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A Systematic Approach for Key Performance Indicator Management

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Abstract Performance evaluation is essential for todays organizations since it allows them to assess their progress towards their objectives through the adoption of Key performance indicators (KPIs). Unfortunately, decisions often miss deep analysis because of the lack of data, huge number of KPIs, unknown dependencies between business processes and KPIs, conflicting goals, and poorly understood relationships among indicators. This study proposes a systematic approach for managing KPIs by integrating several proven techniques and methods in a well-defined and balanced way: (i) the adoption of the business process management (BPM) approach, (ii) the application of the Analytic Hierarchy Process (AHP) method for KPI selection, (iii) the exploitation of ontologies for semantical considerations for KPIs, and (iv) the usage of the data mining techniques for extracting knowledge from KPIs measurements. The approach includes four fundamental phases: design, configuration, enactment, and evaluation. In this regard, the effective and intelligent usage of KPI data and knowledge contributes to accomplishing significant enhancement during the BPM phases. The phases of this approach are illustrated and validated through a real-world case study from the health care sector.

Keywords Key performance indicator · business process management · Analytic Hierarchy Process · SMART criteria · ontology

1 Introduction

Today, the definition and measurement of process indicators and their improvement is a critical task in any successful organization. In todays organizations, several management systems co-exist each with a different focus and, depending on the organizational culture, each with a different importance: classical

line management (hand-in-hand with management accounting (Bhimani et al, 2008)), business process management (van der Aalst et al, 2016), quality management (Edwards, 1982), ISO9000(International Organization for Standardization, 2005), knowledge management (Nonaka, 2008), strategic management (Kaplan and Norton, 2007) etc. Independent of the management system, the definition and measurement of key performance indicators (KPIs) always form an integral, essential part of the management approach. Still, decision makers in the field often get lost in their KPI endeavors. How comes? A literature review provided as part of this study reveals that this is due to: lack of data, a usually huge number of KPIs, unknown dependencies between business processes and KPIs, conflicting goals, and poorly understood relationships among indicators.

Moreover, a difficulty arises in understanding and selecting pertinent indicators from a large available number of proposed indicators. The selection of KPIs is necessary to assess the performance of business processes. However, selecting a small set of KPIs from a large number of those available for a particular business process is often not simple. As a consequence, the need for a methodology in selecting KPIs for business processes analysis has increased. Moreover, this selection is generally contextual, where a lack of understanding of what actually measures these KPIs leads to a failure in monitoring and reporting them. Another main problem concerns managers who do not possess a solid background on KPI dependencies, especially with various business process activities. In addition, organizations make decisions every day to follow their strategies and to achieve their goals. Based on their business processes, they generate a lot of information from business process execution and other data sources. In order to extract information that is relevant to decisions, all of these data need to be organized, frequently updated and enriched by semantics.

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 (Parmenter, 2015).However, this practice presents several drawbacks. First, most business process management systems (BPMS) are closely linked to the structure of available data, providing many reports that may be hard to understand with respect to the overall business strategy. Second, it provides only partial information to decision-makers, without taking into account which activities in the business processes are involved and which inter-relationships between KPIs are considered. After monitoring KPIs, one still needs to answer the question of how to improve the process in terms of its KPIs.

Business data usually contain a lot of explicit and hidden relationships that make them difficult to use. As a consequence, it is required to interpret and link these raw data to their performance measurement and analyze how it can affect other business tasks and other performance measurements.

This paper represents an initiative for adressing these problems. It proposes a systematic approach that guides decision-makers in identifying important factors to be considered in the improvement and evaluation of KPIs as well as

business processes. The approach integrates proven techniques and methods in a well-defined and balanced way: (i) the adoption of the business process management (BPM) approach, (ii) the application of the Analytic Hierarchy Process (AHP) method for KPI selection, (iii) the exploitation of ontologies for semantical considerations for KPIs, and (iv) the usage of the data mining techniques for extracting knowledge from KPIs measurements.

Through the approach proposed in this study, we benefit from (i) the identification of KPIs with existing values to be extracted from event logs generated by the usage of BPMSs, (ii) the definition of specific indicators related to business process goals, (iii) the representation of potential relationships between all necessary concepts based on domain knowledge experts, (iv) the discovery of interesting relationships among indicators based on huge amounts of business process transaction records and (v) the subsequent contextual understanding of KPI pertinence.

