

# Towards managing Key Performance Indicators for measuring business process performance

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**Abstract.** Organizations always need to continually improve and review their critical business processes (BP), especially in the healthcare field. This improvement requires an efficient mean to support the management and the analysis of healthcare processes, to collect all relevant indicators designed for both effective management and process improvement and to understand all interesting results based on data instance logs that reflect the performance of business processes. In order to meet these challenges, we propose a novel approach for managing business process performance enabling the evaluation and optimization of BPs. This approach is illustrated through a real case study in the emergency department of "Farhat Hached" hospital in Sousse (Tunisia).

**Keywords:** Business Process, Business Process Management (BPM); Performance measurement; Key Performance Indicators (KPI); ontology; association rules; Data mining; Emergency Department; HealthCare process

## 1 Introduction

The evaluation of performance stays a topical question to assess how far the organization's goals are achieved. For this reason, BPM technology has become an important instrument for supporting complex coordination scenarios and for improving business process performance [1]. This approach has become a valuable asset in the healthcare domain [2]. It includes methods, techniques, and tools to support the design, enactment, management and analysis of operational business processes involving humans, organizations, applications, documents and other sources of information understanding, task design, and relevant result interpretation of organization's performance[3]. It can be defined also as a structured method of understanding, documenting, modeling, analyzing, simulating, executing, and continuously changing end-to-end business processes and all relevant resources in relation to an organization's ability to add value to the business [4]. In addition, it is crucial not only to understand the actual situation in the emergency department (ED) and to remodel the business processes, if necessary but also to continue the improvement of healthcare business processes based on comprehensive measurement of organization's performance. Indeed, Key Performance Indicators (KPIs) provide critical information to the organization for monitoring and predicting business performance in accordance with strategic objectives [6].

Performing business process analysis in healthcare organizations is particularly difficult due to the highly dynamic, complex, ad-hoc, and multi-disciplinary nature of healthcare processes [5].

Like it is the case for any other business process, continuous performance monitoring of healthcare process is important to assess how far the emergency department goals are achieved while promoting the patient satisfaction and improving the business process. However, in practice, performance measurement activity in health organizations has several practical issues, such as unavailability of performance measurement system, distribution of data in multiple locations and performance indicators that are expressed informally in natural language, incompleteness, lack of traceability of the BP etc; or they define them from the technical view which becomes hardly understandable to non-technical users. In addition, in many organizations including healthcare sector, there is several missing relevant information related to performance qualitative aspect ( e.g KPIs related to patient satisfaction level in the organization) where this kind of performance indicators is in general expressed in natural language. The problem above in such context is how to perform BP in more effective and efficient way without ignoring patient satisfaction aspect. We argue that it is interesting when we associate qualitative measures to quantitative measures and establish the possible links between them.

In this work, we are especially interesting in the improvement of the healthcare process. we can say that there are various challenges related to healthcare performance measurement data which may play serious hurdles in the improvement of health care process. This improvement heavily depends on both key performance indicators and knowledge. Furthermore, we need to know more about the real meaning and the implications of performance measurement value and to understand why an indicator is needed and what it is measuring and what decisions they support. Also, we need to analyze all relevant data in order to make proper decisions. These involve a clear need for approaches that facilitate the understanding of context when implementing healthcare processes. This challenge can be stated by the following three research questions: Is it possible to define a great variety of KPIs so that they are amenable to process evaluation? How can we present their mutual relationships in a way that facilitates decision making? Which KPIs are valuable for the analysis and the evaluation of the BP and how can they be identified?

The remainder of this paper is organized as follow: Section 2 introduces related work. Section 3 gives an overview of the proposed approach. Section 4 describes the healthcare process. Section 5 deals with the various performance measurements. Section 6 describes the proposed semantic representation (ontology) and the possible relationships that hold between different concepts. Section 7 focuses on building association rules using data mining technique, to describe the relationships that hold between different KPIs. The last section gives a brief conclusion.

## 2 Related works

In [8], Ortega establishes that, in practice, KPIs are informally defined usually in ad-hoc, natural language, with its well-known problems or they are defined from an implementation perspective, hardly understandable to not-technical people. In order to solve this problem, the authors propose an approach to improve the definition of PPIs using templates and linguistic patterns. In [16], the authors introduce a methodology for the application of process mining techniques that leads to the identification of regular behavior, process variants, and exceptional medical cases.

