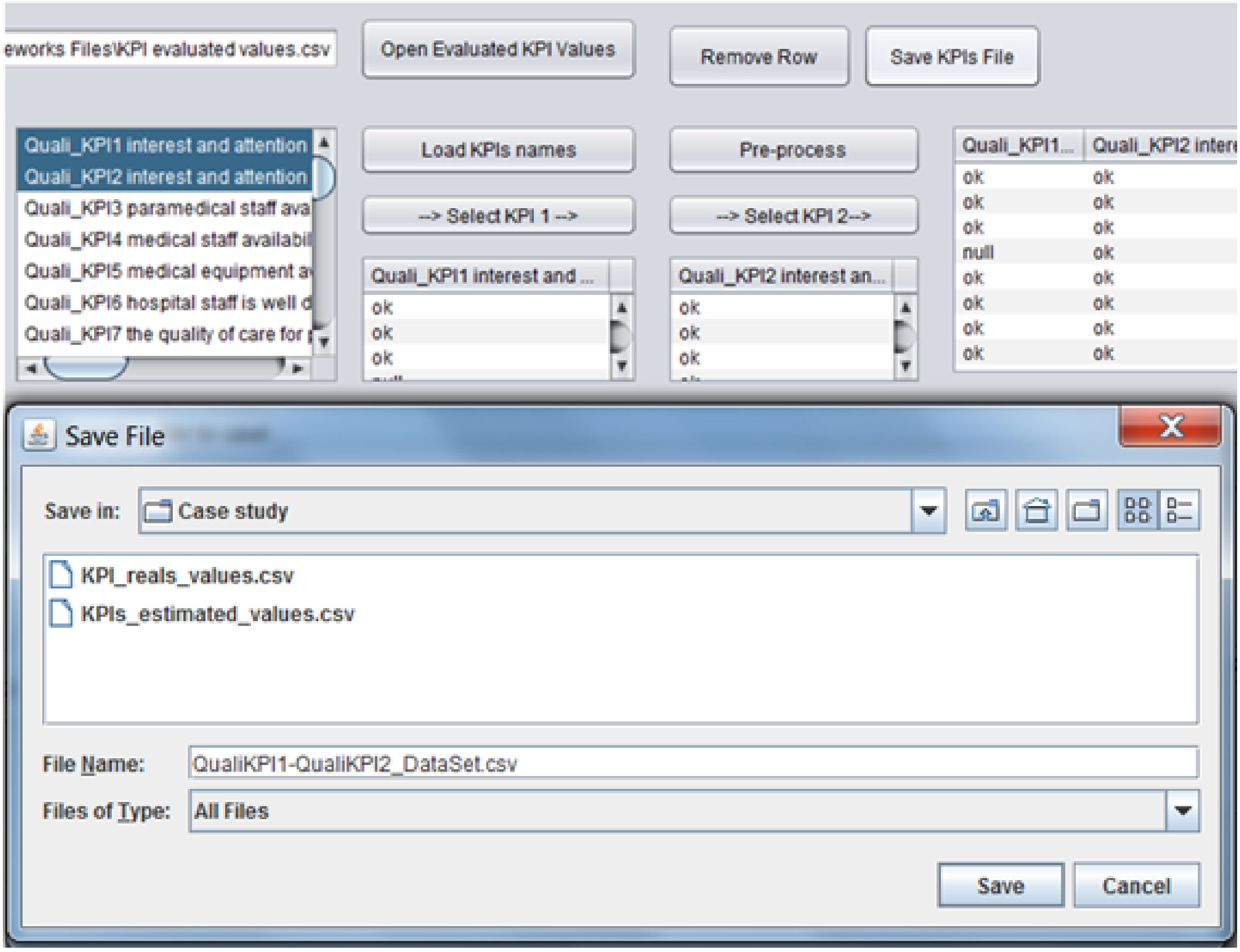


Figure 5.17: Loading KPI names list from the opened evaluated KPI file

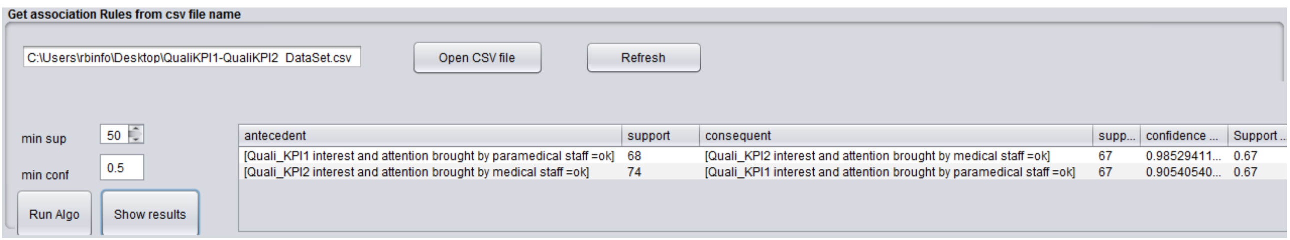
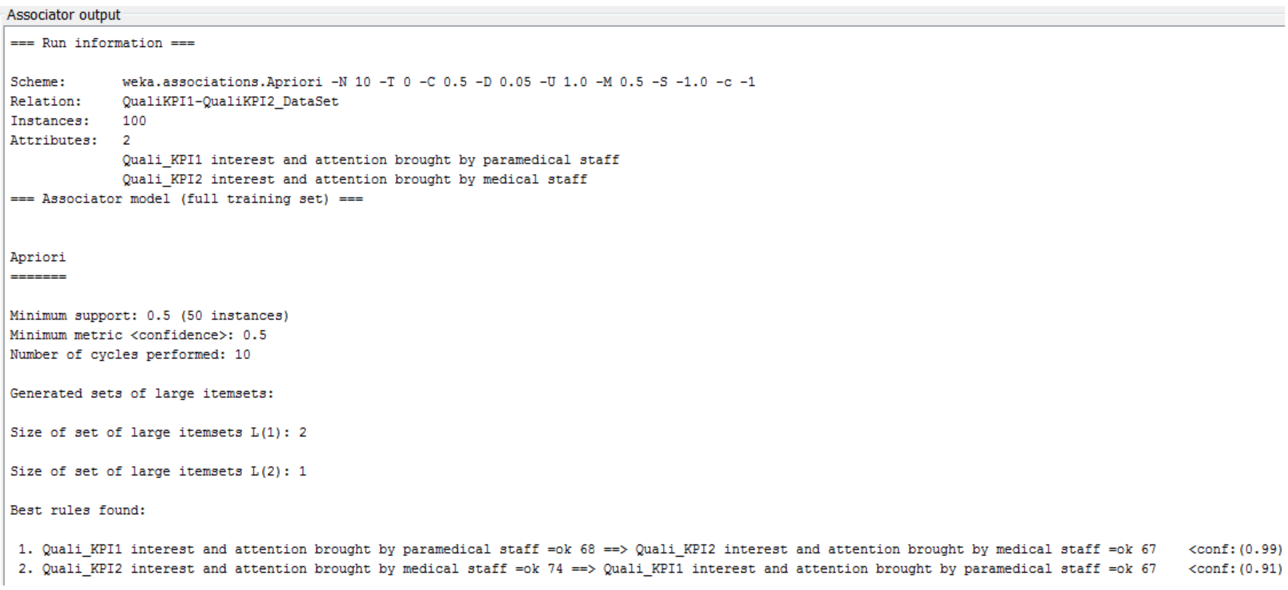


Figure 5.18: Apriori algorithm result for the appropriate KPI data set

To test the quality of association rules values implemented by our framework, we enter the same data set in Weka with the same parameters. The results are shown in Figure 5.19. For the same KPI couples, if we change the *min* support and *min* confidence, the number of rules changes, and consequently, the number of discovered links, to take into account changes and also the number of occurrence for this indicator in all rules changed. For example, if we set *min* support to 0.1 (10 %), the user can analyze the rare cases. For the same KPI couple, we have 4 discovered rules, in which the decision-maker can view the case of *Quail_KPI1* “interest and attention brought by paramedical staff” or *Quail_KPI2* “interest and attention brought by medical staff” which were not as expected by patients.

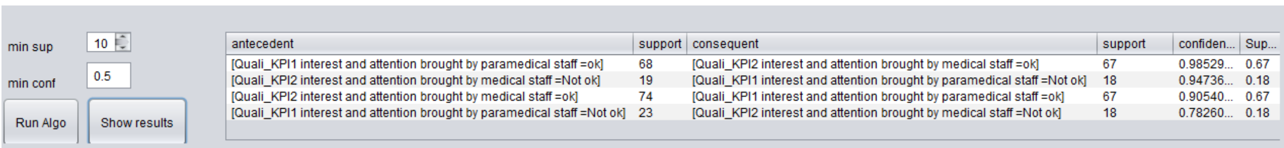
This feature supported by our framework is very important to analyze KPI links before deciding to save them in the KDB where the manager is the only one who decides which indicator to take into consideration to update the ontology and to later improve indicator or BP.

We also found that sometimes the same indicator appears in the antecedent side and sometimes in the consequent side: such as for example *Quail_KPI1* (see Figure 5.20). This kind of rule has no effect on KPI links defined in the ontology for the simple following reason: all possible indicators have object property “Has_link” which is symmetric.


Associator output

```
=== Run information ===

Scheme:       weka.associations.Apriori -N 10 -T 0 -C 0.5 -D 0.05 -U 1.0 -M 0.5 -S -1.0 -c -1
Relation:     QualiKPI1-QualiKPI2_DataSet
Instances:    100
Attributes:   2
              Quali_KPI1 interest and attention brought by paramedical staff
              Quali_KPI2 interest and attention brought by medical staff
=== Associator model (full training set) ===


Apriori
=======

Minimum support: 0.5 (50 instances)
Minimum metric <confidence>: 0.5
Number of cycles performed: 10

Generated sets of large itemsets:

Size of set of large itemsets L(1): 2

Size of set of large itemsets L(2): 1

Best rules found:

 1. Quali_KPI1 interest and attention brought by paramedical staff =ok 68 ==> Quali_KPI2 interest and attention brought by medical staff =ok 67    <conf:(0.99)
 2. Quali_KPI2 interest and attention brought by medical staff =ok 74 ==> Quali_KPI1 interest and attention brought by paramedical staff =ok 67    <conf:(0.91)
```

Figure 5.19: Weka association rules result for the appropriate KPI data set



antecedent	support	consequent	support	confiden...	Sup...
[Quali_KPI1 interest and attention brought by paramedical staff =ok]	68	[Quali_KPI2 interest and attention brought by medical staff =ok]	67	0.98529...	0.67
[Quali_KPI2 interest and attention brought by medical staff =Not ok]	19	[Quali_KPI1 interest and attention brought by paramedical staff =Not ok]	18	0.94736...	0.18
[Quali_KPI2 interest and attention brought by medical staff =ok]	74	[Quali_KPI1 interest and attention brought by paramedical staff =ok]	67	0.90540...	0.67
[Quali_KPI1 interest and attention brought by paramedical staff =Not ok]	23	[Quali_KPI2 interest and attention brought by medical staff =Not ok]	18	0.78260...	0.18

Figure 5.20: Discovered rules with low *min* support for Quali_KPI1 and Quali_KPI2

We can conclude that the number of rules is important. But by using our approach, we help the manager to select the most important indicators. First by using the AHP method which prioritizes the most pertinent KPI. Second, by using expert knowledge-driven from the ontology. And third, by using, our framework which allows the user to set the *min* support and *min* confidence for each KPI couples (not the same parameters for all KPI couples), to preview the Apriori result for this couple and finally to decide the possibility to save the resulting association rules.We continue the same process to test KPI possible link. When they decide that discovered rules are interesting they save them in the KDB (see Figure 5.21).

Figure 5.21: Saving rules form in the KDB

Similarly, if we check the KPI KDB created by the user (see Figure 5.22), especially the *rules_ data* table (see Figure 5.23), we see some saved rules obtained after running the Apriori algorithm.

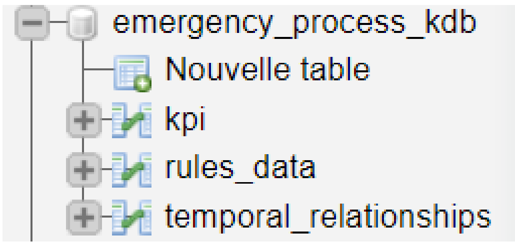


Figure 5.22: KDB structure

ant	supant	cons	supcons	conf
[Quali_KPI1 interest and attention brought by para...	68	[Quali_KPI2 interest and attention brought by medi...	67	0.9852941176470589
[Quali_KPI2 interest and attention brought by medi...	74	[Quali_KPI1 interest and attention brought by para...	67	0.9054054054054054
[Quali_KPI1 interest and attention brought by para...	68	[Quali_KPI3 paramedical staff availability=ok]	60	0.8823529411764706
[Quali_KPI3 paramedical staff availability=ok]	75	[Quali_KPI1 interest and attention brought by para...	60	0.8
[Quali_KPI1 interest and attention brought by para...	68	[Quali_KPI4 medical staff availability=ok]	60	0.8823529411764706
[Quali_KPI4 medical staff availability=ok]	76	[Quali_KPI1 interest and attention brought by para...	60	0.7894736842105263
[Quali_KPI1 interest and attention brought by para...	68	[Quali_KPI5 medical equipment availability=ok]	59	0.8676470588235294
[Quali_KPI5 medical equipment availability=ok]	75	[Quali_KPI1 interest and attention brought by para...	59	0.7866666666666666
[Quali_KPI1 interest and attention brought by para...	68	[Quali_KPI6 hospital staff is well dressed=ok]	64	0.9411764705882353
[Quali_KPI6 hospital staff is well dressed=ok]	87	[Quali_KPI1 interest and attention brought by para...	64	0.735632183908046
[Quali_KPI7 the quality of care for patients by pa...	68	[Quali_KPI1 interest and attention brought by para...	58	0.8529411764705882

Figure 5.23: Rules_data table content

Figure 5.24 summarizes the framework functionalities at this stage. Based on the generated association rules results, domain experts can structure their BP knowledge by adding meaningful relationships between KPIs. The results show that DM technologies can be effectively applied to detect semantic data and provide answers to users' queries. We present in Table 5.5 some indicators confirmed by the DM technique.

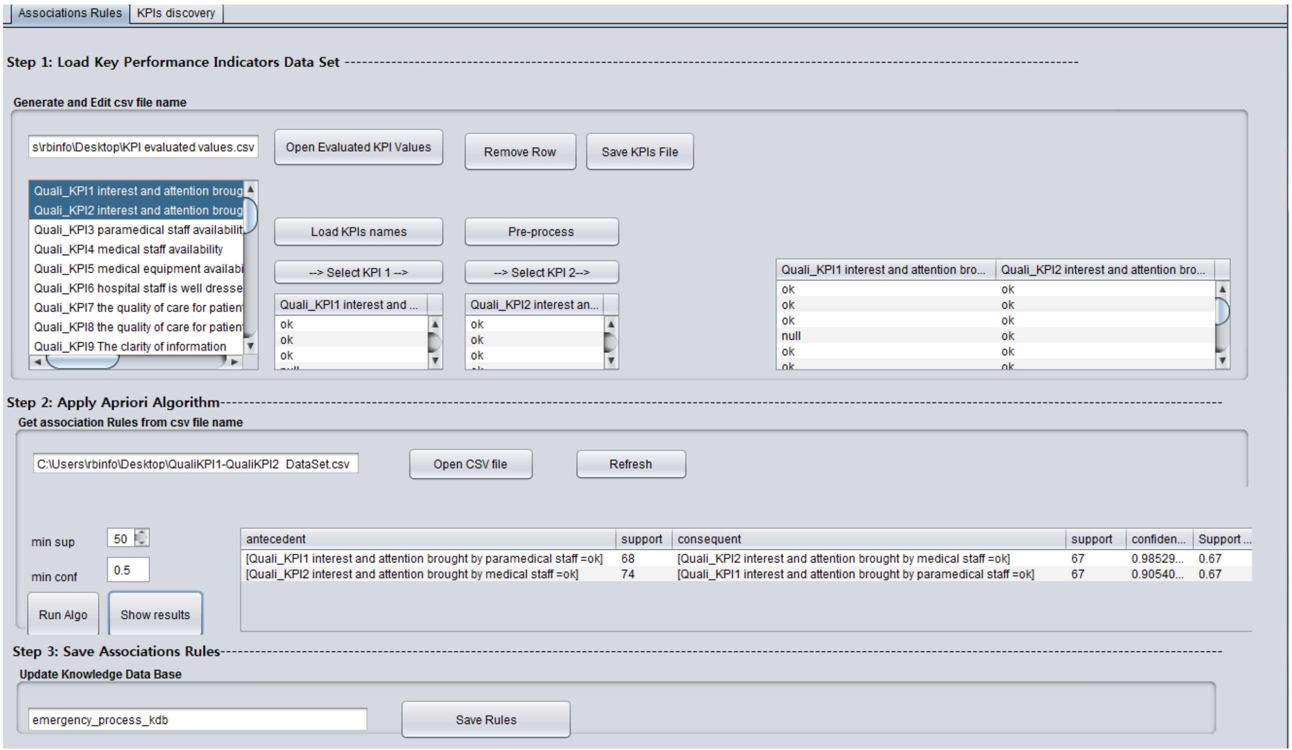


Figure 5.24: Screenshot of association rules form

Table 5.5: KPI Relationships approved by Apriori algorithm

KPI Relationships approved by the application of association rules				
Related Indicators	**Antecednt**	**Consequent**	**Sup**	**Conf**
Quali_KPI1 Interest and attention brought by paramedical staff Quanti_KPI3 The duration of consultation by patient	Quanti_KPI3=ok	Quali_KPI1=ok	11,000	91,667

Quali_KPI2 Interest and attention brought by medical staff Quanti_KPI3 The duration of consultation by patient	Quanti_KPI3=ok	Quali_KPI2=ok	11,000	91,667
Quali_KPI8 The quality of care for patients by medical staff Quali_KPI2 Interest and attention brought by medical staff (doctor)	Quali_KPI8=ok Quali_KPI8=Not ok	Quali_KPI2=ok Quali_KPI2=Not ok	64,000 11,000	91,429 64,706
Quanti_KPI11 the waiting time before the consultation in the supervision room Quanti_KPI4 The duration in supervision room by a patient	Quanti_KPI11=ok Quanti_KPI4=ok	Quanti_KPI4=ok Quanti_KPI11=ok	12,000 12,000	15,000 100,000

For instance, in Table 5.5, we chose two indicators (*Quali_KPI2* and *Quali_KPI8*). The confidence of this rule that contains both indicators is 0.91. A confidence of 91% means that 91% of the patients who were satisfied with *Quali_KPI2* also have a chance to be satisfied with *Quali_KPI8*. *Quali_KPI2* is consequent in the rule form, which can be used to determine which other measurements (*Quali_KPI8* in this example) should be associated with it, in order to have a high level of satisfaction. A support of 64% for *Quali_KPI2* = ok in the first association rule means that 64% of all the transactions under analysis show that patients are satisfied or very satisfied with the interest and attention brought by medical staff.

In Table 5.6, we present some indicators not previously designed in the ontology but they seem interesting according to the decision-maker opinion.