In order to evaluate the proposed approach, we present a thorough case study of the emergency care department of the Farhat Hached University Hospital, Sousse, Tunisia. Performing business process analysis in emergency care is particularly difficult due to the complex nature of corresponding healthcare processes and the importance of a well-coordinated flow of patients.

The remainder of this paper is organized as follows Section 2 introduces the basic concepts that we use in our work such as business process and KPI. Subsequently, we also present the motivation behind the use of each method or technique like Analytic Hierarchy Process (AHP), ontology, and association rules technique in this research. Section 3 describes in detail the research methodology to address the aforementioned goals. Section 4 summarizes recent related works based on similar concepts. Section 5 presents our proposed approach. Section 6 describes the application of our approach in the emergency care case study. The last section gives a brief conclusion.

2 Theoretical Background

Business process management (BPM) is an approach for steering the company, based on its business processes. In (van der Aalst et al, 2016), Van Der Aalst et al. define BPM as a discipline that advocates the use of continuous improvement on processes. In the literature, different BPM lifecycles have been proposed by different researchers. They vary depending on the granularity for identifying the phases and the way of grouping functionalities in the different phases. The BPM lifecycle defines how to improve processing based on the knowledge of historical executions (Dumas et al, 2013). In our work, we focus on all BPM phases and we 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.

Choosing appropriate indicators needs to be based on a good understanding of what is important to the organization. It is necessary to identify and to clarify the criteria, which are going to influence the choice of these indi-

cators. Therefore, it needs an approach to facilitate the structuring, measurement, and synthesis of KPIs. In that sense, in literature, it is generally recommended that KPIs satisfy the SMART (Specific, Measurable, Attainable, Relevant and Time-bounded) criteria (Doran, 1981)(Meyer, 2003)(Shahin and Mahbod, 2007)and we consider crucial to use one of the most popular methods for multiple criteria decision making such as the Analytic Hierarchy Process method citepsaaty2012models. The SMART rule was originally developed for establishing meaningful objectives for projects and later adapted to the identification of metrics and KPIs (Kerzner, 2017). The purpose of the AHP method in this research is to assess the quality of indicators by comparisons and to set new priorities conducting to KPI improvement or additional KPI development. The AHP method is used successfully in many areas, including multi-criteria decision making and seems very suitable to our selection problem for the following reasons: first, it allows for reaching an agreement on a coherent set of KPIs that do not conflict but instead ideally support business process goals and meet the needs of as many stakeholders as possible (requiring, of course, as inputs, subjective judgments from a decision-maker or an expert). Second, the few numbers of criteria (SMART) are considered in this work as appropriate to structure the decision makers mind in order to provide a systematicprioritization of sustainability performance indicators. Third, we dont need an absolute scale but relative values (e.g. less/more; somewhat, very) in opposition to classical measurement (generally based on domain expertise). Fourth, the AHP method allows to keep in our approach a logical consistency of the judgments used to detect when KPI preferences are inconsistent.

Furthermore, we need to create an abstract view of the business domain or its relevant parts that we want to represent.Ontologies are a proven instrument to capture domain knowledge in a generic way and allowing a commonly agreed-upon understanding of a particular domain (Gruber, 1995). In our approach, it is not our purpose to represent the whole BPM specification in a semantic way. We rather want to define a simple ontology that is easy to grasp. First, a well-defined KPI ontology enables the business analyst to describe business activities with all of their full measurements. Second, it makes knowledge explicit and allows for knowledge sharing among domain experts and people engaged in the business process design phase and business improvement phase. Capturing KPIs and modeling 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 accessing and improving the corresponding business process. Therfore, our approach suggests, in oder to make any decision, to analyze (ideally) all the available relevant information related to the KPIs. For this purpose, we suggest data mining, especially association rule-based learning as a research method at this stage.

Data mining (DM) is part of the knowledge discovery from databases and it is an integration of multiple technologies such as statistics, database management, Data Warehousing, and machine learning. Association rule mining (Agrawal and Srikant, 1994) is one of the most essential techniques of data

mining. The main goal of association rules is to find and extract all interesting relationships for a given dataset. There exist many reasons for using data mining techniques in our context. First, the association rules technique is very simple and comprehensible for a non-expert user. The reason for this is in the fact that implications are at the core of human reasoning. Second, the technique extracts the complete set of association rules without the need of an important user implication during the process; and it uses support and confidence measurements as constraints to generate interesting rules; e.g.; to extract the most relevant KPI that can be used to characterize the situation of the business process. To be more concrete, we need to select the more frequent KPI values in a specific business process and analyze the rules that are considered relevant to help analysts in the improvement phase. Third, regarding the unknown dependencies between KPIs, we address three main issues: the adoption of user knowledge for the discovery of KPI dependencies, the interactivity with the user to validate the ontology and the improvement of KPIs and business processes. Fourth, KPI dependencies presented in the ontology have a considerable impact on the performance of business process since knowledge related to the KPI is an essential resource for the improvement of business processes.