Some authors [18, 19, 20, 21] have pointed out the vagueness, imprecision of KPIs values that they are intended to represent, and the lack of an explicit representation of their semantics. According to [21], the major obstacles for effective design and management of Performance Indicators (PI) monitoring systems are related to the fact that PIs are complex objects with an aggregate/compound nature. This often leads to unawareness of indicator semantics as well as of dependencies among indicators. So, the authors in [21] propose to enrich the data cube model with the formal description of the structure of an indicator given in terms of its algebraic formula and aggregation function.

Despite the difficulties in measuring performance indicators in the current health care process, another important aspect is how to cultivate the existing information into useful practices. To solve this issue, Data mining has a great potential to enable healthcare systems to use data more efficiently and effectively [9]. The ability to use a data in databases in order to extract useful information for quality health care is a key of success of healthcare institutions [10]. Data mining techniques provide better medical services to the patients and help the healthcare organizations in various medical management decisions. Some of the services to which apply the data mining techniques in healthcare are: number of days of stay in a hospital, ranking of hospitals, better effective treatments, fraud insurance claims by patients as well as by providers, readmission of patients. They contribute to better identify treatment methods for a particular group of patients and to the construction of an effective drug recommendation systems, etc [9].

Many works applied [11, 12, 13, 14] Apriori algorithm in the healthcare domain. For example, in [11] the author used this algorithm in order to find out the associations between diagnosis and treatments in medical billing data. In [13] this algorithm was applied to discover frequent diseases in medical data in particular geographical locations at a particular period of time.

## 3 Proposed approach

Actually, BPM tools are not yet implemented in the emergency department, and consequently, the data related to measuring each activity in the BP is missing and the data related to measuring patient satisfaction is not supported. Consequently, it will result in high error rate and more effort is necessary in order to develop measuring

performance which employs several quantitative and qualitative key performance indicators. Those indicators can be derived from guidelines, either from observation and conversation with experts or communication with patients, to get all available data about the tasks in this process and then to build the BP and acquire all KPI values. We try to collect as much data and information as possible. This data will enable us to put together a comprehensive picture of the BP and its KPIs.

In this paper, in order to support the decision, several qualitative and quantitative measurements are retained, and a set of association rules organized for overall improvement purposes. In this view, to measure the performance of an Emergency Department (ED), a list of KPIs is gathered from healthcare process and domain expert and is used for testing. In this work, we are based on our observation, conversation with experts and questionnaire with patients to get all available data to acquire all KPI values. This data will enable us to put together a comprehensive picture of the BP.

Hence, selecting KPIs requires a high co-operation between its quantitative indicators and their related qualitative indicators. For this reason, for quantitative indicators, we are based essentially on the availability of jBPMlog to extract all relevant data. Indeed, the data collected during the business process execution play a key role in improving the overall performance of the business process itself. And for qualitative indicators which are more difficult to measure because they are related to patient experience in the ED, we use a Likert scale to record the level of satisfaction of the patient toward the ED. In this case, all KPIs must be consistently organized for overall improvement purposes.

Furthermore, we aim at developing a KPI ontology that fulfills two conditions. On the one hand, it includes relationships between indicators and process tasks. On the other hand, these relationships must help to reduce the existing visual gap between different kinds of KPIs allowing a comprehensive view of both assets (KPIs and tasks).

After that, the analysis of relationships between indicators can be interpreted into knowledge using data mining techniques which are crucial for making useful decisions. In this use case, since the formats of data are different from the quantitative to the qualitative measurements, the analysis of data may take longer time than usual. Due to that, we inserted all persistent data in a new KPI database. The measurement data is very useful in order to extract the meaningful information from it for improving the BP and the satisfaction of patients toward the ED.

## **4 Emergency health care process**

In this section, we provide a description of the healthcare process and we present its corresponding process model and dashboard and the history logs based on jBPM software. JBPM is an open source BPMS. A BPM system is defined as a software system which extends the functionality of traditional workflow management system, not only limited to work routing, but also to all activities of BPM [22]. It features a robust management console and development tools, with user support during the

business process lifecycle including: development, deployment, and versioning [15]. This is important to make sure that the BPM system is able to facilitate performance measurement for the adopted business process.