Table 5.6: KPI relationships discovered by the application of association rules

New KPI Relationships discovered by the application of association rules				
Related Indicators	**Antecednt**	**Consequent**	**Sup**	**Conf**
Quali_KPI1 Interest and attention brought by paramedical staff , Quali_KPI2 Interest and attention brought by medical staff	Quali_KPI2=Not ok Quali_KPI1=ok	Quali_KPI1=Not ok Quali_KPI2=ok	18,000 67,000	94,737 98,529
Quali_KPI7 The quality of care for patients by paramedical staff , Quali_KPI9 The clarity of information	Quali_KPI9=ok	Quali_KPI7=ok	18,000	90,000
Quali_KPI8 The quality of care for patients by medical staff , Quali_KPI9 The clarity of information	Quali_KPI8=Not ok	Quali_KPI9=Not ok	14,000	82,353
Quali_KPI3 Paramedical staff availability , Quali_KPI4 Medical staff availability	Quali_KPI4=Not ok	Quali_KPI3=Not ok	13,000	100,000
Quanti_KPI10 The duration of consultation by patient, Quali_KPI13 Installation in the sorting room	Quanti_KPI10=ok	Quali_KPI3=ok	11,000	91,667

Quanti_KPI18 The waiting time before the consultation in box, Quali_KPI2 Interest and attention brought by medical staff (doctor)	Quanti_KPI 18=ok	Quali_KPI2=Not ok	15,000	23,077
	Quali_KPI2=Not ok	Quanti_KPI18=ok	15,000	78,947
Quali_KPI9 The clarity of information , Quanti_KPI18 The waiting time before the consultation in box	Quanti_KPI18=Not ok	Quali_KPI9=ok	25,000	73,529
	Quali_KPI9=ok	Quanti_KPI18=Not ok	25,000	40,323

We reuse the ontology feature in the framework to edit the selected OWL file. So we open the appropriate OWL file designed in the first phase. Then, for example, we select *Quali_ KPI7*, to see the existing properties related to this table (see Figure 5.25). The user can also add a new link for a specific (name of the object property and the associated value) (see Figure 5.26). To take all changes in consideration the user must save the ontology in question (Figure 5.27).

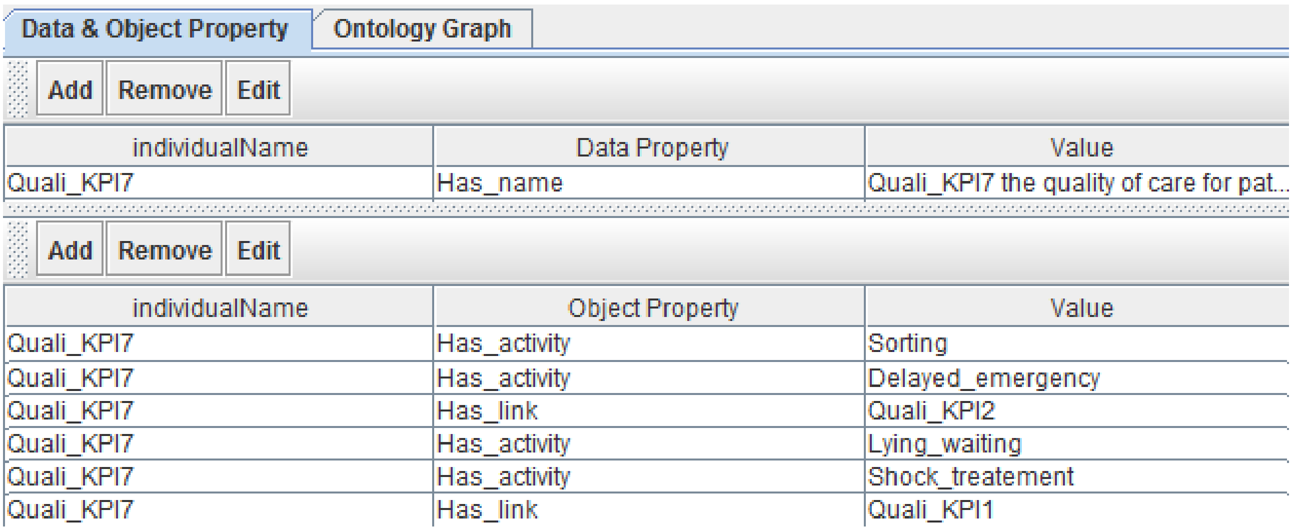


Figure 5.25: Screenshot of properties related to Quali_KPI7

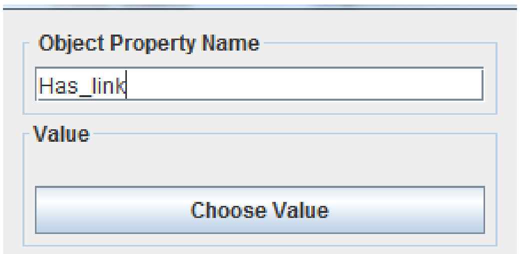


Figure 5.26: Editing properties

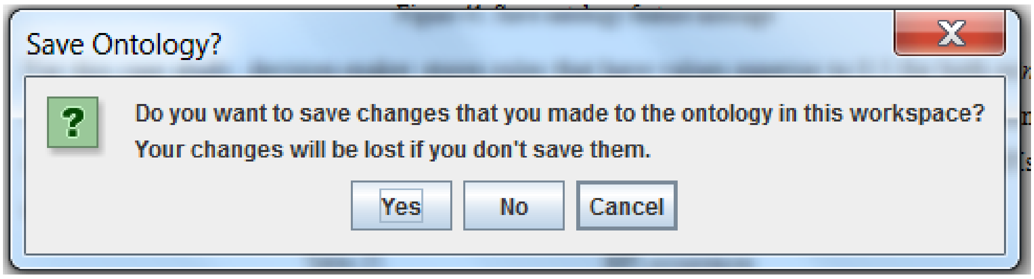


Figure 5.27: Save ontology feature message

For this case study, decision-maker stores rules that have values superior to 0.5 for both *min* confidence and *min* support. Based on the dataset, we remark that all generated rules contain indicators that are judged acceptable and meet the target values. Table 5.7 represents the KPIs occurrences retrieved from the KDB.

Table 5.7: KPI occurrences

Occurrence	**KPIs**
38	Quanti_KPI13 The waiting time per patient in all activities
36	Quanti_KPI14 The total time spent in the ED by the patient in all activities
36	Quali_KPI1 Interest and attention brought by paramedical staff
36	Quali_KPI4 Medical staff availability
36	Quali_KPI3 Paramedical staff availability
35	Quali_KPI5 Medical equipment availability
35	Quali_KPI2 Interest and attention brought by medical staff
35	Quanti_KPI15 The waiting time before consultation by the patient
34	Quali_KPI17 The overall waiting time before treatment by medical staff
34	Quali_KPI7 The quality of care for patients by paramedical staff
34	Quali_KPI8 The quality of care for patients by medical staff
32	Quanti_KPI2 The duration of sorting by patient

33	Quali_KPI13 Installation in the sorting room
28	Quali_KPI16 The overall waiting time before treatment by paramedical personnel
27	Quali_KPI9 The clarity of information
16	Quanti_KPI9 The waiting time before sorting

For example, the waiting time per patient in all activities respect the target values and it is presented in 38 association rules. Indicators with the highest number of occurrences will be considered as the most relevant. They may appear as antecedent or consequent. The number of occurrences of an indicator depends on the number of rules stored in the KDB for specific Apriori parameters. Because this number varies on the period of analysis, the number of patients involved, the number of rules stored, etc. We use our framework, to record this number under "has_ok" data property. The values of these two new properties are considered by the decision-maker to improve KPIs whether from past experience or research on promising practices. For example, for Quali_KPI13, (see Figures 5.28, 5.29 and 5.30) the user could update the corresponding details.

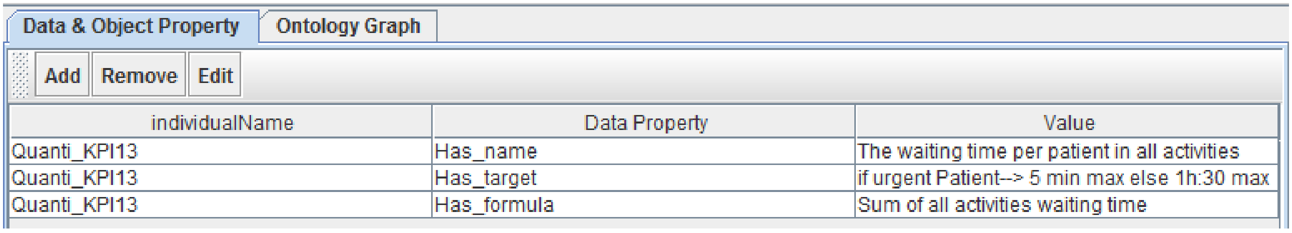


Figure 5.28: Quanti_KPI13 data properties

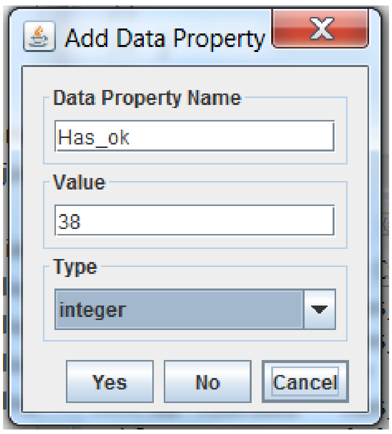


Figure 5.29: Adding new data property to Quanti_KPI13

Data & Object Property | Ontology Graph

Add | Remove | Edit

individualName	Data Property	Value
Quanti_KPI13	Has_name	The waiting time per patient in all activities
Quanti_KPI13	Has_ok	38
Quanti_KPI13	Has_target	if urgent Patient--> 5 min max else 1h:30 max
Quanti_KPI13	Has_formula	Sum of all activities waiting time

Figure 5.30: Quanti_KPI13 updated data properties

Because decision-makers need more than just a glossary to describe the aspects of BP, this KPI ontology is enriched with two data properties. In the following features, we identify the specific indicator that is expected to have an effect on other KPIs. After we add all new properties such as the occurrence of KPI (has_ok, has_not_ok) the link (has_link), we can update our *KPI* table. Based on *KPI* table (see Figure 5.31), the *temporal relationship* table will be filled automatically by comparing the occurrence among indicators. Figure 5.32 gives an overview of this table.

KPI_name	KPI_Properties	KPI_Values
Quanti_KPI5	Has_formula	end date - start date
Quanti_KPI5	Has_target	max 4 hours
Quanti_KPI6	Has_name	Quanti_KPI6 The duration of delayed emergency by p...
Quanti_KPI6	Has_target	max 10 min
Quanti_KPI6	Has_formula	start date of consultation - end date of sorting
Quanti_KPI7	Has_formula	sum of all activities duration
Quanti_KPI7	Has_name	Quanti_KPI7 The duration of all activities by pati...
Quanti_KPI7	Has_target	4 hours
Quanti_KPI8	Has_name	Quanti_KPI8 The waiting time before registration a...

Figure 5.31: A view of KPI table content in the KDB

first_KPI	rank	second_KPI
Quali_KPI1	OK_Occurence_Prior_To	Quanti_KPI2
Quali_KPI8	OK_Occurence_Prior_To	Quanti_KPI2
Quanti_KPI15	OK_Occurence_Prior_To	Quanti_KPI2
Quanti_KPI13	OK_Occurence_Prior_To	Quanti_KPI2
Quali_KPI17	OK_Occurence_Prior_To	Quanti_KPI2

Figure 5.32: A view of the temporal relationship table content in the KDB

The columns *first_KPI* and *second_KPI* are the two compared KPIs in question. The column *rank* may have 4 possible values. First, "OK_Occurence_Prior_to" when the *first KPI* has the number of occurrences (saved on *KPI_values* column in *KPI* table) under "Has_ok" (saved on *KPI_properties* column in *KPI* table) higher than the *second_KPI*. Second, "Ok_Occurence_Same_As" if the *first_KPI* and the *second_KPI* have the same occurrence under "Has_ok" property. Third "Not_OK_Occurence_Prior_To" in the case that the *first_KPI* has the number of occurrences (saved on *KPI_values* column in *KPI* table) under "Has_not_ok" (saved on *KPI_properties* column in *KPI* table) higher than the *second_KPI*. Fourth, "Not_Ok_Occurence_Same_As" if the *first_KPI* and the *second_KPI* have the same occurrence under "Has_not_ok" property. We give the user the possibility of having recommendations to make the improvement phase easier. The user can obtain recommendations by entering the name of the KDB which will contain all three tables and s/he obtains phrases in natural language (see Figure 5.33).

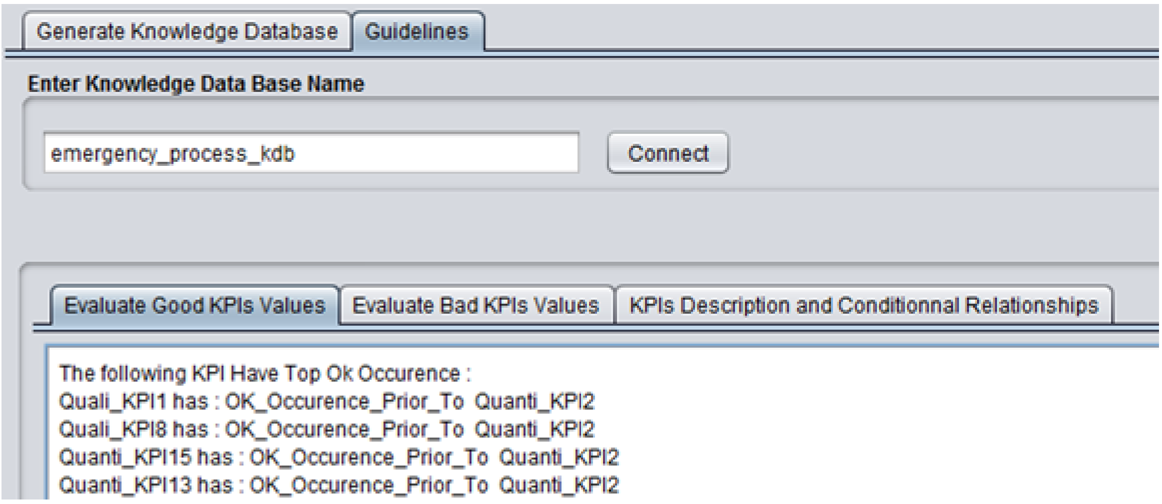


Figure 5.33: A view of some KPI guidelines retained from the KDB

For example, we can find KPIs comparison based on *temporal_relationship* table. We also can find a complete description of all information related to all KPIs based on *KPI* table (see Figure 5.34).

The starting point after updating the KPI ontology is to prepare the appropriate data set for process enhancement. A first file is based on the selection of the appropriate column in the event log retrieved from the *bamtasksummary* table and a second file is based on the combination of some columns retrieved from *processinstanceslog* table with the appropriate instances values retrieved from estimated KPI file.

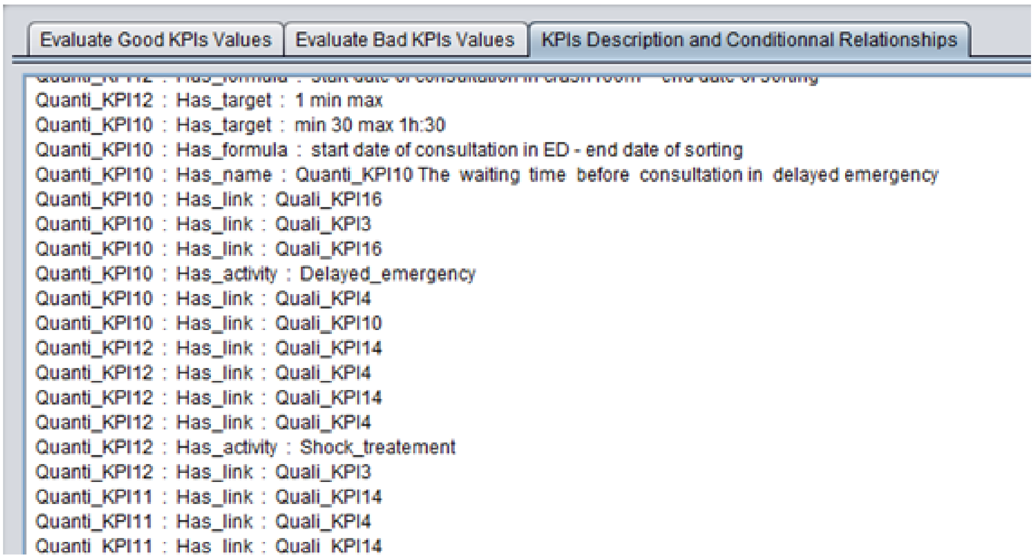


Figure 5.34: A view of some KPI description

These two files are necessary toward BP/ KPI improvement for the following reasons: jBPM logs (e.g. *bamtasksummarry* table and *processinstancelog* table) contain a set of traces where each trace is a sequence of events corresponding to a particular case. Based on the "log visualizer" in the ProM software, we especially focus on the "Summary" tab and we get the following visualization (Figure 5.35).

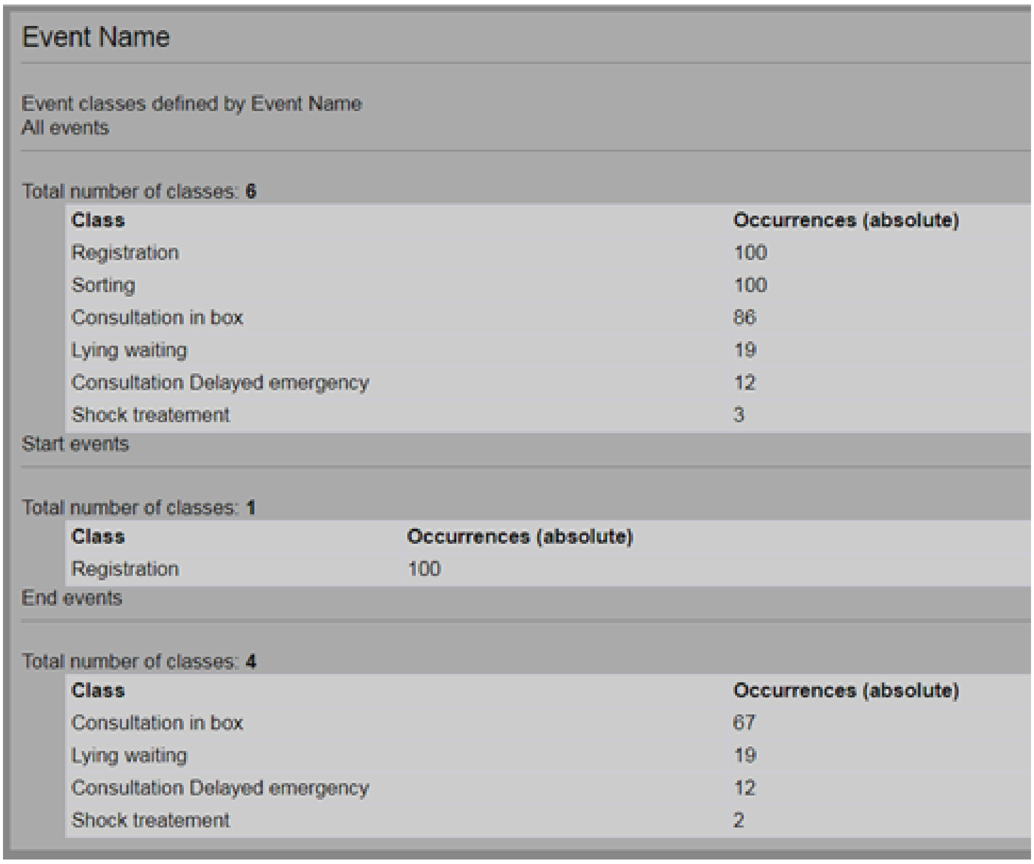


Figure 5.35: Screenshot of process log summary related to the emergency care process

The coloring of activities provided by the software is very important to see for example how frequently each activity occurs or the main paths of the process flow. Based on this view (Figure 5.36), we can see that all cases start with the registration activity. Afterward, all patients enter the sorting room for primary exams. In conclusion, we can say that the main process flows (67% of the log) contain 3 activities which are registration, sorting, and consultation in box. We can also see the events in a selected case to get a detailed view. For example, Figure 5.37 shows information related to the process instance id number 153.