3 Research Methodology

As a starting point of this research work, a selection of papers dedicated to our topic has been considered for the acquisition of the necessary theoretical background. On the basis of these foundations and also on the basis of real observations, we identified a set of research challenges. To meet these challenges, we have elaborated a systematic approach for KPI management. To verify, enhance and validate the proposed systematic approach, its different phases and sub-phases have been applied in a real case. During the case study, verifications and re-adjustments of the proposed approach were carried out on the basis of the obtained results.

In the considered case study, we deal with the emergency care processes of the Farhat Hached University Hospital. This Tunisian hospital was created in October 1942 in Sousse. It is a University Hospital Center (UHC) with 900 beds and with more than 25 specialties. Its emergency departement registers nearly 50 000 patient per year. It includes three main units: hospitalization unit, consultation unit and the intensive care unit.

In this emergency departement, we focused on the healthcare process and we recorded and evaluated real values of quantitative and qualitative indicators, which together offer a better assessment of the process performance. This case study was conducted during May 2016. During this period, a daily observation of the concrete functioning of the emergency care process and a discussion with patients and healthcare professional was necessary. Difficulties and encountered problems were identified and some potential solutions were also expressed.

Using interviews with the head of the emergency departement, the purpose was to (i) identify business process goal, (ii) model the emergency care process which aims to better satisfy the patients and to offer faster services with better quality, (iii) identify and develop a list of KPIs and determine the associated target values, (iv) develop a set of qualitative indicators based on a questionnaire of patients satisfaction in the emergency care service. Questions in the questionnaire are formulated according to Likert scale. Moreover it was needed to have an authorization from the head of emergency department as a visitor allowed to observe patient pathways and interview patients.

As a starting point, we have elaborated a BPMN (Business Process Model and Notation) model of the emergency care process. BPMN as standardized by the Object Management Group (OMG) (Object Management Group, 2006) is considered as a standard for business process modeling. All obtained information and propositions were registered and exploited for readjusting this BPMN model of the emergency care process and reconstructing the its execution instances in a BPMS. Obtained data concerned two aspects: (i) first each time a patient arrived to the emergency department it was registered, and each step through which the patient passed was also registered by mentioning the corresponding time and duration and also the responsible actor, (ii) second, for patients who accepted to be interviewed, they were asked about their level of satisfaction concerning their stay, the clarity of information, the quality of care, etc.

The proposed questionnaire was answered by 100 patients. For each patient, we recorded the start/end date and time of all activities from the arrival of the patient to his/her discharge. We stayed at the emergency departement for 6 hours per day to record KPI values during different periods of time (the morning/afternoon, weekend, etc) and with different patients (different health status, male/female, etc). According to their critical health status or lack of satisfaction about the quality of care, some patients didn't accept to respond to the questionnaire.

4 Related Work

According to the scope of our research, many works use similar concepts, methods or techniques for various purposes. In this section, we aim to position of our approach with respect to related work, based on a list of dedicated questions as follows.

Does the methodology guarantee that the predefined indicators are SMART? This aspect is partially dealt with in the works of (del Río Ortega, 2012) (Resinas et al, 2014) (Shahin and Mahbod, 2007) (Podgórski, 2015). In (del Río Ortega, 2012) (Resinas et al, 2014), the authors used a template for KPI definition. In (Shahin and Mahbod, 2007) (Podgórski, 2015), the authors assumed that the selected KPIs are already relevant. Some works such as (Yaghoobi and Haddadi, 2016) use the interview method or are based on a qualified expert (Maté et al, 2017). Other works such as (Podgórski, 2015) con-

sider literature reviews. In our work, we apply the AHP method by evaluating KPIs alternatives with respect to previously determined criteria.

Does the approach cover quantitative and qualitative aspects in the evaluation of performance? The majority of works (Peral et al, 2017),(Resinas et al, 2014) always cover either quantitative or qualitative indicators (not both simultaneously). For example in (Perez-Alvarez et al, 2016), the authors focus on 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 business processes. In our work, we include the definition of qualitative indicators to take into account opinions of different stakeholders.