#### 4.1 Description the healthcare process

The design phase involves us to look at the big picture of the emergency department which initiates with the patient registration and payment and ends with her/his discharge of the ED. So, we need to focus on what components are involved in the BP.

First, at the beginning of this process, every patient has to pass by Registration activity. After that, in order to arrive to 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, consultation in the box, it can be a simple consultation or surgical consultation, consultation in the crash room the patient is of serious harm which requires immediate medical attention and finally the last case 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 sent to another service (hospitalization or specialized consultation) to ensure continuity of care or the situation of the patient requires long treatments.

#### 4.2 Execution and monitoring of the healthcare process

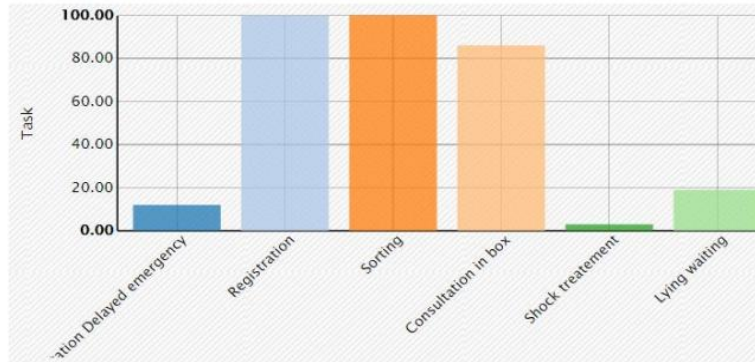
The proposed business process model is deployed with the use of jBPM software, where 100 instances have been created through the execution of the process which can be considered as statistically significant and consequently it forms the basis for continuous process optimization. The jBPM core engine stores the process and task history and provides APIs to perform the Business Activity Monitoring (BAM) operations. Further, the jBPM tooling includes the dashboard builder, which enables its users to create and customize dashboards from the business process history [15]. Measuring performance indicator is basically passing queries to the data source and retrieving the query result.

For example, table 1 and figure 2 represents a graphical representation of KPIs in KIE Workbench environment.

**Table 1.** Task duration related to process instance id 180

process_id	start_date	end_date	taskname	createddate	enddate	status	task duration	duration
180	05/29/16 11:40	05/29/16 12:10	Registration	05/29/16 11:40	05/29/16 11:47	Completed	0h 3m 8s	0h 29m 59s
180	05/29/16 11:40	05/29/16 12:10	Sorting	05/29/16 11:47	05/29/16 11:58	Completed	0h 5m 25s	0h 29m 59s
180	05/29/16 11:40	05/29/16 12:10	Consultation in b	05/29/16 11:58	05/29/16 12:10	Completed	0h 12m 25s	0h 29m 59s

In Table 1 we can find all quantitative indicators values related to task duration details. This dashboard shows all tasks that have been executed.



**Fig.1.** Number of patients in each activity

Figure 1 displays the number of patients manipulated during process executions.

## 5 Emergency health indicators

There are many measurements that could be used in the evaluation of healthcare process. The healthcare process requires a good understanding of what is important to the Emergency Department. To acquire a complete knowledge about the data involved in the business process improvement, the patient's experience and the level of satisfaction seem very interesting. After discussion with experts, we arrange a list of relevant indicator where 32 quantitative indicators (including process indicators, aggregated indicators, and administrative indicators) and 19 qualitative indicators are selected for this study. In the next paragraph, we are especially interested in the quantitative indicators that are related to the process execution and the qualitative indicators according to patient satisfaction level.

### 5.1 Process indicators

By default, jBPM deals with an H2 database. In our work, to persist jBPM historical data, we configure PostgreSQL database system to store the history log through its persistence module. PostgreSQL is an open source object-relational database system [13]. An overview of Bamtasksummary table in jBPM data baseis presented in table 2.