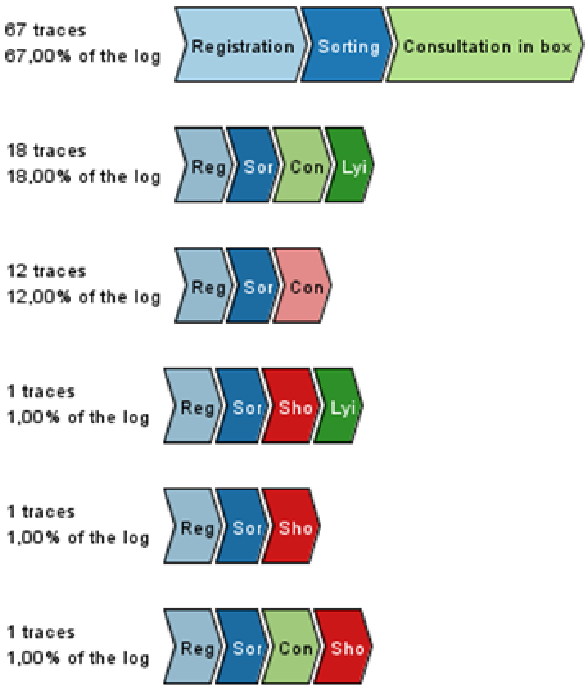


Figure 5.36: Screenshot of possible paths related to the emergency care process

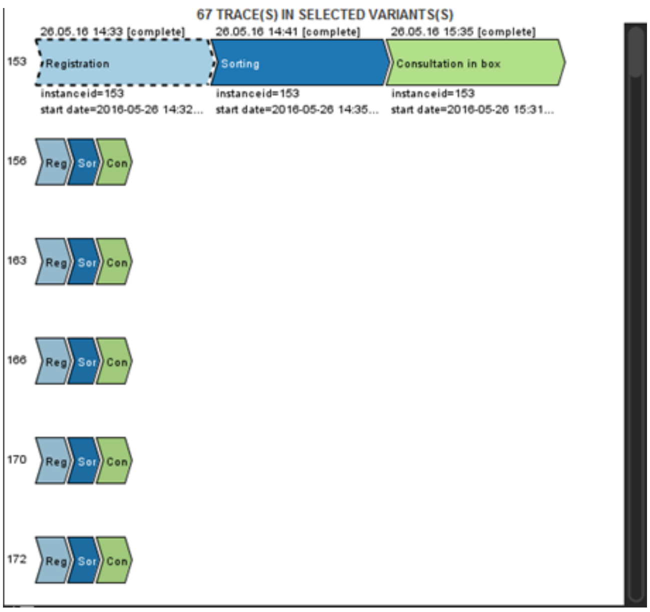


Figure 5.37: Screenshot of some cases related to the selected flow

Based on all available information, we can set the following points:

- The process takes too much time for patients who have a delaying emergency. Especially, it takes an important waiting time before the delaying emergency starts.
- The process takes too much time for patients who are oriented to the supervision room. Especially, it takes an important time to lying waiting activity to end.
- In some cases, the consultation activity takes too much time to end. When we review these observations with the process stakeholders, we conclude the following explanation:
- From the process manager view, patients who are in the delaying emergency can wait because they are not urgent.

For the considerable time occupation in the lying waiting activity, it is explained by the fact that the health of these patients is not stable. For the important time taken in the consultation in box, it is explained by the fact that some patients required complementary exams which are frequently made in other services in the hospital.

We proceed by using ProM software. In this step, we analyze KPI target values retained from KPI estimated file and we combine data with the appropriate rows and columns retrieved from *processinstancelog* table by using the same process instance identifier. After preparing the data set, we import the file into ProM. We can get further analysis by analyzing some links between indicators. For example, we analyze the level of satisfaction between *Quanti_KPI9* the waiting time before sorting with *Quali_KPI13* installation in the sorting room. The aim of this analysis is to check if the waiting time before sorting, respects business rules (i.e., evaluated as ok value), also we check if the qualitative indicators related to this quantitative indicator retained from patient experience are respected (i.e., satisfaction of the patient). To do that, we focus on log visualization to inspect some statistics about it.

In Figure 5.38, we can observe that 42% of patients are satisfied to very satisfied about their installation in the sorting room and the waiting time before sorting also respects the target value (ok value). The waiting time before sorting does not respect the target value for 23% of cases, however, patients are satisfied to very satisfied with their installation in the sorting room. We can also note that 16 % of cases have a neutral response about this qualitative aspect and the waiting time before sorting respects the target value. Now if we want to get some statistics in the case where the quantitative and the qualitative indicators are not respected, we can find 9% of the log file.

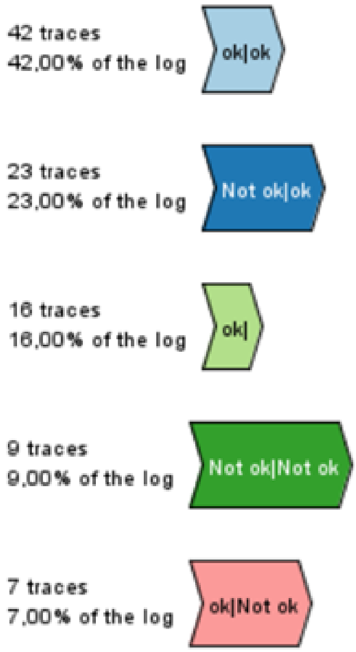


Figure 5.38: A screenshot of statistics related to Quanti_KPI9 with Quali_KPI13

We can inspect this statistic more deeply by browsing the set of cases in the log (Figure 5.39). For instance, we can obtain a detailed view including the corresponding process instances identifiers related to the case where the quantitative and the qualitative indicators are not respected (green color).

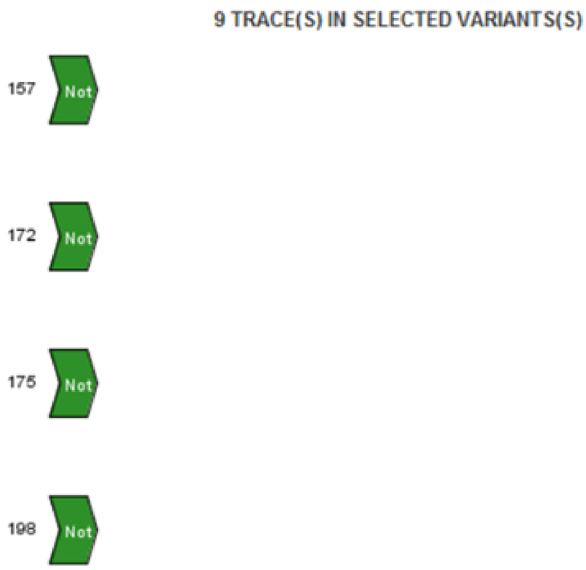


Figure 5.39: A screenshot of some process instances identifier related to selected variant

Using ProM and the appropriate file, we can combine as many attributes (indicators) as we want to get some interesting statistics that help the decision maker to evaluate the performance of the process. We take for example the combination of *Quali_KPI3* paramedical staff availability, *Quali_KPI4* medical staff availability and *Quanti_KPI9* the waiting time before sorting; we obtain the following traces (Figure 5.40).

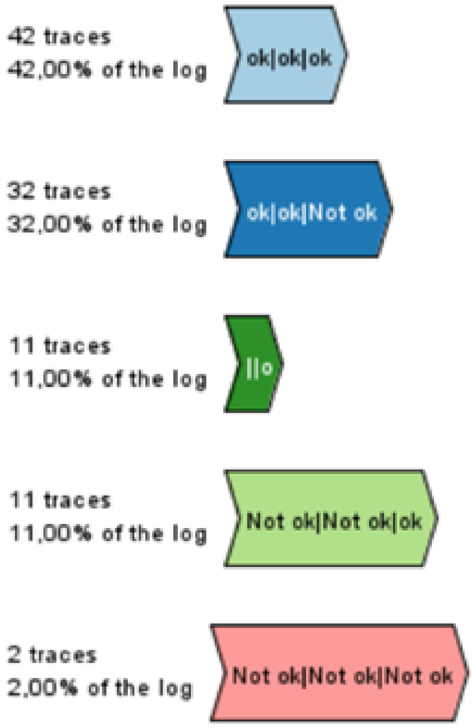


Figure 5.40: Statistics related to Quali_KPI3, Quali_KPI4, and Quanti_KPI9

Like the first example, we can browse cases to verify if there really exists some patient cases that attend less than 5 min before entering the sorting room (*Quanti_KPI9* the waiting time before sorting is ok). However, when they entered to the sorting room, neither paramedical staff nor medical staff is available (*Quali_KPI3* paramedical staff availability and *Quali_KPI4* medical staff availability are not ok). This case is infrequent, only 11% cases were found, but it is important to see concrete examples particularly for "strange" behavior and to help process stakeholder to find things that are hard to believe until they have drilled down to an individual example case.

To summarize, the majority of patients were satisfied during their experience in the emergency department and the majority of quantitative indicators respect the desired target values based on process instances recorded in the system. However, in rare cases, we observe some deviations. As an example, BP doesn't take too much time but patients already had a bad experience. For example, the delaying emergency duration respect the target value. However, patients are not satisfied about the clarity of information provided by doctors in this activity. Some patients are not satisfied in the lying waiting because the regularity of doctor visit is not adequate.

We can conclude that Process Mining software offers different views and different performance information for all activities of the process and resources included in the data set. Furthermore, data are usually very important for the process analysis, because they hold relevant context information and orient the decision-makers to set additional questions and goals, such as the following:

- Which type of patient category required more attention?
- In which activity the process was performing (respect the qualitative and the quantitative aspect)

We often need more attributes and more cases that are relevant and can be used in the analysis in order to respond to these questions. After discussion with patients and decision-makers we can state below some interesting observations:

- The privacy of the patient is not taken into account in the sorting room.
- The necessity of staff to orient the patient according to his/her healthcare status to the appropriate service location
- The necessity to have a system to ensure that data related to each patient (previous analysis, current healthcare status . . .) are collected consistently, both within, and across the healthcare departments. Similarly, diagnosis exam results are missing or overlooked and as a consequence appropriate treatment is delayed or repeated.

The main limitations in this case study are that on the one hand, we track a minimum KPIs dataset to monitor the health of this BP. However, we know that when we have in place a system, we can track more than 100 patients per day, and analyze intensive information. On the other hand, the duration of consultation in box may be long for some instances and for others it may have a maximum duration of 10 minutes. This is because the medical staff demands the patient to do some complimentary exams in other healthcare departments. In this way, we cannot have access to assist the patient in other services and in turn to develop additional indicators related to other healthcare processes in other departments. As a consequence, we wait when the patient gets his/her complimentary exams and return to the consultation box. We can say that the evaluation has to be updated and validated based on the huge volumes of data every day.

By reviewing identified performance in this process and behavior problems stated by the patient, we can add other indicators related to the measurement of satisfaction while respecting the privacy of patients during communication, the waiting time during staff change. The evaluation towards improvement includes specific performance analysis and observation of improvements expected by patients. The guidelines intended as a resource for all stakeholders, including service users, but more specifically, decision-makers who are responsible for developing KPIs and associated target values and for keeping the optimal level of healthcare quality. Globally, improvement suggestions are essential for this process, as they enable patients and healthcare providers to effectively identify where the performance of healthcare services requires improvement.

5.7 Conclusion

In this chapter we illustrate the application of the proposed approach in a real scenario. After obtaining our experimental results in the EC case study, we can say that KPIs synthesis provided from each step in the KPIMgtAssist approach provide meaningful results. These results constitute initial steps toward the improvement that generates open discussion between all stakeholders, including corrective and constructive feedback.

Chapter 6

KPIMgtAssist Application in Higher Education Case Study

6.1 Introduction

In this chapter, we explicitly describe the way in which each step of our KPIMgtAssist approach was conducted in the higher education field. In section 6.2, we present our application domain. In sections 6.3, 6.4, 6.5 and 6.6 we illustrate the main results from our framework and other means used in each phase of KPIMgtAssist approach. In section 6.7, we briefly discuss our framework support. In section 6.8, we conclude this chapter.

6.2 Higher Education Application Field

Higher education is a service organization composed of a set of interrelated BPs from which many students can develop their knowledge at a higher level.
We acknowledge that the processes we advocate form a small part of a much larger BP in this field. But we believe that selecting the right master candidate is an important first step in a successful Master's program. In the Tunisian higher education institutions, Master's SIAD program is typically offered as 'second-cycle' qualification, taking place after undergraduate study which can be an applied license or fundamental license ('first-cycle' LMD 3 years) and prepares students for more advanced 'third-cycle' work at the PhD level. This process also offers partial exceptions to students who have a professional Master's degree or engineer's degree (5 years) to join the graduate study at a master level degree. Process activities differ from one institution to another. In our study, we focus on the selection of undergraduate study candidates in the higher institute of management. We consider that generic practices of selection in higher

education institutions are no longer sufficient for the improvement of the BP. Nowadays, several universities are facing the issue of the candidate selection process. The reality has demonstrated that the administration in some universities has already found difficulties to fulfill the selection process expectations in a reasonable time and with an acceptable cost without considering the student's satisfaction aspect. In this case study, there are many considerations that we should always keep in mind:

- Select the most important quantitative KPIs related to BP. For example, improving the time it takes to notify candidates about the final results is a process improvement which may improve learning because the research Master's program can start on time.
- Select the most important quantitative KPIs from the administrative file. For example, the minimum score retained from pre-registered candidates which may represent revisable, reviewable or reusable indicators. The improvements using this indicator can guarantee the high qualification of the student and then the quality of the dissertation in the final year of such program.
- Select the most important qualitative KPIs related to students' experiences such as the questions are unclear or discussion does not serve a purpose during the interview.

The improvement of qualitative indicators may increase the time spent on relevant issues and increase in-depth questioning and discussion.

6.3 Design of Candidates' Selection BP

In this section, we provide a description of the first phase in BPM life-cycle and present its corresponding phase of KPIMgtAssist approach for the candidates' selection BP.

6.3.1 Candidates' Selection Process Design

There are two main stakeholders in this BP (Figure 6.1): first the candidate and second the Master's committee.

At the design time, we use a graphical container named "pool" for partitioning a set of tasks from other pools. This BP might start in the Master's committee pool that announces the Master's degree opening. Then, the candidate pool might start the online pre-registration. After that, the Master's committee calculates scores for each candidate and decides which candidate is pre-accepted (or not). As soon as the notification date is due, the candidate checks the preselection result. At this level, if the candidate is accepted s/he is invited to an interview. The interview task sets up the profile of an ideal master candidate. Thereafter, the Master's committee calculates the final scores of each candidate and notifies the selected candidate. There are two cases which end this process: If the candidate is accepted, then the Master's committee prepares the final list of accepted candidates. Else, the candidate is rejected.

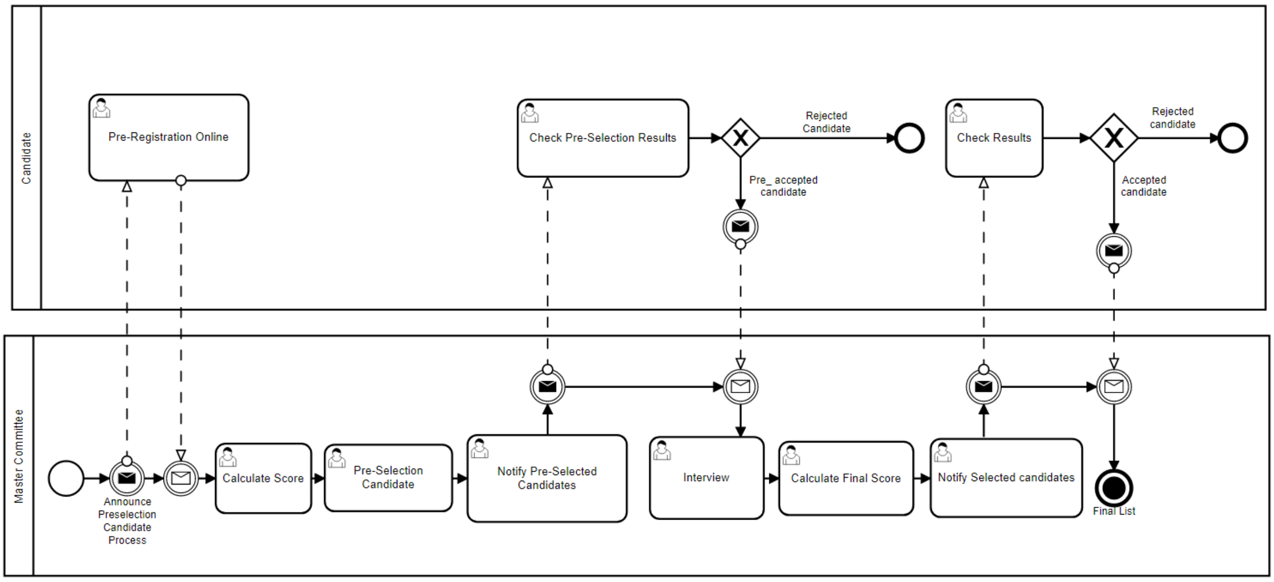


Figure 6.1: Candidates' Selection process

In fact, this process aims to match the appropriate students who have a license diploma from the higher institute of management or from other institutes to join information system for decision support (SIAD) Master's degree in the higher institute of management. This can be achieved while reducing the waiting time in the BP and improving the quality of interviews from the point of view of the interviewed candidates.

The main activities of the candidates' selection process are semi-automatic business activities performed by a Master's committee with the support of an IT system. This kind of activity is typically implemented by an application that exposes a graphical user interface. Moreover, defining KPIs is the next important step after describing the BP model because the next question is: how can we monitor and measure this process to make sure it is achieving a key business objective?

6.3.2 KPI definition for Candidates' Selection BP

After understanding the core BP requirement and to measure BP improvements we can use various KPIs. The choice of KPIs involves domain experts and they should reflect the three main objectives of the BP. First, for the candidates' selection process performances such as knowledge, skill, and other abilities, we can measure this objective from the score calculated for each candidate. Second, increasing process efficiency through the extraction of possible indicators from logs to ensure that the processes still meet the goals. For example, we can measure time using cycle time, waiting time and resource utilization. And third, increasing student satisfaction, by evaluating the BP using qualitative indicators to ensure that this process meets the needs and expectations of the students. For example, indicators related to a qualitative evaluation of SIAD Master's degree interview.