Does the approach help to improve the definition of existing KPIs? This aspect is partially dealt with in (Resinas et al, 2014) where the authors introduce a collaborative platform that provides a place for the BPM community where they can discuss, collaborate and create process-related KPIs. Many approaches ((Shahin and Mahbod, 2007), (Podgórski, 2015)) founded in literature do not help to improve the definition of existing KPIs because the main goal when using AHP method is the prioritization. In our work, we improve the definition of KPIs by proposing a new approach in which we guarantee that all indicators are SMART.

Does the approach help to discover KPIs? This aspect is not supported by any of the aforementioned works. In our work after reviewing the AHP synthesis we can discover new indicators. This step helps us to ensure that KPIs are sufficient with respect to their goal and to check KPI requirements for ambiguities or completeness.

Does the ontology cover all necessary concepts involved in the business 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, (Fanesi et al, 2015) enables metamodeling representations based on a multilayer semantic description of BPMN models on an ontology. In our work, we focus more on the modeling and analysis of KPIs behavior (activities ad SMART KPIs) rather than an abstract specification.

Can the ontology design be validated on the basis of experts knowledge and real business processes execution? Some previous work expresses the semantics of processes in a formal way. For example, in (Bistarelli et al, 2017), the authors represent a prototype system PrOnto which reads processs activities by mining the event log file and extracting a model of the process described in a Unified Modeling Language (UML)Activity Diagram model. The main goal of the authors prototype is to discover business processes from an event log and an appropriate level of abstraction from the business ontology. The use of business processes execution is partially invoked in (Fanesi et al, 2015) that provides some examples of possible queries that usually provide interesting data for the management. In our work, we use real values of KPIs to validate the relations between concepts involved in our proposed ontology and to enrich the description of KPIs.

Does the ontology help to continuously improve KPIs and business processes? This concept is partially dealt with (Saidani et al, 2015) where the authors support contextual factors that are related to business processes and represent dependency situations in the context. In our work, we pay particular attention to the logical relation among the KPIs presented in the ontology (based on the expert domain and based on data mining techniques). This way, the ontology can be easily adapted to meet changing requirements.

Does the association rules help to continuously improve the proposed ontology? To the best of our knowledge, there is no approach that addresses exactly this aspect. For example in (Fanesi et al, 2015), the authors point out that having a unified ontology that includes the process model and the execution data is a requirement to solve this problem. In our work, we propose to enrich the KPI ontology based on association rules deduced from the execution of real scenarios. .

Does the association rules help to continuously improve KPIs and business processes? This concept is partially dealt with (Peral et al, 2017). The authors use data mining to analyze data from different dimensions and conclude the relationships identified. In our work, we focus on BPMS logs where quantitative indicators are available and we enrich the data file with other qualitative indicators. After giving the stakeholders all necessary data and analysis, they have the right to update the KPI list for further evaluation and improvement.

5 A Systematic Approach for KPI Management

Our approach is structured by the BPM lifecycle as described by Matthias Weske in (Weske, 2012) and therefore consists of four fundamental phases: the design phase, the configuration phase, the enactment phase, and the evaluation phase. Figure 1 shows our main contribution under each of the KPI lifecycle phases.

5.1 Design Phase

With respect to the design phase, we add a specific sub-phase dedicated to KPI definition and ontology design. In this phase, we analyze the KPIs that are currently in use and check whether it is necessary to define new KPIs for the defined business process goals. After that, we move on to the definition of KPIs; these steps have to respect business-level knowledge and might include many indicators.

5.1.1 Definition of KPIs

In the first phase of the suggested approach, we essentially deal with various measurements related to the business processes. We deal with two different as pects: qualitative and quantitative. In each aspect, we define and validate the appropriate indicators with different stakeholders of the business process.