**Table 2.** An overview of Bamtasksummary table

createddate timestamp without time zone	duration bigint	enddate timestamp without time zone	processinstanceid bigint	startdate timestamp without time zone
2016-05-26 14:32:23.699	42695	2016-05-26 14:33:13.467	153	2016-05-26 14:32:30.772
2016-05-26 14:33:13.464	364083	2016-05-26 14:41:30.896	153	2016-05-26 14:35:26.813
2016-05-26 14:41:30.892	246660	2016-05-26 15:35:54.844	153	2016-05-26 15:31:48.184
2016-05-26 11:44:25.83	134152	2016-05-26 11:46:49.535	155	2016-05-26 11:44:35.383
2016-05-26 11:46:49.524	218437	2016-05-26 11:50:42.52	155	2016-05-26 11:47:04.083
2016-05-26 11:50:42.515	197293	2016-05-26 12:03:22.647	155	2016-05-26 12:00:05.354
2016-05-26 12:03:22.643	9322161	2016-05-26 15:00:57.104	155	2016-05-26 12:25:34.943
2016-05-26 12:33:44.993	73510	2016-05-26 12:35:09.739	156	2016-05-26 12:33:56.229
2016-05-26 12:35:09.736	269042	2016-05-26 12:41:52.786	156	2016-05-26 12:37:23.744
2016-05-26 12:41:52.779	1050390	2016-05-26 13:00:35.476	156	2016-05-26 12:43:05.086
2016-05-26 09:37:12.317	79784	2016-05-26 09:38:48.809	157	2016-05-26 09:37:29.025
2016-05-26 09:38:48.806	82116	2016-05-26 10:03:26.327	157	2016-05-26 10:02:04.211
2016-05-26 10:03:26.322	332223	2016-05-26 10:56:15.236	157	2016-05-26 10:50:43.013

Quantitative KPIs are derived from a close look at the activities involved in the BP. For more details, we define 6 indicators (Quanti\_KPI7 The duration of registration by patient, Quanti\_KPI8 The duration of sorting by patient, Quanti\_KPI9 The duration of consultation by patient, Quanti\_KPI10 The duration in supervision room by patient, Quanti\_KPI11 The duration of delayed emergency by patient, Quanti\_KPI12 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 (Quanti\_KPI13 The sum of all previous activities duration). The value for this indicator corresponds to the duration column in the bam task summary table.. We also define 6 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 value corresponding to these indicators represent the waiting time of an activity. Thus, such indicators are important to see for example, how long a patient waits for a consultation. It is defined as the time difference between created date of a consultation task and its actual start date. In jBPM logs, we don't 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 Quanti\_KPI23 (The waiting time per patient in all activities) which represent the sum of waiting time per patient in all activities. Finally, we define Quanti\_KPI27 (The total time spent in the Emergency Department by the patient in all activities). Its value is retrieved from the duration column in process instance log table.

From the available data in jBPM logs, we conclude that not all KPI can be directly retrieved from these logs and the representation of KPI values especially in the calculation of waiting time and duration in milliseconds can be misunderstood by the decision maker. For this reason, we create another data table which contains all real values related to our research. An overview of this table is presented in Table 3.

**Table 3.** An example of real values of quantitative indicators table

	quanti_kpi7 character varying(255)	quanti_kpi8 character varying(255)	quanti_kpi9 character varying(255)
22	00:00:18	00:01:22	00:04:17
23	00:01:08	00:00:53	00:05:14
24	00:03:13	00:00:10	00:01:26
25	00:01:04	00:02:16	
26	00:01:16	00:01:33	00:24:31
27	00:02:11	00:02:59	01:35:20
28	00:02:11	00:03:23	00:15:17
29	00:03:11	00:03:13	
30	00:00:37	00:03:57	00:01:11

## 5.2 Qualitative indicators

By addressing patient queries, the qualitative aspect will be in a better position to improve satisfaction toward the healthcare processes. This qualitative inquiry is necessary to get close enough to the patient and capture the level of his/her satisfaction and to examine the quality of care provided to patients attending the ED. Hence, at the end of the process, each patient was invited to provide feedback about his satisfaction.

Those indicators concern the qualitative aspects of care in the ED, such as staff attitudes towards patients and the quality of care but they also concern some quantitative aspects such as paramedical staff availability, the overall waiting time before treatment by paramedical personnel and the regularity of doctor visits. This is due for example to the fact that sometimes the nurse is available but the patients who are in less urgent state 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 patient's level of satisfaction with those indicators. The aim of this questionnaire is to determine why patients are unsatisfied and what we can do to make them better satisfied.