By measuring this type of indicators, it is expected that bottlenecks in the BP are discovered and hence can be solved. Typical indicators belonging to this domain are waiting time and time between two activities e.g. interview activity and notification activity. In this case study, the duration of some activities, for example, that of the pre-registration activity is not important regarding the business goals. More specific indicators related to the right choice of the available candidate are critical and play an important role in reaching business goals. Hence, the main objectives of a personal selection process are to evaluate the differences among candidates and to select the right candidate.

Therefore, we advocate a focus on the global indicators e.g. min score retained rather than on its detailed measures e.g. indicators related to good degree results in undergraduate studies. In fact, we determine the level of detail of our indicators according to the strategic objective of the BP. For this, a generic indicator would be enough and it makes sense to select the candidate, as long as it is possible to distinguish value-adding from nonvalue-adding during the score retained, first, from pre-selection activity based on proof of academic qualifications, and second, during the score retained based on the interview activity. These two indicators provide a baseline profile of the knowledge and skills of students. Once the committee member decided which candidates are accepted, a more concrete measurement of knowledge is required for conclusive evidence. For this reason, we set qualitative indicators related to the experience of students during the interview.

This kind of qualitative indicators may be more difficult and time-consuming to quantify. For this reason, we use a Likert scale for the five first questions to evaluate student satisfaction. The rest of the indicators play a much more integrative role for the improvement of BP from candidate experience surveys.

The main advantage of setting these indicators is to help Master's committee to understand the shortcomings in the business processes from another point of view and to make sure to get an unbiased decision e.g. be sure for each candidate interview, that there are at least one experienced member and a person who does not have an interest in selecting the candidate. These qualitative indicators open feedback and input from other actors as well as the ability to collaborate, negotiate in an understandable and effective way.

As we can see, the candidates' selection process is a process with a certain number of KPI, all of which may contribute to improving it. The problem is not deciding on the criteria for the best possible candidate beforehand because this is related to Higher Education Institutions rules, practices, and guidelines for matching appropriate students to a specific Master's degree and also related to the evaluation of experts based on interviews and competency profiles to rank candidates.

As for the first case study, we start by adopting the AHP method and SMART criteria. In the following sub sections we describe the pairwise comparison and revision of quantitative KPIs under each criterion, the pairwise comparison of each SMART criterion under the goal, and the pairwise comparison and revision of qualitative KPIs under each criterion.

A. Pairwise comparison and revision of quantitative KPI under each criterion

At this stage, the goal of applying the AHP method and the revision process is to discover which KPI is the most important in the candidates' selection process. In turn, we can validate, discover, or add other indicators previously defined. For example regarding the min score retained from a preregistered candidate, we can ask some questions like: is it necessary to have an indicator related to max score or the average score? what's more important is having the min score from all pre-registered candidate or having them filtered by the specific undergraduate study (e.g. applied license, fundamental license) or may be filtered by the institute (e.g. candidate preregistered from another institute). In this way, the revision process when setting KPIs weight in the pairwise comparison helps business analysts and expert analysts in keeping a proper improvement plan for current and future indicators measurements.

In realistic criterion, the Master's committee is interested in all indicators related to the fact that the work is well done because it will reflect the quality of the selection of candidates. So, they give more importance to the minimum score retained than the number of candidates. As we can see, the min score retained from preregistered candidates is in the first rank because all other indicators depend on this indicator (e.g. the number of all preselected candidates depends on this min score retained). The min score retained from pre-accepted candidates is also equally important because it has an influence on the number of interviewed candidates and in turn on the number of final selected candidates. If the min score and the number of candidates are relevant, then the third group of rated indicators are the waiting time between two fixed activities and the max of the candidates' selection process duration.

Now let's move on to set preference under "Specific" criterion, for example, the indicator related to the number of pre-selected candidates who have a fundamental license is moderately more important than the indicator related to the min score retained from a preregistered candidate because this indicator is not clear enough and maybe it needs a reformulation in reviewing indicators step. For example, if this indicator is generic, we can adopt "the min score retained from a preregistered candidate who has a fundamental license". Figure 6.2 shows an example of a comparison between two indicators. We can see that the waiting time from interview activity to the notification activity is moderately more important than the indicator related to the min score retained from the pre-accepted candidate. This indicator is not clear enough about the pre-accepted candidates e.g. is this candidate from the higher education institution or from other institutes? Is the candidate holding an applied license or fundamental license?

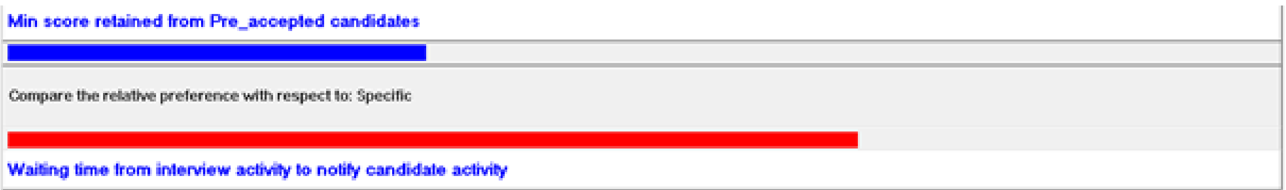


Figure 6.2: Comparison between two indicators under "Specific" criterion

Quantitative indicators retained from administrative files have a mathematic formula and quantitative indicators related to the BP execution can be retrieved using SQL based on the available jBPM logs. For example, the number of preselected candidates can be associated with the number of instances, since an instance of candidates' selection process represents a candidate. The number of candidates is used in many indicators with different requirements based on condition e.g. candidate accepted or based on data element defined in the task forms when modeling the BP and stored in jBPM logs e.g. set in the pre-registration task if the candidate has a fundamental license. All quantitative indicators are measurable. Therefore, they are equally important.

KPIs must be associated with target values, i.e., it is important to set the target value from the time the preselection is started to the time it is approved or rejected. These targets should be determined in line with BP goal.

Under the "Attainable" criterion, it is easier to determine if the targets of indicators are acceptable and reachable. Higher education institutions should respect the target values announced about the notification results. For this reason, indicators related to time dimension are the first highest ranked group. Then the number of preregistered candidates is the fourth-ranked indicator. For example, the min score retained from pre-registered candidates is moderately more important than the indicator related to the number of preregistered candidates because we can set and change the min score based on academic proof of the available preregistered candidates but we cannot set a fixed target value about the number of preregistered candidate i.e., every undergraduate student has a chance to join the Master's degree. According to the situation, the target value of the number of preselected candidates and the min score retained can be adjusted according to the available preregistered candidates number. In fact, we can set a reasonable min score in the preselection activity. In turn, this min score gives an overview of the respectable number of candidates called for the interview. Based on the available interviewed candidates, the Master's committee sets the target value to calculate the final score of the accepted candidates. Based on the final ranked list, we try to answer questions such as how to improve the process in order to meet the KPIs targets values?.

The Time-based criterion help business analysts in defining indicators, for example, which is the most important? is it having an indicator which indicates the average, the *min* or the *max* process duration?. So, after setting this indicator under time-based criteria, we change this indicator from the average to the *max* process duration. Also, we add 3 additional indicators related to resource utilization e.g. Number of personnel assigned to the pre-selection activity which has a great influence on other indicators to complete in time.

The human resources assigned in the first two phases in "Master's committee pool" is the highest-rated indicator because this indicator is more time-sensitive than the others. This importance is justified by the fact that any resource utilization or waste during the process execution has a direct impact on BP time cycle. Then, if we manage and respect the limited time-span of the first 4 activities for completion, it will have a great influence on the time completion of the other activities, and as a consequence, an influence on the process duration. Having recorded all responses, AHP synthesizes the priorities of alternatives with respect to each SMART criterion. The result is given in Figure 6.3.

Min score retained from Preregistered candidates who has a fundamental license	,041
Min score retained from Preregistered candidates who has a Applied license	,041
Min score retained from Preregistered candidates who has a fundamental license from other institutes	,040
Max waiting time from pre-registration online activity to notify candidate activity	,039
Max waiting time from interview activity to notify candidate activity	,039
Max process duration	,039
Min score retained from accepted candidates (after interview) who has a fundamental license	,039
Min score retained from accepted candidates who has a Applied license	,039
Min score retained from accepted candidates who has a fundamental license from other institutes	,039
Number of personal assigned in the calculation score activity	,038
Number of personal assigned in the pre-selection activity	,037
Number of jury during the interview	,036
Number of accepted candidate before administrative registration	,036
Number of candidates on the waiting list	,036
Number of newly registered candidates in first level SIAD master degree	,036
Number of candidates who repeat M1	,036
Number of registered candidates in second level SIAD master degree	,036
Number of abundant Candidates	,036
Number of graduated candidates	,036
Number of all Pre-registred candidates	,035
Number of all Preselected candidate who has a fundamental license	,035
Number of all Preselected candidate who has a applied license	,035
Number of all Preselected candidate who has a fundamental license from other institutes	,035
Number of all interviewed candidates	,035
Number of final selected candidate who has a fundamental license	,034
Number of final selected candidate who has a applied license	,034
Number of final selected candidate who has a fundamental license from other institutes	,034

Figure 6.3: AHP synthesis

B. Pairwise comparison of each SMART criterion under the goal

The "Realistic" criterion is more important than other criteria because it is important to be sure about the value, of an indicator e.g. Ensure that qualitative indicators (questions) will give a Master's committee the information that they need in the evaluation and the improvement of the BP. The "Specific" criterion is ranked as the second because indicators should be clear about the main aims of the BP and understandable by the candidate, with as little ambiguity as possible. "Attainable" is the third-ranked criterion because it's necessary to take into account which satisfaction aspect must reach the desired value. The "Measurable" and "Time-based" criteria are less moderate than the other criteria because it is not easy to quantify qualitative indicators and it is unnecessary to have a time frame for completion because all indicators were treated during the interview activity.

C. Pairwise comparison and revision of qualitative KPIs under each criterion

Now we move to the adoption of the AHP method and SMART criteria for qualitative indicators and we focus and describe some AHP steps as follows:
Once we have SMART criteria ranked, we must check the first suggested questions (qualitative indicators) in order to come up with an action plan of how the Master's committee can improve the BP.

When setting KPI weight under "Relevant" criterion, we try to answer a question such as: does this indicator help to better understand BP situation?
In the realistic criteria, the Master's committee is interested in all indicators, related to the questions during the interview, which are aligned with master's degree plan and with the appropriate amount of time to respond to each question. In this way, these indicators are moderately more important than other qualitative indicators.

To compare indicators under "Specific" criterion, we check whether the question is clear for the candidate and whether it adds insight and understanding for the master's committee. After comparing all qualitative indicators, we conclude that they are equally important.

All qualitative indicators are equally important under "Time-Based" criterion because the satisfaction evaluation was carried out at the same time frame.

For the comparison under "Measurable" criterion, some qualitative indicators can be measured by another indicator. For example the time of response for each question, the installation during the interview (e.g. number of the available desks, chair, opened windows).

All qualitative indicators are equally important under "Attainable" criterion because the master's committee should take into account the satisfaction of the candidate to improve the quality of the offered service.

After reviewing the primary list of performance measures obtained, Tables 6.1, 6.2 and 6.3 show the SMART KPI list.

Table 6.1: List of qualitative indicators

Qualitative Indicators
Is an appropriate amount of time provided for each question during the interview? How are the interviewers' communication skills during the interview? about your installation during the interview? the questions during the interview aligned with the master's degree plan? Is the atmosphere in which the interview is conducted encouraging not only to give answers but also to ask questions?
- Have you noticed any task during the preselection process that was done unsafely (incorrectly)? How did you discover it? - Describe how the process can best be performed. - Did you know what criteria you were assessed against? Do you consider that the selection was fair?

Table 6.2: List of quantitative indicators from administrative files

Quantitative indicators from administrative files		
Indicators	**Formula**	**Target Value**
Min score retained from Preregistered candidates who have a fundamental license	Average of the first undergraduate study+ 1,5*Average of the second undergraduate study+1,5*Average of the third undergraduate study - 3*the number of control session - 5 * number of repeating in the undergraduate study years	Min 45

Min score retained from Preregistered candidateswho have an Applied license		Min 53
Min score retained from accepted candidates (after the interview) who has a fundamental license	Min score retained from Preregistered candidate + note of accepted candidate during the interview	Min 60
Min score retained from accepted candidates who have an applied license		Min 62
Min score retained from accepted candidates who have a fundamental license from other institutes		Min 68
Number of personnel assigned to the calculation score activity		Min 3 personnel
Number of personnel assigned to the pre-selection activity		
Number of the accepted candidate before administrative registration		Min20 Max 25
Number of candidates on the waiting list		Max 5
Number of newly registered candidates in first level SIAD Master's degree		Min20 Max 25
Number of candidates who repeat M1		Max 1
Number of registered candidates in second-level SIAD Master's degree		Min20 Max 25
Number of abundant candidates		Max 1
Number of graduated candidates		Min 20 Max 25

Table 6.3: List of quantitative indicators from process execution

Quantitative indicators from process execution		
indicators	**Related table(s) to Formulate SQL**	**Target Value**
Number of all Pre-registered candidates	Total number of instances From *processinstancelog* table	-
Number of all Preselected candidates who have a fundamental license	From *variableinstancelog* table and *bamtasksummary* table	Max 40
Number of all Preselected candidates who have an applied license		Max 6
Number of all Preselected candidates who have a fundamental license from other institutes		Max 20
Number of all Pre-selected candidate		Sum 86
Number of all interviewed candidates		Max 86
Number of final selected candidates who have a fundamental license		Max 18
Number of final selected candidates who have an applied license		Max 3
Number of final selected candidates who have a fundamental license from other institutes		Max 5
Waiting time from pre-registration online activity to notify candidate activity	From *bamtasksummary* table (start date–end date)	Between [min 7 days, max 20 days]
Waiting time from interview to notifying the candidate		Max 2 day

Process duration	From *processinstancelog* table	Max 42 day
Number of members during the interview	From *bamtasksummary* table	Min 6 academic personnel

6.3.3 Ontology Design and Population for Candidates' Selection BP

Using the Protegé editor, we follow the same class hierarchy. The main difference concerns the creation of appropriate instances and setting data/object properties values related to the candidates' selection process. Figure 6.4 shows the proposed ontology.

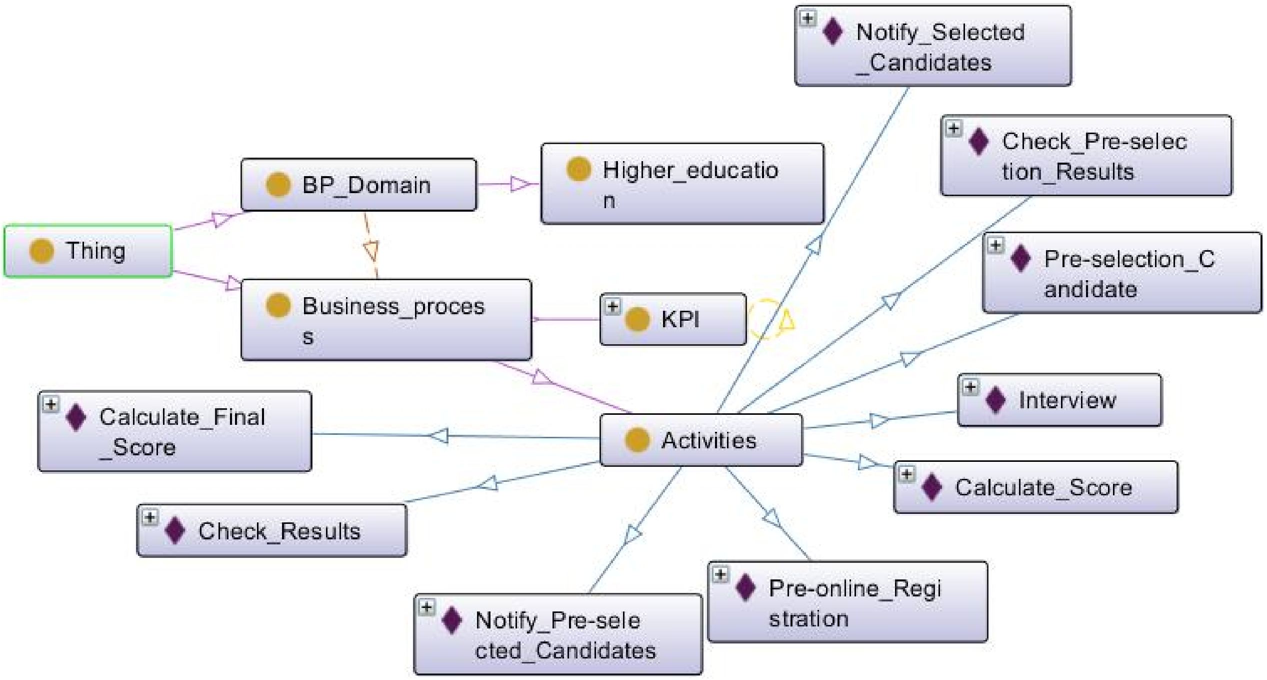


Figure 6.4: KPI ontology related to candidates' selection BP

Tables 6.4 and 6.5 summarize the main links between indicators established by an expert of the higher institution domain. For example, if the min score retained before and after the interview is high, then the number of candidates who left has a high chance to be minimum and as a consequence, the number of candidates obtaining their diploma has a big chance to be high. When the number of preselected candidates is as high as the number of interviewed candidates, then the number of the accepted candidates at the end of this process is as high as the number of candidates in the waiting list. When the global process duration (duration of each activity and its waiting time) is minimum then the global satisfaction of the candidate is high. As a consequence, when the global satisfaction is high the number of administrative registration is high.

Table 6.4: Main links between quantitative indicators

Quantitative KPI name	Related Quantitative KPI
Quanti_KPI9 Min score retained from preregistered candidates who have a fundamental license Quanti_KPI10 Min score retained from preregistered candidates who have an a license Quanti_KPI11 Min score retained from preregistered candidates who have a fundamental license from other institutes Quanti_KPI12 Min score retained from accepted candidates (after the interview) who have a fundamental license Quanti_KPI13 Min score retained from accepted candidates who have an applied license Quanti_KPI14 Min score retained from accepted candidates who have a fundamental license from other institutes	Quanti_KPI25 Number of candidates who left Quanti_KPI26 Number of candidates obtaining their diploma.
Quanti_KPI1 Number of all Preselected candidates who have a fundamental license Quanti_KPI2 Number of all Preselected candidates who have an applied license Quanti_KPI3 Number of all Preselected candidates who have a fundamental license from other institutes	Quanti_KPI4 Number of all interviewed candidates

Quanti_KPI4 Number of all interviewed candidates	Quanti_KPI20 Number of accepted candidates before administrative registration Quanti_KPI21 Number of candidates on the waiting list

Table 6.5: Main links between qualitative indicators

Quantitative KPI name	**Related Qualitative KPI**
Quanti_KPI22 Number of newly registered candidates in first level SIAD Master's degree Quanti_KPI16 Max waiting time from the online pre-registration to notifying Quanti_KPI15 Max waiting time from the first notification to second notification of candidate candidates Quanti_KPI8 Max process duration Quanti_KPI17 Number of the jury during the interview	Quali_KPI7 Global candidate satisfaction

6.4 KPIs Values Determination and Relationships Configuration

In this section, we present the main features of the framework related to the selection candidate case study. For example, after, the user clicks on "Quantitative" subclasses, s/he gets all qualitative indicators belonging to this subclass (see Figure 6.5). By clicking on the selected individual, s/he gets all data properties and object properties displayed in a separated table (see Figure 6.6).