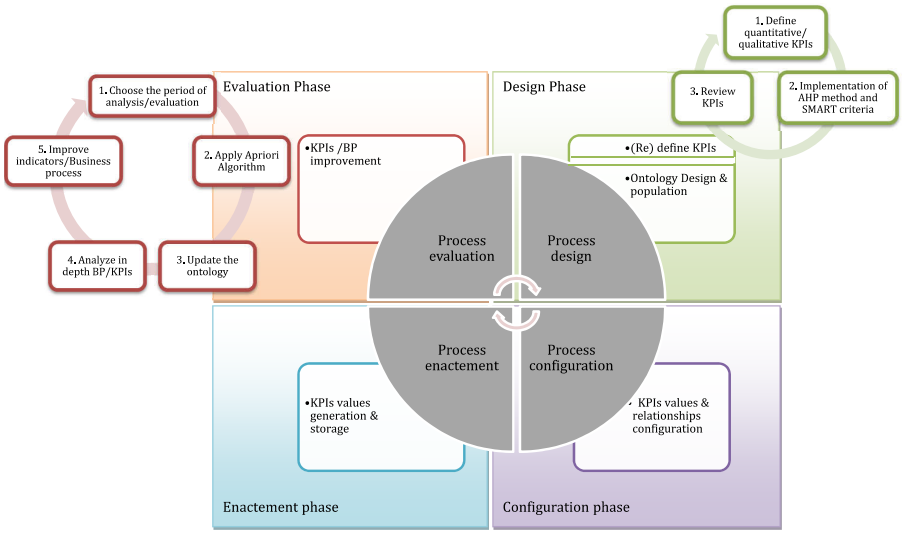

Fig. 1 KPI management lifecycle

5.1.2 Ontology Design and Population

An ontology is about modeling entity types and their relationships. This way, it allows to gain an understanding of existing domain concepts and their relationships in a language close to natural language. In addition, the business analyst can instantiate classes and create instances, by adding KPIs from the SMART measurements validated by the AHP method and fulfilling the suitable activities related to a specific business process. This step will help the early understanding of all involved concepts by the analysts before the business process gets implemented. In our ontology, we represent, on one hand, the relationships between an activity and the attached KPIs, and on another hand, the relationships between indicators, we define a set of properties. Furthermore, properties can have inverses and they may be transitive or symmetric. Those definitions of relationships and the relative individuals need to be modeled in order to aid the monitoring of KPIs that contribute to performance improvement.

5.2 Configuration Phase

Our approach relies on the availability of BPMS logs to extract relevant data. In our work, we persist data logs to perform further analysis of historical information. Furthermore, we prepare a knowledge database to record meaningful

data about KPIs. Data can be considered and utilized for analyzing processes, providing real knowledge about their execution and facilitating the identification of improvement opportunities. This knowledge database serves as an input to examine the previous periods business process objectives, achievements, performance, and challenges.

5.3 Enactment Phase

After the enactment of the business processes and once the KPIs have been developed, it is necessary to determine what data needs to be collected for each KPI used to measure performance.

Based on our SMART KPIs defined in the first phase, we might also need to review an administrative document or statistics. The KPI data can be classified into two categories, i.e., real values and estimated values reflecting the nature of the information observed and treated. While KPI real values are about all observed data, KPI estimated values are all evaluated data after comparing the real value with the target value or tolerant value fixed by the decision-maker. KPI estimated values have two values (KPI may have an unacceptable value or "Not Ok" in the case of the KPIs performance real value is below the threshold and acceptable or ok value in the case of the KPIs performance real value is above the threshold).

5.4 Evaluation Phase

After we analyze business process based on process dashboards provided by the BPMS, we move on in this phase to the corresponding KPIs improvement step. The proposed KPI lifecycle started by choosing the period of analysis and the preparation of the appropriate data set. The period of analysis in which business processes are executed is of great interest to evaluate our KPIs in reaching a business process objective. The period of analysis can be related to the organization, to the actors, etc. This fact requires defining carefully the period of analysis to evaluate businsess processes.

After the decision-makers choose the period of analysis, we apply the association rule mining to select interesting rules. To do that, we focus on KPI estimated values. As a result, we are usually faced with a huge amount of associations rules with some inconsistencies that may contain some interesting novel knowledge. So, we need to refer to the domain expert to validate these rules. Next, we can update the ontology. We use knowledge retained from association rules for several cases such as the conformance checking and compliance with specific rules which can facilitate the monitoring of processes for verifying compliance with best practices. In fact, first, it helps to find inconsistencies with 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 results in updating object or data properties based on the data mining knowledge base.

With the aim at extracting knowledge from event logs that are recorded by BPM systems and mining KPI content associated with process instances data, we use process mining. The essential thing is in carefully preparing which data helps decision-maker to firstly analyze activities in the business process. Secondly, it also helps to get some conclusion about indicators towards process enhancement.

After all process flows were investigated and all interesting KPIs were 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 and business processes. At this level, human intervention is essential to remove the ambiguity and to make effective decisions. The major advantage of using association rules extracted from the business process execution and knowledge containted in the ontology is to evaluate the BP. Our aim to identify KPI which variations require changes in the processes execution. All this information can be converted into knowledge to improve KPIs or business processes if necessary.