In order to feed the qualitative database, we are based on the responses of the patient, and consequently, a set of qualitative results is recorded by using a Likert scale. A new table in the database is then created in which respective responses of the patient are inserted as the values of KPIs. 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 database have a null value. Table 4 show some data values in the qualitative table.

**Table 4.** Example from qualitative database (Quali\_KPI1 to Quali\_KPI6 column)

	qualikpi1 character varying(255)	qualikpi2 character varying(255)	qualikpi3 character varying(255)	qualikpi4 character varying(255)	qualikpi5 character varying(255)	qualikpi6 character varying(255)
17	very satisfied	very satisfied	very satisfied	very satisfied	very satisfied	very satisfied
18	very satisfied	very satisfied	very satisfied	very satisfied	dissatisfied	very satisfied
19	very satisfied	very satisfied	very satisfied	very satisfied	very satisfied	very satisfied
20	satisfied	satisfied	very satisfied	very satisfied	very satisfied	very satisfied

## 5.3 Integration view of quantitative and qualitative KPIs values

KPIs data mainly contain all the quantitative and qualitative measurements regarding patients. The storage of such type of data is variously depending on the period of analysis and the evaluation of organization performance.

Due to the continuous increasing of the size of measurement healthcare data, we focus on the analysis of the KPIs in the observation period.

Recording real/ estimated values of indicators of both quantitative and qualitative aspect offers a better comprehension of the situation. So, we insert all qualitative indicator values from the questionnaire into the new KPI table where we take into account the consistency of several quantitative and qualitative measurements based on the process instance identifier.

At this stage, we track the healthcare process and we identify and extract the appropriate KPI. The data collected during business process execution is used for deriving the key performance indicators (KPI). In addition, we record all real values of indicators of both quantitative and qualitative aspect, which offer a better comprehension of the situation.

The final table contains all information related to quantitative process indicators and qualitative indicators related to the same process instance id. In order to give more sense to ensure that the health care process is fulfilling the expectations of experts' domain and patients, this data need to be checked and evaluated to detect if KPI values are reaching the desired results. As a result, we create another table which contains all estimated values related to the patient instances. This table contains two values (Ok codes the KPI value is tolerant and accepted by ED and Not ok is the KPI value in not acceptable). Table 5 displays some data from this table.

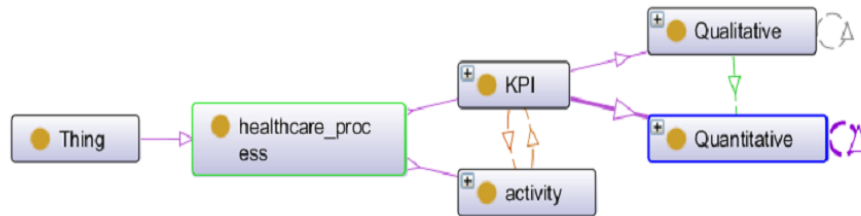
**Table 5.** Data from Estimated KPI table

	quali_kpi16 character va	quali_kpi17 character va	quali_kpi18 character va	quali_kpi19 character v	quanti_kpi7 character va	quanti_kpi8 character va	quanti_kpi9 character varying(255)
1	ok	ok			ok	Not ok	ok
2	ok	ok	ok		ok	ok	ok
3	ok	ok			ok	ok	Not ok
4	Not ok	Not ok			ok	ok	
5	ok	ok	ok		ok	ok	ok
6	ok	ok			ok	ok	ok
7	ok	ok			ok	Not ok	ok
8	ok	ok			ok	ok	ok

The main advantage of this table is that it provides the basic information to the decision maker to execute corrective actions in case of important deviations. So, in order to extract the meaningful information from 100 KPIs healthcare rows data, Data mining is beneficial in such a situation.

## 6 KPI ontology

The main benefit of this ontology is to offer the opportunity to continuously improve the BP by manipulating relationships and later to identify the reason of bottlenecks. The input in this phase is: process tasks and qualitative and quantitative indicators, thus facilitating their future improvement. In this section, we present in figure 2 our ontology for the representation of KPIs and process activities. So, in order to make more informed decisions, we collected as much data and information as possible about the possible relations.