The only table which is partially filled at this stage is the KPI table (Figure 6.7). On the one hand, it is the only one because it contains the KPI name (has_name data property value for each individual belonging to KPI class) which will serve later as an input to fill the appropriate KPI real values. On the other hand, it is partially filled because it will later complete with all approved object properties (before and after applying the Apriori algorithm) by the decision-maker.

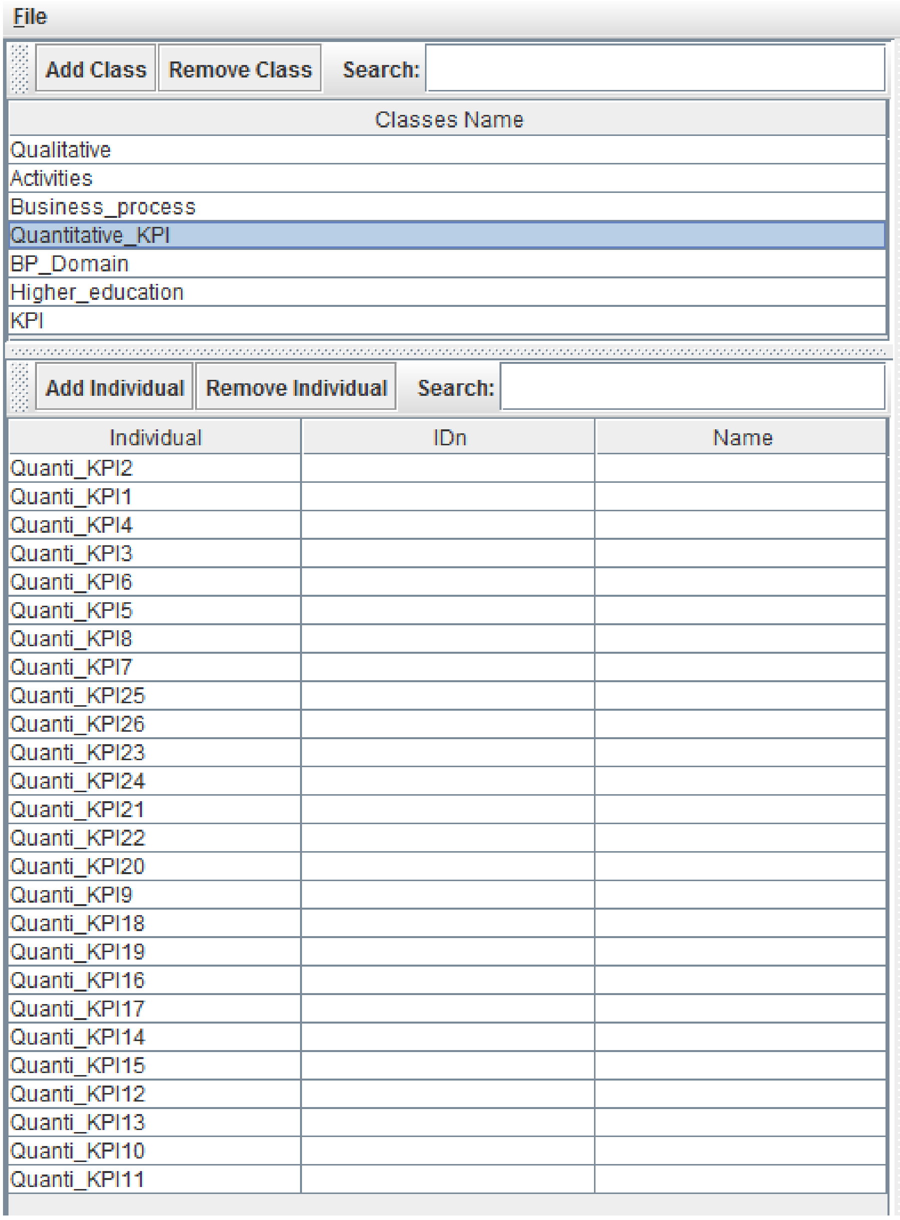


Figure 6.5: Loading individuals related to Quantitative KPI class

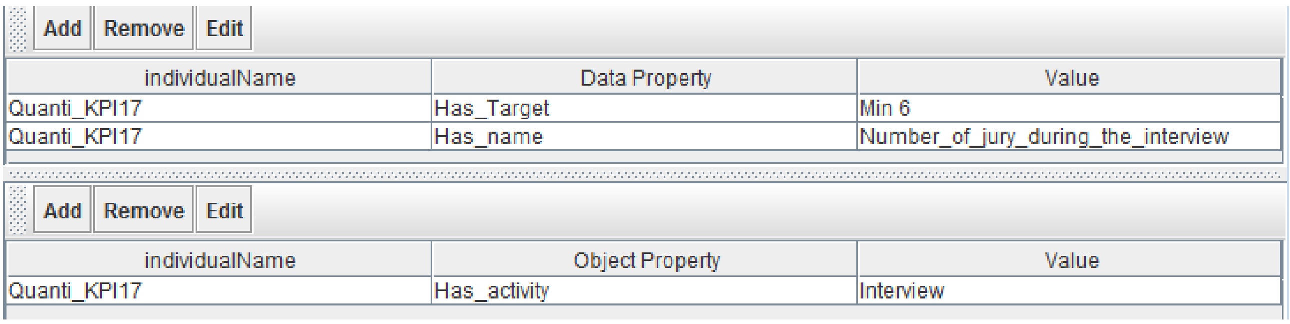


Figure 6.6: Loading properties related to *Quanti_ KPI17*

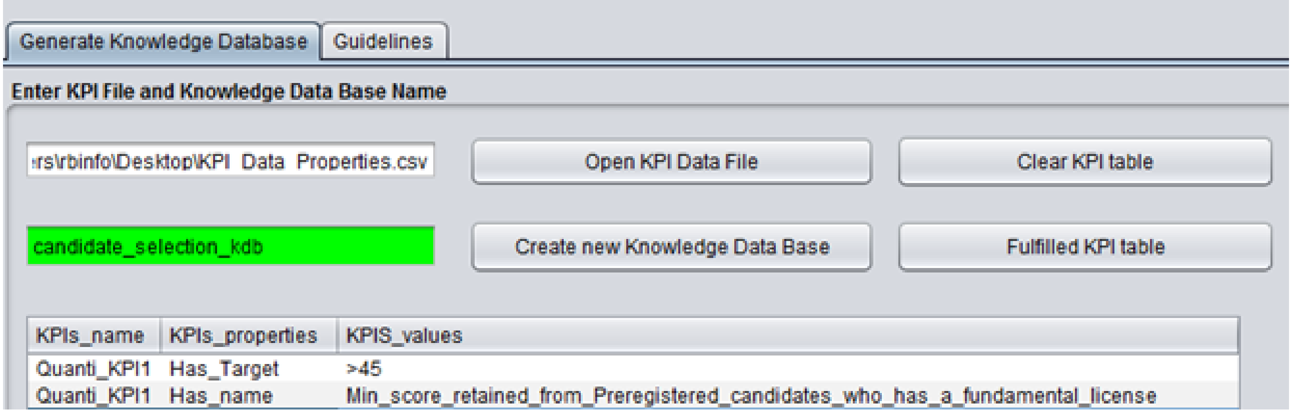


Figure 6.7: KDB filling

Figure 6.8 shows an overview of *KPI* table at this stage. The first column contains the name of the individual, the second column contains data type property name and the third column contains all values for each property.

KPI_name	KPI_Properties	KPI_Values
Quanti_KPI2	Has_name	Number_of_all_Preselected_candidate_who_has_a_appl...
Quanti_KPI2	Has_Target	Max 6
Quanti_KPI1	Has_Target	Max 40
Quanti_KPI1	Has_name	Number of all Preselected candidate who has a fund...
Quanti_KPI4	Has_Target	Max 86
Quanti_KPI4	Has_name	Number_of_all_interviewed_candidates
Quanti_KPI3	Has_name	Number_of_all_Preselected_candidate_who_has_a_fund...
Quanti_KPI3	Has_Target	Max 20
Quanti_KPI6	Has_name	Number_of_final_selected_candidate_who_has_a_appli...
Quanti_KPI6	Has_Target	max 3
Quanti_KPI5	Has_name	Number_of_final_selected_candidate_who_has_a_funda...
Quanti_KPI8	Has_Target	max 42 days
Quanti_KPI8	Has_name	max_waiting_time_from_pre-registration_online_acti...
Quanti_KPI7	Has_Target	max5
Quanti_KPI7	Has_name	Number_of_final_selected_candidate_who_has_a_funda...
Quanti_KPI25	Has_Target	max 1
Quanti_KPI25	Has_name	Number of abundant Candidates

Figure 6.8: A view of KPI table content

6.5 Enactment of Candidates' Selection BP

In this case study, there are also many challenges for the following factors.

The first challenge, although the BPMS logs are not available, the process must have generated at least 300 process instance ids (candidates) because the first activity in the BP concerns the online preregistration, and this preregistration may include any candidate who wants to join the Master's degree.

For the second challenge, like in the first case study, not all candidates accept to respond to the questionnaire.

The third challenge is that we are dealing with two kinds of indicators: basic indicators related to candidate instances and aggregated indicators related to many candidate instances or many activities. These indicators cover many data sources (not like the first one which focuses especially on indicators related to process performance indicators) in which we must record from an administrative file (statistic, report) all possible KPI data.

For the Fourth challenge, related to the main objective of this BP, concerns the fact that we are obliged to deal with another indicator which is not directly gathered during the execution of selection candidates' process. For example, regarding the objective of this BP which is mainly focused on the selection of the appropriate candidate to join the Master's degree, we were obliged to have additional indicators (like the number of registered candidates or the number of candidates obtaining their diploma) after the end of the current BP. These new indicators are very important in the evaluation of the candidates' selection process for further improvement.

This improvement may not have a direct impact on current university years but in the following years. For this reason, we must get all possible KPI values from as many university years as possible. For the fifth challenge, we remark that all quantitative indicators are aggregated, which makes the BP execution for each process instance (candidate) for each university year very difficult. For this reason, candidates' selection process model is deployed with the use of jBPM software only for the 2017-2018 university year, where 22 preregistered candidates have another diploma (engineering, or another Master's degree); 98 preregistered candidates have fundamental licenses from other institutes; 76 preregistered candidates have applied licenses from other institutes; 68 preregistered candidates have no confirmed diploma; 103 candidates (Applied license and fundamental license) are from the higher institute of management. This study was conducted over 40 days (from 18 July 2017 to 27 out 2017) in the higher institute of management on sousse.

6.5.1 BP Enactment

As mentioned before, the process execution covers only the current university year. After the deployment of the BP, we enter the different process instances related to this year. Figure 6.9 displays a screenshot of *Variableinstancelog* table. An overview of the process execution instances for some tables is shown in Appendix B.

processid character varying(255)	processinstanceid bigint	value character varying(2	variableid character varying(255)
Selecting.Candidates	726	L.A	Diplome
Selecting.Candidates	726	[redacted]	Name candidate
Selecting.Candidates	726	Institut Supéri	Institute
Selecting.Candidates	727	L.A	Diplome
Selecting.Candidates	727	[redacted]	Name candidate
Selecting.Candidates	727	ISET Sousse	Institute
Selecting.Candidates	728	L.A	Diplome
Selecting.Candidates	728	[redacted]	Name candidate
Selecting.Candidates	728	Institut des Ha	Institute
Selecting.Candidates	729	L.F	Diplome
Selecting.Candidates	729	[redacted]	Name candidate
Selecting.Candidates	729	Faculté des Sci	Institute
Selecting.Candidates	730	L.A	Diplome
Selecting.Candidates	730	[redacted]	Name candidate
Selecting.Candidates	730	Faculté des Sci	Institute
Selecting.Candidates	731	L.F	Diplome

Figure 6.9: Screenshot of Variableinstancelog table

After preprocessing all necessary data sources to trackback previous university years, we present in Table 6.6, the KPIs list and corresponding KPIs real values for each university year.

Table 6.6: KPI real values for each university year

KPI	**2017-2018**	**2016-2017**	**2015-2016**	**2014-2015**	**2013-2014**	**2012-2013**	**Target value**
Quanti_KPI9 Min score retained from Preregistered candidates who have a fundamental license	45	45.18	40	36	36	35.14	Min 45

Quanti_KPI10 Min score retained from Preregistered candidates who have an Applied license	53	50,56	38	39	42	35.8	Min 53
Quanti_KPI11 Min score retained from Preregistered candidates who have a fundamental license from other institutes	50.11	53.56	58	40	38	34	Min 50
Quanti_KPI12 Min score retained from accepted candidates (after the interview) who have a fundamental license	64.1	58.56	63	50	52	55	Min 60
Quanti_KPI13 Min score retained from accepted candidates who have an Applied license	62.9	62.39	64	47	55	59	Min 62
Quanti_KPI14 Min score retained from accepted candidates who have a fundamental license from other institutes	55	66.17	85	62	0	55	Min 68
Number of all Pre-registered candidates	358	-	-	-	-	-	-
Quanti_KPI1 Number of all Preselected candidates who has a fundamental license	40	51	30	40	40	37	Max 40

Quanti_KPI2 Number of all Preselected candidates who have an applied license	5	6	10	6	6	8	Max 6
Quanti_KPI3 Number of all Preselected candidates who has a fundamental license from other institutes	20	18	6	14	13	33	Max 20
Quanti_KPI4 Number of all interviewed candidates	62	75	37	41	36	59	Max 86
Quanti_KPI5 Number of final selected candidates who have a fundamental license	20	19	17	20	20	13	Max 18
Quanti_KPI6 Number of final selected candidates who have an applied license	3	1	4	3	6	2	Max 3
Quanti_KPI7 Number of final selected candidates who have a fundamental license from other institutes	2	3	1	1	0	6	Max 5
Quanti_KPI16 Max waiting time from pre-registration online activity to notify candidate activity	37	44	49	55	46	61	Max 20 days
Quanti_KPI15 Max waiting time from the first notification to the final notification	3	7	28	23	11	15	Max 3 day
Quanti_KPI8 Max process duration	40	51	77	78	57	76	Max 42 day

Quanti_KPI17 Number of jury during the interview	7	7	6	6	6	6	Min 6
Quanti_KPI18 Number of personnel assigned in the calculation score activity	3	3	3	3	3	3	Min 3
Quanti_KPI19N Number of personnel assigned in the pre-selection activity	2	2	2	2	2	2	Min 3
Quanti_KPI20 Number of accepted	28	25	19	25	29	30	Min20
candidates before administrative registration							Max 25
Quanti_KPI21 Number of candidates on the waiting list	5	7	6	4	0	0	Max 5
Quanti_KPI22 Number of newly registered candidates in first level SIAD Master's degree	19 1.1	19	22	27	27	30	Min 20 Max 25
Quanti_KPI23 Number of candidates who repeat M1	2	2	0	0	4	12	Max 1
Quanti_KPI24 Number of registered candidates in second level SIAD Master's degree	15	17	21	22	26	17	Min20 Max 25
Quanti_KPI25 Number of abundant Candidates	0	2	0	1	0	0	Max 1

Quanti_KPI26 Number of graduated candidates	14	20	15	20	10		Min 20 Max 25

Like the emergency care process, we propose some pertinent questions related to the candidate point of view to capture the level of his/her satisfaction and to help the Master's committees to improve the candidates' selection process. The proposed questionnaire can be found in appendix D. We synthesize questionnaire results in Table 6.7. The proposed questionnaire was answered by 16 candidates registered in the first level Master's degree.

Table 6.7: Responses synthesis for qualitative indicators

Indicator	**Very satisfied**	**Satisfied**	**Neutral**	**Dissatisfied**	**Very dissatisfied**
Was an appropriate amount of time provided for each question during the interview?	2	9	4	1	0
How were the interviewers' communication skills during the interview?	1	7	8	0	0
What about your installation during the interview?	0	9	6	0	1
Are the questions during the interview aligned with the master's degree plan?	3	4	6	3	0
Was the atmosphere of the interview encouraging not only to giving answers but also to asking questions?	2	5	4	4	1
Total	8	34	28	8	2

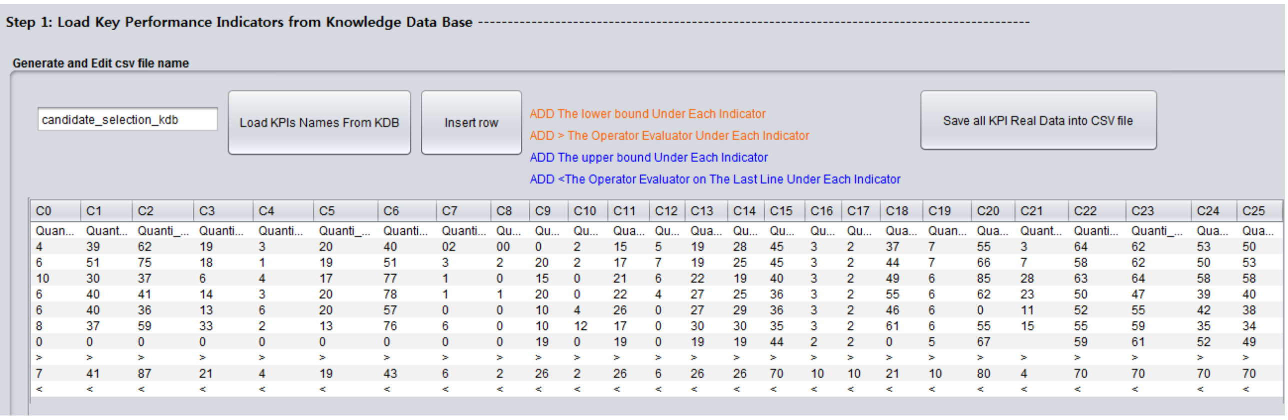
Candidates' answers recorded using Likert response formats are analyzed quantitatively. For the first qualitative indicator, we conclude that the majority of candidates were satisfied with the time allocated for each question during the interview. For the second qualitative indicators, 50% of responses were neutral and the other 50% of candidates were satisfied. For the rest of the qualitative indicators, the majority of candidates were satisfied with their installation in the interview room, the proposed question and the general atmosphere during the interview.

This questionnaire was developed for two main reasons: detailed questions provide diagnostic information with regard to the specific aspect of the interview to help them to improve their performance and open questions provide feedback to the master's committee to improve the candidates' selection process.

6.5.2 KPIs values generation storage

In the selection candidate case study, we were especially interested in the second menu because the first menu is illustrated in the first case study and also the majority of indicators are gathered from administrative files.