6 Case Study and Corresponding Results

It is imperative to set appropriate KPIs for managing health care process information in an effective way. More precisely, we focus on the Emergency Care emergency care process in the Farhat hached emergency departement and, in the sequel, we give a description of the fulfillment of the phases constituting our approach.

6.1 Design Phase

The main activities in the emergency departement are as follow: First, at the beginning of this process, every patient has to go through the registration activity. After this, in order to arrive at a preliminary conclusion about the status of the patient, a sorting activity represents the second task in the business process 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, two possible cases exist: the patient is treated and leaves the emergency departement or the patient is transferred to another service.

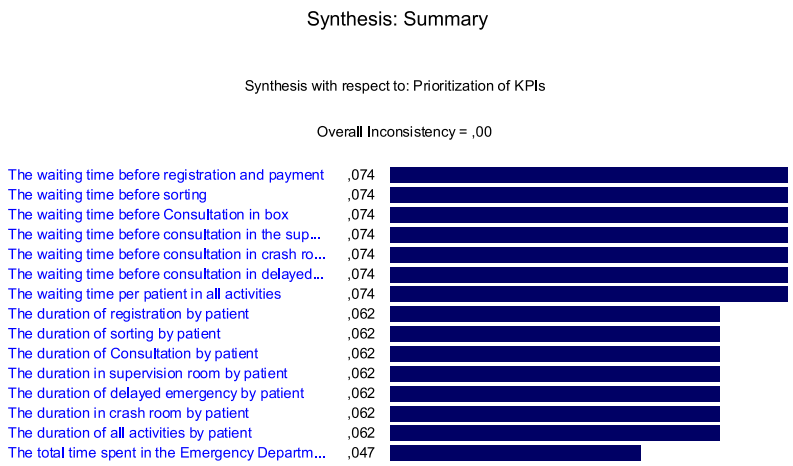

Fig. 2 AHP synthesis for quantitative KPIs

6.1.1 Definition of KPIs for the Emergency Care Business Process

This healthcare process requires a good understanding of what is important to the emergency departement. The initial list of KPIs contains many measurements, which are intended to evaluate the satisfaction of patients toward the emergency departement.

We start by adopting the AHP method and SMART criteria for our indicators and we apply AHP the following: First, we design the graphical hierarchical representation of the problem. The hierarchical structure design starts from the top level, which sets up the main problem and continues through the main SMART criteria to the bottom level that usually suggests KPIs for that particular problem. Second, we compare the relative importance of each SMART criterion under the goal of KPIs selection. Finally, we establish the pairwise comparison (validated with an expert in this domain) and we review each KPI under each criterion. AHP synthesizes the priorities of alternatives with respect to each SMART criterion. The result is given in Figures 2 and 3.

6.1.2 Ontology Design and Population for the Emergency Care Business Process

Two prerequisites must be met, before the business process ontology can be created. The first step provides the definition of the class hierarchy. For the first level, we have related the process to a specific domain (in this case the healthcare field). For the second level, we have two main concepts (activities and KPIs). The second step focuses on the creation of instances from concepts