Under the Database menu, we connect to the MySQL server as in the first case study. When the user connects successfully, s/he moves on to fill the KPI file with real values. In this case study, we are based on six rows referring to the university years' data since aggregated indicators contain global pertinent information for BPs improvement. Figure 6.10 shows an overview of the table during the fullfilling step.

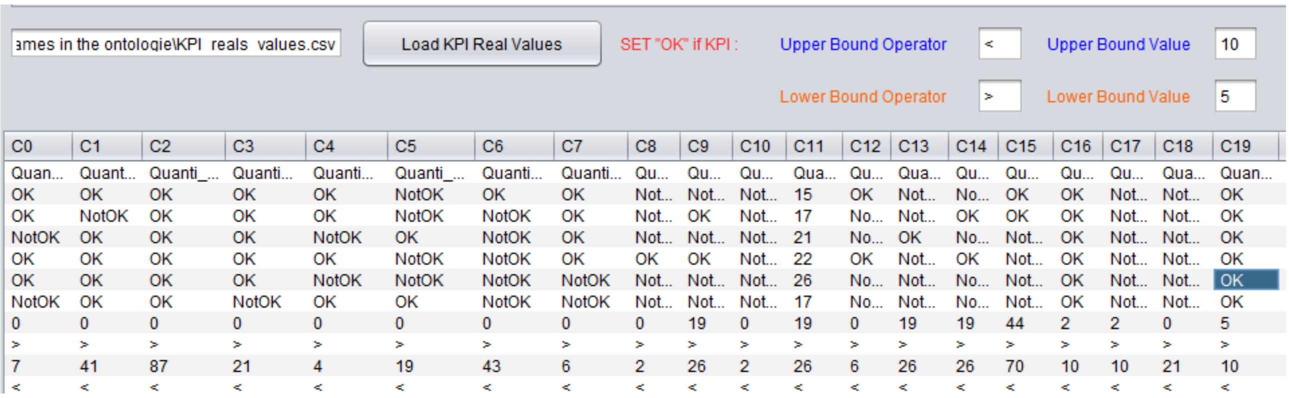


C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Quan...	Quant...	Quanti_...	Quanti...	Quanti...	Quanti_...	Quanti...	Quanti...	Qu...	Qu...	Qu...	Qua...	Qu...
4	39	62	19	3	20	40	02	00	0	2	15	5
6	51	75	18	1	19	51	3	2	20	2	17	7
10	30	37	6	4	17	77	1	0	15	0	21	6
6	40	41	14	3	20	78	1	1	20	0	22	4
6	40	36	13	6	20	57	0	0	10	4	26	0
8	37	59	33	2	13	76	6	0	10	12	17	0
0	0	0	0	0	0	0	0	0	19	0	19	0
>	>	>	>	>	>	>	>	>	>	>	>	>
7	41	87	21	4	19	43	6	2	26	2	26	6
<	<	<	<	<	<	<	<	<	<	<	<	<

C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25
Qua...	Qu...	Qu...	Qu...	Qu...	Qua...	Quan...	Qua...	Quant...	Quanti...	Quanti_...	Qua...	Qua...
19	28	45	3	2	37	7	55	3	64	62	53	50
19	25	45	3	2	44	7	66	7	58	62	50	53
22	19	40	3	2	49	6	85	28	63	64	58	58
27	25	36	3	2	55	6	62	23	50	47	39	40
27	29	36	3	2	46	6	0	11	52	55	42	38
30	30	35	3	2	61	6	55	15	55	59	35	34
19	19	44	2	2	0	5	67		59	61	52	49
>	>	>	>	>	>	>	>	>	>	>	>	>
26	26	70	10	10	21	10	80	4	70	70	70	70
<	<	<	<	<	<	<	<	<	<	<	<	<

Figure 6.10: Screenshot of fulfilling KPI data

Figure 6.11 shows a screenshot of evaluating KPI real values step.



ames in the ontologie\KPI reals values.csv | Load KPI Real Values | SET "OK" if KPI : | Upper Bound Operator < | Upper Bound Value 10
Lower Bound Operator > | Lower Bound Value 5

C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19
Quan...	Quant...	Quanti_...	Quanti...	Quanti...	Quanti_...	Quanti...	Quanti...	Qu...	Qu...	Qu...	Qua...	Qu...	Qua...	Qu...	Qu...	Qu...	Qu...	Qua...	Quan...
OK	OK	OK	OK	OK	NotOK	OK	OK	Not...	Not...	Not...	15	OK	Not...	No...	OK	OK	Not...	Not...	OK
OK	NotOK	OK	OK	OK	NotOK	NotOK	OK	Not...	OK	Not...	17	No...	Not...	OK	OK	OK	Not...	Not...	OK
NotOK	OK	OK	OK	NotOK	OK	NotOK	OK	Not...	Not...	Not...	21	No...	OK	No...	Not...	OK	Not...	Not...	OK
OK	OK	OK	OK	OK	NotOK	NotOK	OK	OK	OK	Not...	22	OK	Not...	OK	Not...	OK	Not...	Not...	OK
OK	OK	OK	OK	NotOK	NotOK	NotOK	NotOK	Not...	Not...	Not...	26	No...	Not...	No...	Not...	OK	Not...	Not...	OK
NotOK	OK	OK	NotOK	OK	OK	NotOK	NotOK	Not...	Not...	Not...	17	No...	Not...	No...	Not...	OK	Not...	Not...	OK
0	0	0	0	0	0	0	0	0	19	0	19	0	19	19	44	2	2	0	5
>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>
7	41	87	21	4	19	43	6	2	26	2	26	6	26	26	70	10	10	21	10
<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<

Figure 6.11: Screenshot of evaluating KPI data

6.6 Evaluation of Candidates' Selection BP

In this section, we present the obtained results for the two case studies because some framework features (e.g. analyzing the occurrence of indicators in association rules) cannot be applied in the selection candidate case study. This is explained by the following reasons:

- Our quantitative indicators in the selection candidate case study are classified as aggregated indicators or global indicators, organized by university years.
- For process manager goals, we don't define basic indicators related to process instance id (e.g. the candidate), we were only based on dashboards retained from logs for the 2017-2018 university year.
- We do not evaluate the qualitative indicators retained from the questionnaire because we do not have sufficient responses and enough information about the quantitative indicators related to the same process instance. When we try to get the global satisfaction of candidates in order to have the same KPI category (all indicators are aggregated), we found ourselves with missing information about the global satisfaction of candidates for the previous university year.

In this section, we present a candidates' selection BP dashboards, and some framework functionalities and ProM features for the KPIs/BP improvement phase.

6.6.1 Process Dashboards

We can configure data providers according to decision-makers needs. Figure 6.12 present a dashboard which can be essential to see the start and the end of each task designed in BP.

Process ID	Process	Process version	Task	Task Start date	Task End date
498	selecting	1.0	Pre-Registration	07/18/17 3:24 P	07/18/17 3:26 P
497	selecting	1.0	Pre-Registration	07/18/17 3:23 P	07/18/17 3:26 P
499	selecting	1.0	Pre-Registration	07/18/17 3:38 P	07/18/17 3:40 P
500	selecting	1.0	Pre-Registration	07/18/17 3:39 P	07/18/17 3:40 P
502	selecting	1.0	Pre-Registration	07/19/17 3:42 P	07/19/17 3:50 P
503	selecting	1.0	Pre-Registration	07/19/17 3:43 P	07/19/17 3:50 P
504	selecting	1.0	Pre-Registration	07/19/17 3:44 P	07/19/17 3:55 P
505	selecting	1.0	Pre-Registration	07/19/17 3:46 P	07/19/17 3:55 P
506	selecting	1.0	Pre-Registration	07/19/17 3:46 P	07/19/17 3:56 P
507	selecting	1.0	Pre-Registration	07/19/17 3:47 P	07/19/17 3:56 P

Figure 6.12: Task duration related to candidates' selection process

6.6.2 KPIs/BP improvement

Figure 6.13 shows various functionalities supported by the framework. First, the user was able to load the KPI names list from the opened evaluated KPI file. After that, s/he saves the KPI data set in another CSV file. Next, we move on to applying the Apriori algorithm. To do that, we open the KPI data set. For example, it may contain *Quanti_KPI25* and *Quanti_KPI9*. Figure 6.14 shows the Apriori algorithm results for the previous data set and the saved rules message when the decision-maker wants to store these association rules in the KDB. As already stated, we tested the same data set with Weka tool, and it gave us the same results.

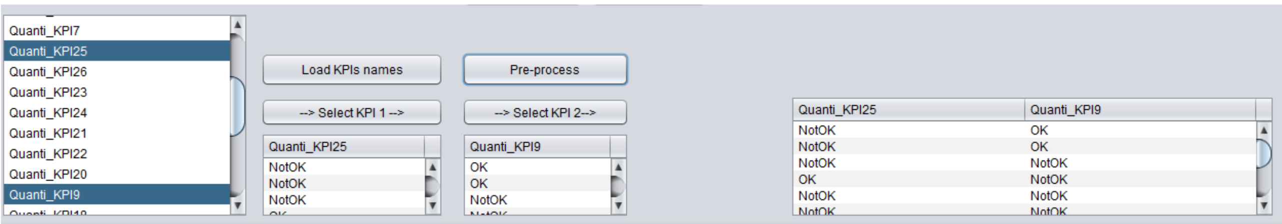


Figure 6.13: Selecting KPI names list from the opened evaluated KPI file

Implementing Apriori in this way leaves to the analyst the task of discovering interesting rules. First, we set the minimum support used for the selected indicators in the data set. The KDB contains only frequent itemsets which satisfy the minimum support and minimum confidence constraints. Then, in a second step, each frequent itemset is used to generate all possible rules from it. All the rules which do not satisfy the minimum confidence constraint are removed.

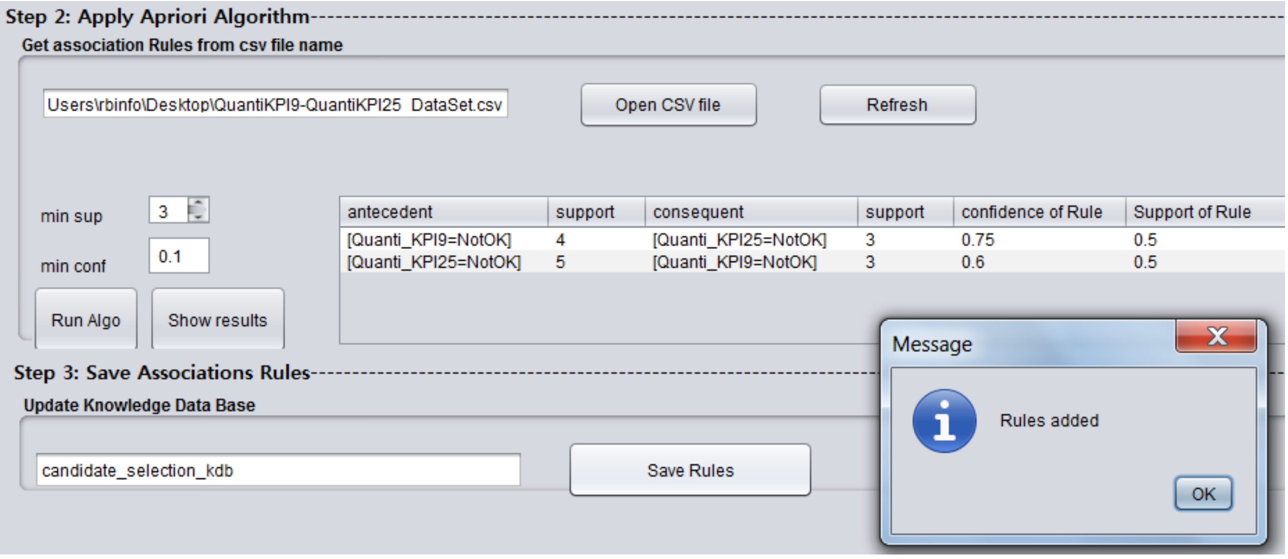


Figure 6.14: Rules obtained from the appropriate KPI data set

Typically, only the decision-maker has the right to increase or decrease the minimum support as well as the minimum confidence to keep the number of association rules found at a manageable size and also display or remove potentially interesting rules with less support. We continue the same process to test KPIs possible links. In Figure 6.15, we take the example of *Quanti_KPI1* and *Quanti_KPI4*.

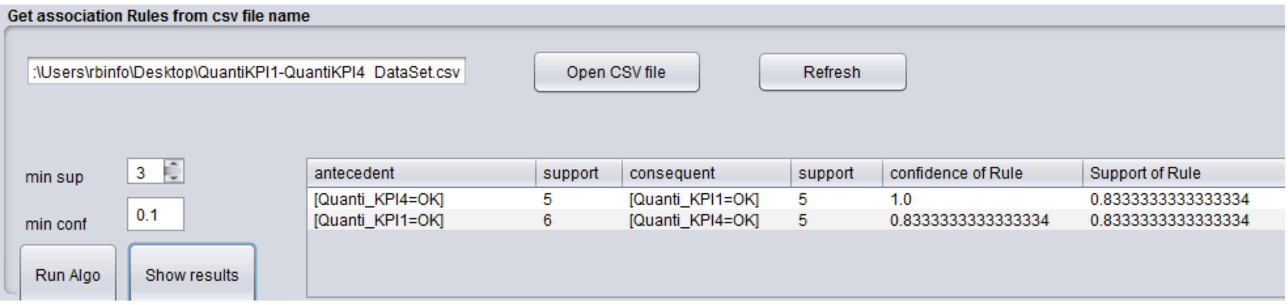


Figure 6.15: Rules obtained from *Quanti_KPI1* and *Quanti_KPI4* data set

The amount of interaction needed during exploration is very high and includes discovering, analyzing and rearranging data. Similarly, if we check the KPI KDB created by the user, especially the rules data table, we see some saved rules obtained after running the Apriori algorithm.

All indicators were approved by the DM technique. In Table 6.8, we present some indicators not previously included in the ontology, but they seem interesting according to the decision maker opinion.

Table 6.8: KPIs relationships discovered by the application of association rules

Antecedent	**Consequent**
Quanti_KPI22 Number of newly registered candidates in first level SIAD Master's degree	Quanti_KPI24 Number of registered candidates in second-level SIAD Master's degree
Quanti_KPI20 Number of accepted candidates before administrative registration	Quanti_KPI22 Number of newly registered candidates in first level SIAD Master's degree
Quanti_KPI23 Number of candidates who repeat M1	Quanti_KPI24 Number of registered candidates in second-level SIAD Master's degree
Quanti_KPI15 Max waiting time from the first notification to the final notification candidate activity	Quanti_KPI8 Max process duration
Quanti_KPI16 Max waiting time from pre-registration online activity to notifying candidate activity	Quanti_KPI8 Max process duration

Like the emergency care case study, first we start by preparing the data that should be analyzed. We extract instances related to the candidates' selection process retrieved from the *bamtasksummary* table. After that, we import these data into ProM and set the appropriate parameters. First, we use the log visualizer and event log explorer to understand the process flows.

In Figure 6.16, we can see that the total number of pre-registered students is about 358, where only 63 students (process instances) are accepted for an interview and complete the BP steps. In the candidates' selection process, a critical bottleneck at the online preregistration activity and the interview activity could be detected. Obtaining selection results duration was terrible for the already preselected candidates, and speeding up the interview date was critical.

We also discovered the activities during the process flow (Figure 6.17). We also observed that all registered candidates pass by the same first five activities. These activities delayed the overall process throughput for preselected candidates. Understanding why some candidates are not retained to get the interview and why some selected candidates retained after the interview don't complete their administrative registration, could reduce this wasteful time and inappropriate candidates and significantly speed up the process for the candidates and the Master's committee and reduce candidates dissatisfaction and complaints as well.

Log Summary

Total number of classes: **9**

Class	Occurrences (absolute)
Pre-Registration Online	358
Check Pre-Selection Results	358
Calculate Score	358
Notify Pre-Selected Candidate List	358
Pre-Selection Candidates	358
Calculate Final Score	63
Check Results	63
Interview	63
Notify Selected candidates	63

Start events

Total number of classes: **1**

Class	Occurrences (absolute)
Pre-Registration Online	358

End events

Total number of classes: **2**

Class	Occurrences (absolute)
Check Pre-Selection Results	295
Check Results	63

Figure 6.16: Log visualizer summary

As for the first case study, we can browse the individual cases related to a specific BP path. Figure 6.18 shows some details related to a specific process instance (student) that completes all BP activities. In Figure 6.18, the candidate that has 460 process instance identifiers was registered online in 18/07/2017 and waited about 16 days before the score calculation has started. After checking the preselection result, s/he was invited to the interview. However, the interview activity started after 16 days from the preselection result checking activity. After 2 days, this candidate was notified about the final retained candidates list.

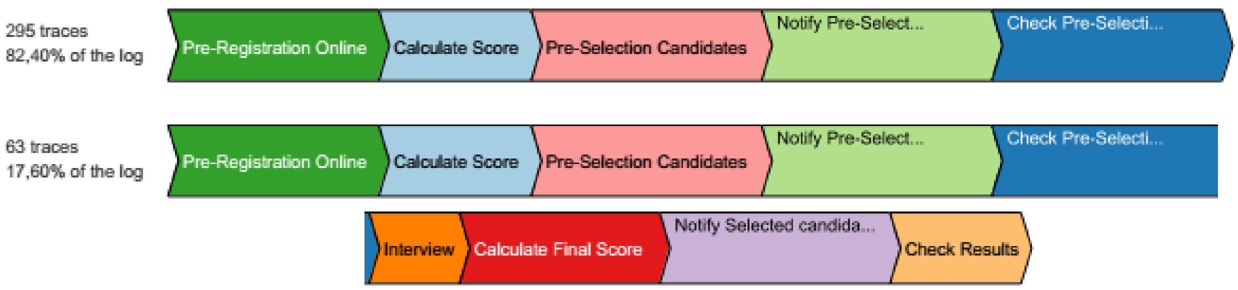


Figure 6.17: Paths visualization for cases registered online in 2017-2018 university year

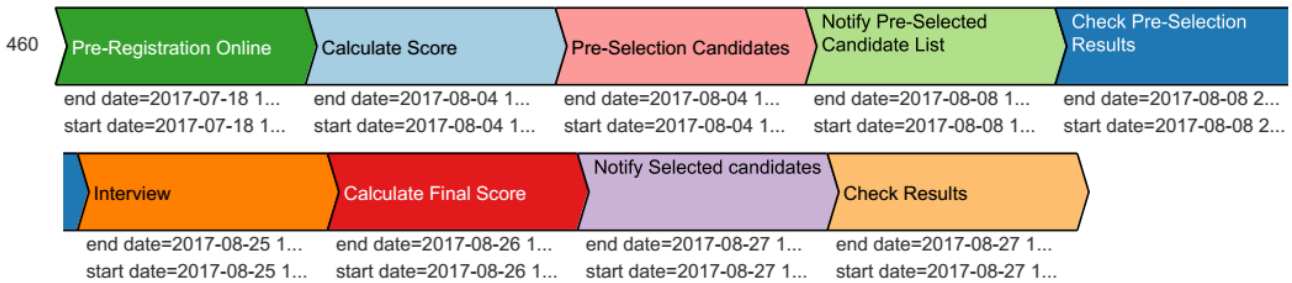


Figure 6.18: Paths visualization for process instance identifier number 460

Based on all available information, we could have the following observations:

- The process takes too much time for preselected candidates. It especially takes an important waiting time before the interview starts.