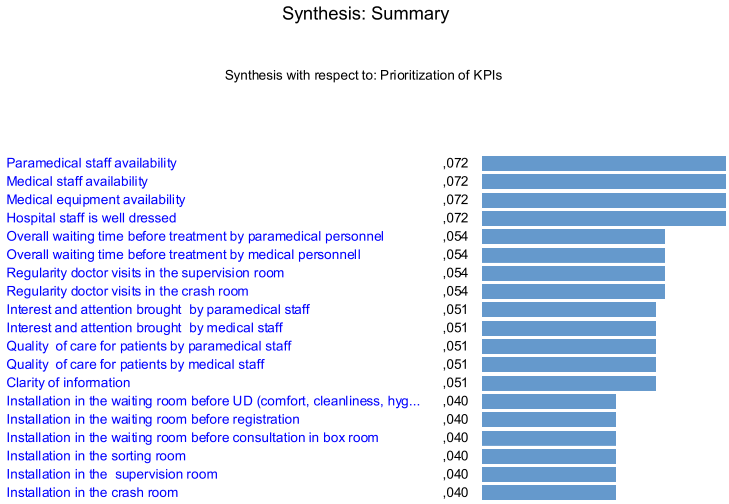

Fig. 3 AHP synthesis for qualitatives KPIs

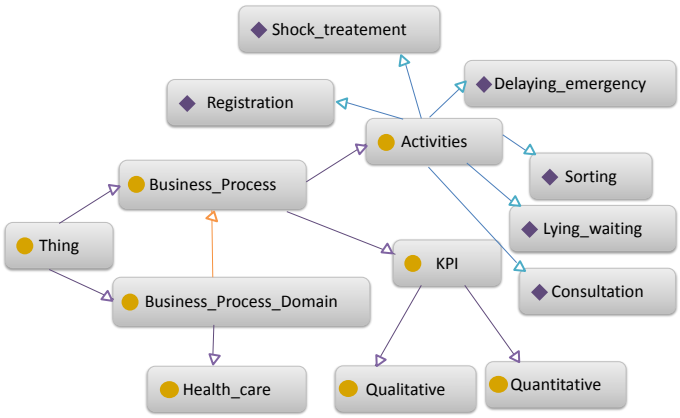

Fig. 4 Emergency care ontology

(i.e., individuals). The resulting emergency care ontology is shown in Figure 4. The class "Activities" corresponds to any activity modeled in the business process. Next, we turn to the KPIs that incorporate the SMART qualitative and quantitative KPIs of the healthcare process. After that, we specify a set of properties to describe relationships among indicators.

6.2 Configuration Phase

We analyze log information generated during the execution of business processes, which is typically stored in a relational database. This database is a crucial element for the extraction of KPIs measurements from the BPMS. After the analysis of the available data in logs, we also configure configure roles of process participants.

6.3 Enactment Phase

After the deployment of the business process, we entered the different process instances of the emergency care process. By interviewing patients about their satisfaction, the qualitative aspect will be considered, thus giving a better way to the emergency care process. In this sense, we define a set of qualitative indicators such as *interest and attention brought by medical/paramedical staff*, *the quality of care for patients by medical staff* and *the clarity of information.* Quantitative KPIs are derived from a close look at the activities involved in the business process. For more details, we define six indicators related to the time that the process actor actually spends doing each activity: *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.* We also define another indicator related to the *duration of all the activities by the patient* (the sum of all previous activities duration). We also define six indicators related to the time the process waits for a certain activity to be finished, from the initial request to the eventual delivery, i.e., these indicators represent the waiting times of different activities,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.

6.4 Evaluation Phase

In this step, the proposed KPI lifecycle started by choosing the period of analysis and the preparation of indicators data set.

After that, we apply association rule mining to select interesting rules. To do so, we focus on the file of KPI estimated values.. We start by setting the minimum support used for the selected indicators in the data set. The knowledge database contains only frequent itemsets that satisfy the minimum support. Then, in a second step, the frequent itemsets are used to generate all possible rules from them, i.e., all rules that satisfy the minimum confidence constraint. 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. We continue the same process to test KPI dependencies. Table 1 shows an example result of this association rule mining.

Table 1 Example of Apriori algorithm result

Antecedent	Consequent	Confidence
[Quali_KPI1 interest and attention brought by paramedical staff =ok]	[Quali_KPI2 interest and attention brought by medical staff =ok]	0.98
[Quali_KPI2 interest and attention brought by medical staff =ok]	[Quali_KPI1 interest and attention brought by paramedical staff =ok]	0.90
[Quali_KPI1 interest and attention brought by paramedical staff =ok]	[Quali_KPI3 paramedical staff availability=ok]	0.88
[Quali_KPI3 paramedical staff availability=ok]	[Quali_KPI1 interest and attention brought by paramedical staff =ok]	0.8
[Quali_KPI1 interest and attention brought by paramedical staff =ok]	[Quali_KPI4 medical staff availability=ok]	0.88
[Quali_KPI4 medical staff availability=ok]	[Quali_KPI1 interest and attention brought by paramedical staff =ok]	0.78
[Quali_KPI1 interest and attention brought by paramedical staff =ok]	[Quali_KPI5 medical equipment availability=ok]	0.86

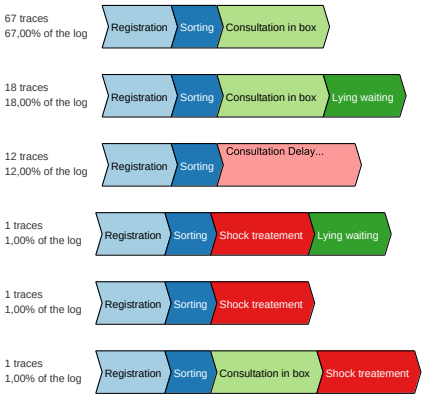

Fig. 5 Screenshot of possible paths related to the emergency care process

We continue with a deep analysis based on process mining technique.