- The process takes too much time in online pre-registration activity.

When we review these observations with the process stakeholders, we conclude the following explanation:

- From the Master's committee view, the online preregistration closed after 17 days from the opening date to give the chance for all students to be informed about the deadline to join the Master's degree.

For the considerable waiting time before the interview, it is explained by the fact that candidates are divided into groups based on their initial diplomas (e.g. holding a fundamental license, holding an applied license or from others institutes) and the time necessary for checking the availability of the corresponding jury.

In this step, we were based on the semantic representation of KPIs in the ontology and discovering rules retained on the KDB for improving indicators in different ways. First, we can review the target value of an indicator. For example, in the ontology, experts may judge that there is a link between *Quanti_KPI4* "Number of all interviewed candidates" and

Quanti_ KPI20 "Number of the accepted candidates before administrative registration" and this is explained by the following properties: when we have many candidates to which the interview was given, we have a high probability that we have many accepted candidates. Now, when we test this link using DM technique, we find that *Quanti_ KPI4* is ok and *Quanti_ KPI20* is not ok. This is due to the fact that *Quanti_ KPI20* has unacceptable value for 4 years (does not respect the interval [Min20 Max 25]) and *Quanti_ KPI4* respects the threshold value (*max* 86). Based on this information, the decision-maker may review the target value of one or both indicators. The ideal way would be to have both indicators acceptable; sometimes when we have an indicator which is acceptable and the other is not, this may cause undesirable consequence especially on the satisfaction of candidates to which the interview is given and finally the Master's committee only decides to accept a few numbers of them.
Another example concerns the *Quanti_ KPI22* "Number of newly registered candidates in first level SIAD Master's degree" and *Quanti_ KPI24* "Number of registered candidates in secondlevel SIAD Master's degree". Both indicators are unacceptable (not ok), which alerts the decision-maker to review the target value of these indicators.

As in the first case study, we often need more data that can be used in the analysis in order to respond to these questions. After discussion with candidates, we conclude that the interview condition is well judged. Regarding now the open question, we summarize the main interesting points below:
- The selection was unfair because the acceptance ratio of the external students is very low compared to the acceptance ratio of internal students.
- Many candidates were accepted but they weren't present on the day of the interview because they were already selected in other institutions. In this way, many qualified students lost their chance to be selected.
- The formula of the final score is unclear for students.
- The time provided for each candidate is not previously known by the candidate and it is not the same for all candidates.
- The questions are not related to the general Master's topic and are very limited to the undergraduate study.
- The motivation of students is not really taken into account.

Based on these points, we appreciate the importance of these opened questions for the following reason: the proposed questionnaire is limited to the expert's vision evaluation; however, the open question response gives some interesting guidelines from candidate's point of view toward BP improvement.

When we review candidates guidelines based on the qualitative questionnaire evaluation and try to verify why external candidates have less chance to be selected, we see that the min retained score is very high compared to the min retained score for the internal students. Also, we see that the number of retained candidates from other institutes is less than the number of candidates from the Master's committee institution. Furthermore, if we check the number of preselected candidates and the number of interviewed candidates, we see a gap between the two numbers because not all preselected candidates attend the interview. When we try to verify this link with DM, we see that the number of interviewed candidates always took "ok" estimated value because it respects its target value (*max* 86). Based on this, two possible improvements can be made. The first one is related to the KPI, where the decision-makers are invited to modify the target value or at least set a lower and a higher bound. They can also refine this indicator by category (e.g. the interviewed candidate who has a fundamental license from other institution, the interviewed candidates who have a fundamental license and the interviewed candidates who have an applied license). The second one is related to the BP, where the decision-maker offers the candidate the option to express/present his level of motivation and his capability to attend the interview before the interview activity starts.

Regarding other points extracted from the open questions, which concern the criteria of selection, we found that not all candidates understood these criteria and some formula were not really explicit. In this case, besides the announcement of the candidate selection planning and the corresponding dates, the Master's committee is invited to present to candidates in an explicit and clear manner, how the score is calculated, and what conditions are retained in each preselection or selection decision.

Before we analyze the relationships between indicators, we state that some indicator, do not really respect their threshold values. But the confusing situation is that some indicators respect their target value but according to candidates' point of view. This may not reflect that the situation is good. After analyzing the causes, it can be related to the threshold values themselves or it may be related to another informational aspect. Taking the same example related to the number of interviewed candidates, we clearly see that for all the six university years, these indicators were judged as acceptable, and when we ask candidates how BP can be improved, many ideas are proposed like giving more time to the candidates to introduce themselves, their motivation, their current research and also the right to ask the jury committee about the opportunities of this Master's degree and the perspectives of the obtained diploma in the current professional and academic research.

In this step, we have only focused on the subset of the initially considered KPI. The choice of this sub-set was based on time. Other points of view can, of course, be considered in further KPIs studies, such as the quality level of the selected candidate and the pertinence of the selection.

6.7 Discussion

We can state that the ontology feature in our framework covers a set of user needs like the simplicity where the terms used and their relationships are as simple as possible in order to facilitate the developers' work. The flexibility of the ontology appears through the fact that it allows adding semantics to contextual elements (e.g. can support the simple addition of KPI and new relationships). The expressiveness where the ontology allows describing the involved concepts in detail (e.g. it allows to specify concepts and relationships between different components of the ontology).

Using the ontology features, one of the striking benefits consists in the fact that the ontology can be fully tailored to the needs of the organization. The ontology is designed in a way that allows business analysts to visualize all concepts in a single place. After that, based on the association rules and domain knowledge, the ontology can be easily adapted to meet changing requirements. This will make the entire ontology more comprehensible and readable for all developers. The ontology feature facilitates the interaction between domain specialists to make it more convenient for both sides to read and/or manipulate the ontology. It is interesting to enable specialists to read and navigate through the ontology and its concepts. In addition, there are editing facilities to modify and update the ontology. Now domain specialists are placed in an environment in which they can freely provide feedback on an existing ontology simply by interacting with the OWL file. Especially with KPI association rules saved in the KDB, this should enable a novel mechanism to interact with an ontology: users can explore KPIs link and edit "has_ok" or "has_not_ok" data property, and use this as a mechanism for enrichiment to the ontology developer.

Furthermore, there are many advantages when implementing the Apriori algorithm in our framework. First, we give the opportunity to the user to select the concerned KPIs and indicate the appropriate parameters. In this case, rules always correspond to 2-itemsets and the output results depend on the entered *min* support and *min* confidence for each KPI couple. Apriori algorithm results are validated and verified by entering the same data set into Weka tool with the same parameters and it gives us the same results.

The originality of our work concerns how to explore and analyze the obtained rules in order to search for recurring relationships in a given data set and then all found results are used for the discovery of interesting relationships between KPIs established in our ontology.

Our proposed framework was helpful for the two case studies. In addition, it avoids manual work as much as possible and it can display the result immediately and also store all interesting data in a KDB. Furthermore, it incorporates the interaction between different knowledge expert domains (e.g. business analysts, ontology designers, database managers...) and it provides a friendly graphical user interface where the extraction, the creation and the updating of information are easy. This was the case for many tasks, but some other tasks could be fulfilled without our framework intervention. For this reason, we also were based on other complementary adopted means to support our KPIMgtAssist approach.

6.8 Conclusion

In this chapter, we illustrate the application of the proposed approach in the higher education field. Especially we take the example of the selection candidate case study. We demonstrate how our framework and other adopted means successfully support our approach steps and we also present some improvement proposals.

Part IV

Conclusion and Future work

Chapter 7

Conclusion and future work

This thesis addressed the topic of KPIs in the Business Process Management field. We summarize in section 7.1 our main contributions. Accordingly, we describe in section 7.2 some limitations of our work. Then, we describe our directions for future research in section 7.3.

7.1 Summary

Business processes are used every day and everywhere. Likewise, the BP in the organization defines the business itself and deals with day-to-day operations. Consequently, each process may be improved by mainly focusing on the most relevant KPIs. In fact, this dissertation proposes to solve an important gap for BPM practitioners who will identify, monitor, and improve KPIs and (with them) the business processes. Thus, the proposed research can have the potential to contribute to theory and practice. In this regard, we give specific attention to BPM especially KPI as a commitment to consistent and iterative BP performance improvement that meets BP objectives. Furthermore, we argue that the effective and intelligent use of KPI data and KPI knowledge will contribute to accomplishing significant enhancement gains during the BPM steps. However, the management of a set of KPIs can incorporate several techniques and methods that help KPIs to be maintained. In this thesis, we aim to represent a KPI life-cycle as a series of steps and even follow a logical order to help BP stakeholders in understanding and gaining awareness of their process's level of performance.

Regarding our problematic stated in the first chapter, there is a need to develop a coherent and integrated approach. We propose to accomplish it by integrating KPI life-cycle into BPM lifecycle. To achieve this, we are especially interested not only in the quantitative indicators that are related to the process execution and administrative files but also to qualitative indicators related to satisfaction levels. These two kinds of KPIs together bring information in order to make decisions.

First, besides the BP modeling phase, we develop a KPI selection algorithm based on the AHP method and SMART criteria for KPI definition, which allows a primary KPI selection. On the other hand, taking these SMART indicators and BP activities together provides a significant route for KPI semantic representation.

Second, besides BPMS configuration, we prepare a KPI Knowledge Database that provides a new root to the persistence of all KPI information retrieved from the different data sources.

Third, mainly based on BP execution logs and other data sources, tracking KPI real values and estimated values are adopted as a way of monitoring and this is a crucial concept that has received a lot of attention in many domains.

Fourth, besides reporting module provided by the BPM system, KPI rules discovery using DM algorithm and KPI relationships design using ontology are successfully exploited. In addition, both abstract and concrete KPI links established by decision-makers are designed. We "temporarily" simplify their "mental" BP improvement by their knowledge from the ontology file and complementing them by discovered rules.

Moreover, the process of implementing our approach involves collaboration between many actors like BP analysts, ontology developers and domain experts and requires ongoing interaction between them. This collaboration is difficult to carry out because actors tend to use different toolsets, which can hamper this interaction. In this sense, to decrease this distance between all actors,we propose and developed a supporting framework.This framework provides functionalities as well as connections to a KDB.

Furthermore, to show the feasibility of our approach and its framework, we have presented its application through two case studies from real-world scenarios: one process from the healthcare domain and another from the higher education domain. The framework presents a fundamental step to acquire a complete knowledge of the data involved in the BP improvement. The application in the healthcare process as well as in candidates' selection process demonstrates continuous performance monitoring feasibility by using our proposed framework. Hence, it will allow to obtain some guidelines related to the choice and use of appropriate indicators. It developed and tracked a structure for performance measurement within which basic or aggregated performance measures can be identified and developed. Furthermore, it aims to help business users organize and make sense to the vast amounts of data about BP and its external environment. This framework establishes a bridge between many tools functionalities and the knowledge of domain experts. It can be viewed from a different perspective, making it possible to keep related information in a single place.

Taken together, these contributions provide a significant knowledge capture towards process enhancement and support our dissertation in providing a solid background for KPI definition, selection, monitoring and improvement leading it to a new level of maturity.

7.2 Work limits

In this section, we present the main shortcomings inspiring for further extensions.

First, it is required to have good expertise in order to be able to define the starting list of KPIs. However, our target users may have limited knowledge and expertise and they are consequently unable to start using our approach.

Second, when the user sets the appropriate parameters before running the Apriori algorithm (*min* support and *min* confidence), this will have a great influence on the generated rules that will be retained in updating KPIs links presented in the ontology. We can thus note that the user in this step can be unable to specify the correct parameters values and in some cases, this may generate an inadequate decision in updating some links in the KPI ontology.

Third, after modeling and executing the BP, the user may need to understand the presence of deviations between the prescribed behavior in the deployed models and the data in the process event log.

Fourth, after the decision-maker analyzes data and KPI synthesis, s/he will be able to identify possible improvements or decide to reengineer the BP in question. However not all improvement plans can really be applied.

We can state that our concrete application of the proposed approach starts by a difficult challenge in which we do not have an existing event log. The main limits related to this issue is that the implementation of the BP in the emergency department does not really cover all patient flows, because we are essentially based on our observation of record duration and waiting time of patient instances from their arrival to the emergency department. The missing patient's satisfaction in the same period may modify the obtained association rules and then the interpretation of the importance of indicators. Furthermore, the qualitative aspect in the candidates' selection process is not fully exploited when applying the Apriori algorithm, because satisfaction statistics report had not been generated before. As a consequence, these data are unavailable and the global qualitative indicator is discarded in the learning process. In this case study, we also discard basic indicators related to each candidate process instance because the decision-maker gives more importance only to global indicators. As a consequence, it becomes difficult to discover KPI occurrence and to use Process Mining software in the last phase. In this second case study, not all indicators defined in the first step are exploited to continue the following approach step because some of them are out of the scope of the candidates' selection BP, but, they have a great impact in the evaluation of the achievement of the defined BP goals.

7.3 Future work

Our approach places KPI management from a new perspective by taking BPM, AHP, Ontology, DM advantages. But regarding the BP goal, we may extend our approach to include further indicators and may be further techniques related to work limit.

For the first limit, we can say that KPIs reflect the employee's performance target. So we can develop a questionnaire that would help BP users in the definition of possible KPIs in the direction of business goals. Furthermore, we can suggest the possible and basic indicators where the domain expert can understand the performance by looking at the process from multiple perspectives.

For the second limit, we can explore the fuzzy ontology concept in order to support the uncertainty of information. This ontology uses fuzzy logic to reason about vague and uncertain knowledge.

For the third limit, in order to extract different kinds of information related to the analyzed processes, a new question arises on how Process Mining could be used. On this view, we can explore for example conformance checking techniques in case we have an existing process model designed using BPMN for a BP to compare this a-priori model with the corresponding event log in order to check out if the behavior observed in practice conforms to the documented process (e.g. business rules, policy definition and standards). This technique enables to detect and locate deviations that may occur in reality.

For the fourth limit, in order to establish process improvement opportunities, another technique can be used in combination with Process Mining to facilitate BP analysis, which is a simulation technique. This technique has received great attention in the literature. We can say that simulation technique imitates the behavior of the process. We can use this technique to evaluate different improvement alternatives before they are put into practice. In this way, we can increase process effectiveness by eliminating process bottlenecks on the critical path and low efficient tasks. This combination opens many research questions such as: how can we discover and generate a simulation model from an event log, on what basis does the user choose the appropriate alternative BP models? After the simulation is performed, what kind of information and what possible KPIs can be retrieved from the generated event log of the resulting simulation and what can be used for decision making?

The improvement phase is crucial in any Business Process Management project, especially in transforming a BP into an enhanced state. In this context, we find that Business Process Improvement Patterns (BPI-Patterns) are an attempt to describe successful solutions for typical, recurring problems to model operational Business Process Improvement steps. The use of patterns raises many questions in the enhancement phase such as: what measures should be taken to apply the BPI-Pattern? How can we select a suitable pattern that might allow the company to perform further analysis and improvement? How can the selected BPIPattern affect the structure of business processes? What kind of KPI can be gathered from the new BP followed by the instructions retrained from the selected BPI-pattern?

For the main shortcomings related to the availability of logs in the two presented case studies, it is important and recommended to have a high-quality event log. Event data may come from many sources including a database system or a spreadsheet. This limitation leads to the necessity to coordinate between different systems, people and processes and then prove the strength of a BPM solution. Many further questions need more investigation. For example, how we can deal with a huge amount of logs and satisfaction reports to determine pertinent indicators?. How we can select and manage several indicators related to strategic, tactical and operational levels. And how we can extract KPIs based on a complex BP (e.g. BP with many sub-BPs, BP related to many sectors and departments (pools and lanes), business processes performed by many actors, often across different organizational units or even companies). How to take into consideration other points of view in terms of performance for our BP and related KPIs (for example quality, pertinence, and cost)?

The propositions for future perspectives presented in this section show other research areas that can be related to the field of process measurements in the context of BPM and that can further evolve many other methods and techniques that could be applied for sustaining process improvement.

Publications

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Appendix A

An overview of the healthcare process execution logs

pk [PK] bigint	createddate timestamp without time zone	duration bigint	enddate timestamp without time zone	processinstanceid bigint	startdate timestamp without time zone	status character varying(255)	taskid bigint	taskname character varying(255)
8	2016-05-26 11:44:25.83	134152	2016-05-26 11:46:49.535	155	2016-05-26 11:44:35.383	Completed	485	Registration
9	2016-05-26 11:46:49.524	218437	2016-05-26 11:50:42.52	155	2016-05-26 11:47:04.083	Completed	486	Sorting
10	2016-05-26 11:50:42.515	197293	2016-05-26 12:03:22.647	155	2016-05-26 12:00:05.354	Completed	487	Consultation in box
11	2016-05-26 12:03:22.643	9322161	2016-05-26 15:00:57.104	155	2016-05-26 12:25:34.943	Completed	488	Lying waiting
12	2016-05-26 12:33:44.993	73510	2016-05-26 12:35:09.739	156	2016-05-26 12:33:56.229	Completed	489	Registration
13	2016-05-26 12:35:09.736	269042	2016-05-26 12:41:52.786	156	2016-05-26 12:37:23.744	Completed	490	Sorting
14	2016-05-26 12:41:52.779	1050390	2016-05-26 13:00:35.476	156	2016-05-26 12:43:05.086	Completed	491	Consultation in box
15	2016-05-26 09:37:12.317	79784	2016-05-26 09:38:48.809	157	2016-05-26 09:37:29.025	Completed	492	Registration
16	2016-05-26 09:38:48.806	82116	2016-05-26 10:03:26.327	157	2016-05-26 10:02:04.211	Completed	493	Sorting
17	2016-05-26 10:03:26.322	332223	2016-05-26 10:56:15.236	157	2016-05-26 10:50:43.013	Completed	494	Consultation Delayed emergency

Figure A.1: Screenshot of Bamtasksummary table

id [PK] bigint	duration bigint	end_date timestamp without time zone	externalid character varying(255)	u: cl	out cha	p: bi	processid character varying(255)	processinstanceid bigint	processname character varying(255)	processversion character varying(255)	start_date timestamp without time zone
3	11791263	2016-05-26 15:00:57.049	org.jbpm:EDProj:1.0	a			EDProj.EmergencyProcess	155	EmergencyProcess	1.0	2016-05-26 11:44:25.786
4	1610422	2016-05-26 13:00:35.397	org.jbpm:EDProj:1.0	a			EDProj.EmergencyProcess	156	EmergencyProcess	1.0	2016-05-26 12:33:44.975
5	4742882	2016-05-26 10:56:15.165	org.jbpm:EDProj:1.0	a			EDProj.EmergencyProcess	157	EmergencyProcess	1.0	2016-05-26 09:37:12.283
6	7473130	2016-05-25 17:18:09.846	org.jbpm:EDProj:1.0	a			EDProj.EmergencyProcess	160	EmergencyProcess	1.0	2016-05-25 15:13:36.716
7	2463886	2016-05-25 16:54:00.344	org.jbpm:EDProj:1.0	a			EDProj.EmergencyProcess	161	EmergencyProcess	1.0	2016-05-25 16:12:56.458
8	898277	2016-05-25 10:30:45.676	org.jbpm:EDProj:1.0	a			EDProj.EmergencyProcess	163	EmergencyProcess	1.0	2016-05-25 10:15:47.399
9	2963317	2016-05-25 09:50:41.623	org.jbpm:EDProj:1.0	a			EDProj.EmergencyProcess	165	EmergencyProcess	1.0	2016-05-25 09:01:18.306
10	1526909	2016-05-25 14:30:16.988	org.jbpm:EDProj:1.0	a			EDProj.EmergencyProcess	166	EmergencyProcess	1.0	2016-05-25 14:04:50.079
11	3208020	2016-05-25 14:55:57.495	org.jbpm:EDProj:1.0	a			EDProj.EmergencyProcess	168	EmergencyProcess	1.0	2016-05-25 14:02:29.475
12	2786610	2016-05-25 15:04:55.649	org.jbpm:EDProj:1.0	a			EDProj.EmergencyProcess	170	EmergencyProcess	1.0	2016-05-25 14:18:29.039
13	3762123	2016-05-24 16:00:27.128	org.jbpm:EDProj:1.0	a			EDProj.EmergencyProcess	172	EmergencyProcess	1.0	2016-05-24 14:57:45.005
14	3760058	2016-05-24 16:12:00.062	org.jbpm:EDProj:1.0	a			EDProj.EmergencyProcess	173	EmergencyProcess	1.0	2016-05-24 15:09:20.004

Figure A.2: Screenshot of Processinstancelog table

log_date timestamp without time zone	externalid character varying(255)	nodeid character varying(255)	nod chai	nodename character varying(255)	nodetype character varying(255)	processid character varying(255)	processinstanceid bigint
2016-05-26 11:44:26.333	org.jbpm:EDProj:1.0	processStartEvent	0	''	StartNode	EDProj.EmergencyProcess	154
2016-05-26 11:44:26.333	org.jbpm:EDProj:1.0	4600C903-39BB-4A58-8130-504DFC8D85B8	1	Registration	HumanTaskNode	EDProj.EmergencyProcess	154
2016-05-26 11:44:26.345	org.jbpm:EDProj:1.0	processStartEvent	0	''	StartNode	EDProj.EmergencyProcess	154
2016-05-26 11:46:03.273	org.jbpm:EDProj:1.0	E7D6CB01-29C5-4D27-8918-CC032D09DFFE	2	Sorting	HumanTaskNode	EDProj.EmergencyProcess	154
2016-05-26 11:46:03.289	org.jbpm:EDProj:1.0	4600C903-39BB-4A58-8130-504DFC8D85B8	1	Registration	HumanTaskNode	EDProj.EmergencyProcess	154
2016-05-26 11:50:21.965	org.jbpm:EDProj:1.0	2D203E39-5611-4ECC-AC58-76E84D0EBDA2	3	''	Split	EDProj.EmergencyProcess	154
2016-05-26 11:50:21.966	org.jbpm:EDProj:1.0	1013C82C-737B-452C-BE4F-FBB974C51F2B	4	Consultation in box	HumanTaskNode	EDProj.EmergencyProcess	154
2016-05-26 11:50:21.987	org.jbpm:EDProj:1.0	2D203E39-5611-4ECC-AC58-76E84D0EBDA2	3	''	Split	EDProj.EmergencyProcess	154
2016-05-26 11:50:21.991	org.jbpm:EDProj:1.0	E7D6CB01-29C5-4D27-8918-CC032D09DFFE	2	Sorting	HumanTaskNode	EDProj.EmergencyProcess	154
2016-05-26 12:03:09.112	org.jbpm:EDProj:1.0	AAAE0421-A611-4F96-9ECC-F81527A97A3B	5	''	Split	EDProj.EmergencyProcess	154
2016-05-26 12:03:09.113	org.jbpm:EDProj:1.0	36AF77A8-F5C7-496D-ADE4-18C604892926	6	'	Join	EDProj.EmergencyProcess	154
2016-05-26 12:03:09.113	org.jbpm:EDProj:1.0	737A7386-6B53-4545-98C4-1CFB4978235F	7	Lying waiting	HumanTaskNode	EDProj.EmergencyProcess	154
2016-05-26 12:03:09.126	org.jbpm:EDProj:1.0	36AF77A8-F5C7-496D-ADE4-18C604892926	6	'	Join	EDProj.EmergencyProcess	154
2016-05-26 12:03:09.127	org.jbpm:EDProj:1.0	AAAE0421-A611-4F96-9ECC-F81527A97A3B	5	''	Split	EDProj.EmergencyProcess	154
2016-05-26 12:03:09.128	org.jbpm:EDProj:1.0	1013C82C-737B-452C-BE4F-FBB974C51F2B	4	Consultation in box	HumanTaskNode	EDProj.EmergencyProcess	154
2016-05-26 11:44:25.788	org.jbpm:EDProj:1.0	processStartEvent	0	''	StartNode	EDProj.EmergencyProcess	155
2016-05-26 11:44:25.788	org.jbpm:EDProj:1.0	4600C903-39BB-4A58-8130-504DFC8D85B8	1	Registration	HumanTaskNode	EDProj.EmergencyProcess	155
2016-05-26 11:44:25.833	org.jbpm:EDProj:1.0	processStartEvent	0	''	StartNode	EDProj.EmergencyProcess	155
2016-05-26 11:46:49.509	org.jbpm:EDProj:1.0	E7D6CB01-29C5-4D27-8918-CC032D09DFFE	2	Sorting	HumanTaskNode	EDProj.EmergencyProcess	155

Figure A.3: Screenshot of Nodeinstancelog table

id [PK] bigint	logtime timestamp without time zone	taskid bigint	type character varying(255)
1428	2016-05-26 11:34:39.562	464	ADDED
1429	2016-05-26 11:34:47.901	464	STARTED
1430	2016-05-26 11:35:17.053	464	EXITED
1431	2016-05-26 11:35:21.401	465	ADDED
1432	2016-05-26 11:36:06.58	465	EXITED
1433	2016-05-26 11:33:49.075	466	ADDED
1434	2016-05-26 11:34:05.604	466	STARTED
1435	2016-05-26 11:35:11.887	466	EXITED

Figure A.4: Screenshot of TaskEvent table

id [PK] bigint	log_date timestamp without time zone	externalid character varying(255)	ol ch	processid character varying(255)	processinstanceid bigint	value character varying(255)	variableid character varying(255)	variableinstanceid character varying(255)
20	2016-05-26 11:44:25.769	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	155	[redacted]	NamePatient	NamePatient
21	2016-05-26 11:44:25.772	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	155	[redacted]	NumPatient	NumPatient
22	2016-05-26 11:44:25.785	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	155	64	AgePatient	AgePatient
23	2016-05-26 11:50:42.482	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	155	false	Delayed emergency	Delayed emergency
24	2016-05-26 11:50:42.483	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	155	true	consultation box	consultation box
25	2016-05-26 11:50:42.484	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	155	false	Shock treatement	Shock treatement
26	2016-05-26 12:03:22.615	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	155	false	ExitCB	ExitCB
27	2016-05-26 12:03:22.618	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	155	true	Lying waiting	Lying waiting
28	2016-05-26 15:00:57.04	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	155	true	ExitLW	ExitLW
29	2016-05-26 15:00:57.041	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	155	false	ExitLW	ExitLW
30	2016-05-26 12:33:44.973	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	156	[redacted]	NamePatient	NamePatient
31	2016-05-26 12:33:44.974	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	156	[redacted]	NumPatient	NumPatient
32	2016-05-26 12:33:44.974	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	156	40	AgePatient	AgePatient
33	2016-05-26 12:41:52.762	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	156	false	Delayed emergency	Delayed emergency
34	2016-05-26 12:41:52.763	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	156	true	consultation box	consultation box
35	2016-05-26 12:41:52.764	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	156	false	Shock treatement	Shock treatement
36	2016-05-26 13:00:35.388	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	156	true	ExitCB	ExitCB
37	2016-05-26 13:00:35.389	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	156	false	Lying waiting	Lying waiting
38	2016-05-26 09:37:12.282	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	157	[redacted]	NamePatient	NamePatient
39	2016-05-26 09:37:12.282	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	157	[redacted]	NumPatient	NumPatient
40	2016-05-26 09:37:12.283	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	157	28	AgePatient	AgePatient
41	2016-05-26 10:03:26.314	org.jbpm:EDProj:1.0	'	EDProj.EmergencyProcess	157	true	Delayed emergency	Delayed emergency

Figure A.5: Screenshot of Variableinstancelog table

createdon date	deploymentid character varying(255)	descriptio character	duedate date	name character varying(255)	parentid bigint	priority integer	processid character varying(255)	processinstanceid bigint
2016-05-25	org.jbpm:EDProj:1.0	''		Consultation in box	-1	0	EDProj.EmergencyProcess	313
2016-05-25	org.jbpm:EDProj:1.0	''		Lying waiting	-1	0	EDProj.EmergencyProcess	313
2016-05-25	org.jbpm:EDProj:1.0	''		Registration	-1	0	EDProj.EmergencyProcess	314
2016-05-25	org.jbpm:EDProj:1.0	''		Sorting	-1	0	EDProj.EmergencyProcess	314
2016-05-25	org.jbpm:EDProj:1.0	''		Consultation in box	-1	0	EDProj.EmergencyProcess	314
2016-05-25	org.jbpm:EDProj:1.0	''		Registration	-1	0	EDProj.EmergencyProcess	315
2016-05-25	org.jbpm:EDProj:1.0	''		Sorting	-1	0	EDProj.EmergencyProcess	315
2016-05-25	org.jbpm:EDProj:1.0	''		Consultation in box	-1	0	EDProj.EmergencyProcess	315

Figure A.6 : Screenshot of AuditTaskImpl table

Appendix B

An overview of the candidates' selection process execution logs

enddate timestamp without time zone	processinstanceid bigint	startdate timestamp without time zone	status character varying(255)	taskid bigint	taskname character varying(255)
2017-07-18 15:16:17.353	484	2017-07-18 15:14:13.764	Completed	1140	Pre-Registration Online
2017-07-18 15:16:50.653	485	2017-07-18 15:14:50.074	Completed	1141	Pre-Registration Online
2017-07-18 15:16:37.709	486	2017-07-18 15:15:00.013	Completed	1142	Pre-Registration Online
2017-07-18 15:17:26.775	487	2017-07-18 15:16:59.648	Completed	1143	Pre-Registration Online
2017-07-18 15:18:25.727	488	2017-07-18 15:17:49.854	Completed	1144	Pre-Registration Online
2017-07-18 15:18:49.94	489	2017-07-18 15:17:43.317	Completed	1145	Pre-Registration Online
2017-07-18 15:19:03.157	490	2017-07-18 15:18:56.704	Completed	1146	Pre-Registration Online
2017-07-18 15:19:42.505	491	2017-07-18 15:19:07.076	Completed	1147	Pre-Registration Online
2017-07-18 15:19:59.82	492	2017-07-18 15:19:51.259	Completed	1148	Pre-Registration Online
2017-07-18 15:20:13.27	493	2017-07-18 15:19:32.55	Completed	1149	Pre-Registration Online
2017-07-18 15:20:24.939	494	2017-07-18 15:18:02.015	Completed	1150	Pre-Registration Online
2017-08-04 10:27:52.144	484	2017-08-04 10:20:01.142	Completed	1151	Calculate Score
2017-08-04 10:28:07.712	486	2017-08-04 10:27:00.468	Completed	1152	Calculate Score
2017-08-04 10:28:23.82	485	2017-08-04 10:27:01.239	Completed	1153	Calculate Score
2017-08-04 10:28:40.885	487	2017-08-04 10:28:10.251	Completed	1154	Calculate Score
2017-08-04 10:28:57.12	488	2017-08-04 10:27:04.402	Completed	1155	Calculate Score
2017-08-04 10:29:23.443	489	2017-08-04 10:28:59.776	Completed	1156	Calculate Score

Figure B.1: Screenshot of Bamtasksummary table

processid character varying(255)	processinstanceid bigint	processname character varying(255)	processversion character varying(255)	start_date timestamp without time zone
Selecting.Candidates	531	selecting	1.0	2017-07-19 17:30:34.757
Selecting.Candidates	532	selecting	1.0	2017-07-19 17:31:58.258
Selecting.Candidates	533	selecting	1.0	2017-07-19 17:32:41.112
Selecting.Candidates	534	selecting	1.0	2017-07-19 17:33:56.723
Selecting.Candidates	535	selecting	1.0	2017-07-20 17:37:27.585
Selecting.Candidates	536	selecting	1.0	2017-07-20 17:38:00.99
Selecting.Candidates	537	selecting	1.0	2017-07-20 17:38:28.63
Selecting.Candidates	538	selecting	1.0	2017-07-20 17:39:02.435
Selecting.Candidates	539	selecting	1.0	2017-07-20 17:39:36.687
Selecting.Candidates	540	selecting	1.0	2017-07-20 17:40:07.808

Figure B.2: Screenshot of Processinstancelog table

nodename character varying(255)	nodetype character varying(255)	processid character varying(255)	processinstanceid bigint
Pre-Selection Candi	HumanTaskNode	Selecting.Candidates	549
Calculate Score	HumanTaskNode	Selecting.Candidates	549
Pre-Selection Candi	HumanTaskNode	Selecting.Candidates	550
Calculate Score	HumanTaskNode	Selecting.Candidates	550
Pre-Selection Candi	HumanTaskNode	Selecting.Candidates	551
Calculate Score	HumanTaskNode	Selecting.Candidates	551
Pre-Selection Candi	HumanTaskNode	Selecting.Candidates	552
Calculate Score	HumanTaskNode	Selecting.Candidates	552

Figure B.3: Screenshot of Nodeinstancelog table

id [PK] bigint	logtime timestamp without time zone	taskid bigint	type character varying(255)
4245	2017-07-27 12:23:12.291	1645	ADDED
4246	2017-07-27 12:25:07.219	1646	ADDED
4247	2017-07-27 12:25:58.419	1647	ADDED
4248	2017-07-27 12:26:26.203	1648	ADDED
4249	2017-07-27 12:26:58.49	1649	ADDED
4250	2017-07-27 12:27:21.155	1650	ADDED

Figure B.4: Screenshot of TaskEvent table

processid character varying(255)	processinstanceid bigint	value character varying(255)	variableid character varying(255)
Selecting.Candidates	726	[redacted]	Name candidate
Selecting.Candidates	726	Institut Supérieur de Gestion de S	Institute
Selecting.Candidates	727	L.A	Diplome
Selecting.Candidates	727	[redacted]	Name candidate
Selecting.Candidates	727	ISET Sousse	Institute
Selecting.Candidates	728	L.A	Diplome
Selecting.Candidates	728	[redacted]	Name candidate
Selecting.Candidates	728	Institut des Hautes Etudes Commerc	Institute
Selecting.Candidates	729	L.F	Diplome
Selecting.Candidates	729	[redacted]	Name candidate
Selecting.Candidates	729	Faculté des Sciences de Gafsa	Institute
Selecting.Candidates	730	L.A	Diplome
Selecting.Candidates	730	[redacted]	Name candidate
Selecting.Candidates	730	Faculté des Sciences Économiques e	Institute
Selecting.Candidates	731	L.F	Diplome
Selecting.Candidates	731	[redacted]	Name candidate
Selecting.Candidates	731	Faculté des Sciences Économiques e	Institute

Figure B.5: Screenshot of Variableinstancelog table

name character varying(255)	parentid bigint	priority integer	processid character varying(255)	processinstanceid bigint	pi in	status character varying(255)	taskid bigint
Calculate Score	-1	0	Selecting.Candidates	579	3	Completed	1339
Calculate Score	-1	0	Selecting.Candidates	580	3	Completed	1340
Calculate Score	-1	0	Selecting.Candidates	581	3	Completed	1341
Calculate Score	-1	0	Selecting.Candidates	582	3	Completed	1342
Calculate Score	-1	0	Selecting.Candidates	583	3	Completed	1343
Calculate Score	-1	0	Selecting.Candidates	584	3	Completed	1344
Calculate Score	-1	0	Selecting.Candidates	585	3	Completed	1345
Calculate Score	-1	0	Selecting.Candidates	586	3	Completed	1346
Calculate Score	-1	0	Selecting.Candidates	587	3	Completed	1347
Calculate Score	-1	0	Selecting.Candidates	588	3	Completed	1348
Calculate Score	-1	0	Selecting.Candidates	578	3	Completed	1349

Figure B.6: Screenshot of AuditTaskImpl table

Appendix C

Questionnaire of patient's satisfaction in the emergency care service

Date:……../……../20……	Age:……	Gender: ……	Medical file number:…
Have you come: By day ☐ During the week ☐	By night ☐During the weekend ☐		

Please check the box that best reflects your opinion.

	Very satisfied	Satisfied	Neutral	Dissatisfied	Very dissatisfied
Interest and attention brought by paramedical staff	☐	☐	☐	☐	☐
Interest and attention brought by medical staff	☐	☐	☐	☐	☐
Paramedical staff availability	☐	☐	☐	☐	☐
Medical staff availability	☐	☐	☐	☐	☐
Availability of medical equipment	☐	☐	☐	☐	☐
Hospital staff is well dressed	☐	☐	☐	☐	☐
Quality of care by paramedical staff	☐	☐	☐	☐	☐
Quality of care by medical staff	☐	☐	☐	☐	☐

Clarity of information	☐	☐	☐	☐	☐
Your installation in the waiting room before delayed emergency	☐	☐	☐	☐	☐
Your installation in the waiting room before registration	☐	☐	☐	☐	☐
Your installation in the waiting room before consultation in the box room	☐	☐	☐	☐	☐
Your installation in the sorting room	☐	☐	☐	☐	☐
Your installation in the supervision room	☐	☐	☐	☐	☐
Your installation in the crash room	☐	☐	☐	☐	☐
Overall waiting time before the intervention of paramedical personnel	☐	☐	☐	☐	☐
Overall waiting time before the intervention of medical staff	☐	☐	☐	☐	☐
Regularity of doctor visits in the supervision room	☐	☐	☐	☐	☐
Regularity of doctor visits in the crash room	☐	☐	☐	☐	☐

Add any comments or suggestions that may be helpful to emergency care staff

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Thank you very much for your participation

Appendix D

Questionnaire for qualitative evaluation of SIAD Master's degree interview

Candidate's Name:……………………………………Date:……../……../20……

Please check the box that best reflects your opinion.

	Very satisfied	Satisfied	Neutral	Dissatisfied	Very dissatisfied
Is an appropriate amount of time provided for each question during the interview?	☐	☐	☐	☐	☐
How were the interviewers' communication skills during the interview?	☐	☐	☐	☐	☐
What about your installation during the interview?	☐	☐	☐	☐	☐
Are the questions during the interview aligned with the master's degree plan?	☐	☐	☐	☐	☐
Is the atmosphere in which the interview is conducted encouraging not only to giving answers but also to asking questions?	☐	☐	☐	☐	☐

- Have you noticed any task during the preselection process that was done unsafely (incorrectly)? How did you discover it?

Describe how the process can best be performed.

Did you know what criteria you were assessed against? Do you consider that the selection was fair?

Add any comments or suggestions that may be helpful to the Master's committee

Thank you very much for your participation