First, we start by preparing the data that should be analyzed. We extract instances related to the process execution logs. After that, we import this data into ProM (process mining tool)[1]. This process mining tool was chosen, because it has an intuitive interface and allows for automatic process visualization. The coloring of activities provided by the software is very important to see, for example, how often each activity occurs or or the possible execution scenarios. Based on this view (Figure 5), we can see that all cases start with the registration activity. Afterwards, all patients enter the sorting room for primary medical exams. In conclusion, we can say that the main process flows (67% of the log) contain 3 activities which are *registration*, *sorting*, and *con-*

[1] http://www.promtools.org/

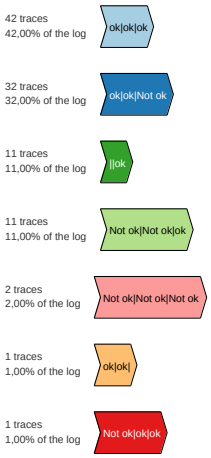

Fig. 6 Statistics related to Quali_KPI3, Quali_KPI4, and Quanti_KPI9

sultation in box. We can also see the events in a selected case to get a detailed view.

By usig ProM, we can get further analyze some links between indicators. 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.

If we take, for example, the combination of Quali KPI3 (*paramedical staff availability*), Quali KPI4 (*medical staff availability*) and Quanti KPI9 (*waiting time before sorting*), we obtain the traces as shown in (Figure 6). We can browse the cases to verify whether there actually exist some cases of patients that waited to enter the sorting room (less than 5 min), meaning that Quanti KPI9 (*the waiting time before sorting*) is acceptable. However, when patients entered to the sorting room, neither paramedical staff nor medical staff was available, meaning that Quali KPI3 (*paramedical staff availability*) and Quali KPI4 (*medical staff availability*) are not acceptable. This case is infrequent, as only 11% of cases were found, but it is particularly important to see concrete examples for strange behavior such as that and to help process stakeholder to find issues that are rather hard to believe until they have been drilled down to an individual example case.

6.5 Lessons Learned from the Case Study

Based on the obtained results from the conducted case study, we highlight the following observations:

– The emergency care process takes a long waiting time for patient with low level of urgency.

- The emergency care process takes too much time for patients who are transferred to medical monitoring. Especially, it takes a long time for patients under observation.
- 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 perspective, it is acceptable that patients with low level of urgency have to wait until they will be treated.
- For the long time in the monitoring room, which is explained by the fact that the health of these patients is not stable.
- For the long time taken in the consultation in a box room, which is explained by the fact that some patients required complementary medical exams, which are often made in another services in the hospital.

After discussion with patients and decision-makers, we can state some interesting observations as follows:

- The privacy of patients is not taken into account in the sorting room.
- Staff should decide if the patient need to be transferred to the appropriate location according to his/her healthcare status.
- A dedicated system is necessary to ensure that data related to each patient (previous analysis, current healthcare status) are collected consistently, both within, and across the healthcare departments. Similarly, some diagnosis results are missing or overlooked and, as a consequence, appropriate treatment is delayed or repeated.

By reviewing problems stated by patients, we can add other indicators related to the respect of the patients privacy and the waiting time during staff change.

7 Conclusion

In this work, we represented a systematic approach for managing KPIs that helps business process stakeholders in simultaneously analyzing and improving their processes together with the associated KPIs. In our presentation, we rely on (i) the adoption of the BPM approach including the design, deployment, enactment and evaluation phases, (ii) the application of the AHP method for multi criteria KPI selection based on SMART criteria, (iii) the exploitation of ontologies for semantical considerations for KPIs and presentation of dependencies between KPIs, and (iv) the usage of the data mining techniques for extracting knowledge from various KPIs measurements.

In order to validate the proposed systematic approach, we conducted a case study in the emergency department of a Tunisian university hospital. The obtained results have been proved useful to improve the considered KPIs, thus making it possible to easily enhance the emergency care process.

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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Through the approach proposed in this study, we benefit from (i) the identification of KPIs with existing values to be extracted from event logs generated by the usage of BPMSs, (ii) the definition of specific indicators related to business process goals, (iii) the representation of potential relationships between all necessary concepts based on domain knowledge experts, (iv) the discovery of interesting relationships among indicators based on huge amounts of business process transaction records and (v) the subsequent contextual understanding of KPI pertinence.