**Fig.2.** the main classes of our ontology

Ontology is defined as a set of terms used to describe a given domain and derive inferences from it [7]. OWL ontology is composed of individuals, properties, and classes. The tool used for this ontology is protégé editor. Individuals represent all KPIs and all activities in which we are interested in our use case. In order to represent in one hand, the relationship between an activity and the attached KPI, and in another hand, the relationship between indicators, we define a set of object properties. Therefore, we created three object properties related to our KPIs. For example, the property “related\_with” might link the possible individuals from the qualitative class (KPI related to a patient satisfaction) to the related individuals in the quantitative class. Also, in order to represent the relationships between indicators in the same category, the owl model implements the properties “Depend\_quantitative” and “Depend\_qualitative” which indicate the links between quantitative/ qualitative indicators, their relationships and mainly represent the need to share data between them. Furthermore, properties can have inverses, transitive or symmetric. For example, the inverse of “has\_activity” is “has\_indicator”. 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.

## 7 Extracted knowledge from KPIs data

The data mining module uses a well-known data mining algorithm to extract association rules from the given data. With the help of raw data in KPI database, we use SIPINA data mining tool where the Apriori algorithm for data mining is applied.

Data Mining mainly extracts the meaningful KPIs data which were previously recorded in the Estimated KPIs table and derived from the event logs and the qualitative inquiry. This performance measurement can be then interpreted and translated into knowledge where discovering interesting decisions become possible.

In fact, to make any decision, it is important to analyze all the relevant row data of our performance measurement. For this purpose, we use data mining, especially association rule learning as a research method in this stage.

### 7.1 Association rule mining algorithm: Apriori

R. Agarwal and his colleagues at IBM Almaden Research Center introduced a novel association rule algorithm called [17] where the association mining can be applied to real databases to extract association rules.

The Apriori algorithm requires two user parameters configuration: the first one is support and second is confidence. Such parameters are used to significantly limit the search for frequent item sets.

Apriori algorithm is interested in finding all such rules having high enough support and confidence. It has two steps:

- (1) finding frequent itemsets, that is, those which have enough support,
- (2) converting them to rules with enough confidence, by splitting the items into two, as items in the antecedent and items in the consequent [16]

### 7.2 Association rule mining algorithm: Experimentation Results

Based on Estimated KPI value table, the objective of this step is to understand KPIs interaction. By using 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. Association rule mining algorithm needs to be configured before learning. So, we give appropriate values for the parameters in advance. Figures 3 and 4 show some results obtained based on Apriori algorithm to predict the occurrence of an item based on the occurrences of other items in the transaction.

Id	Antecedent	Consequent	Length	Support	Confidence	Recall	F-measure	Lift	Conviction
1	quali_kpi17=ok	quali_kpi16=ok	2	0.6200	0.9118	0.9841	0.9466	1.4472	3.7255
2	quali_kpi16=ok	quali_kpi17=ok	2	0.6200	0.9841	0.9118	0.9466	1.4472	10.5147

Fig.3. Example 1 of association rules

For example, for Rule 1 (Id=1) the fraction of transactions that contain both quail\_KPI17 (The overall waiting time before treatment by medical staff) and quail\_KPI16 (The overall waiting time before treatment by paramedical personnel) is 0.62 and the confidence for this rule is 0.81. This value measures how often items in quail\_KPI16 appear in transactions that contain quail\_KPI17.

5	quali_kpi1=ok	quali_kpi2=ok	2	0.6700	0.9853	0.9054	0.9437	1.3315	9.2647
6	quali_kpi3=ok	quali_kpi2=ok	2	0.6600	0.8800	0.8919	0.8859	1.1892	2.0382
7	quali_kpi4=ok	quali_kpi2=ok	2	0.6700	0.8816	0.9054	0.8933	1.1913	2.0647
8	quali_kpi5=ok	quali_kpi2=ok	2	0.6300	0.8400	0.8514	0.8456	1.1351	1.5679
9	quali_kpi6=ok	quali_kpi2=ok	2	0.7100	0.8161	0.9595	0.8820	1.1028	1.3858
10	quali_kpi7=ok	quali_kpi2=ok	2	0.6200	0.9118	0.8378	0.8732	1.2321	2.6471
11	quali_kpi8=ok	quali_kpi2=ok	2	0.6400	0.9143	0.8649	0.8889	1.2355	2.7227

Fig.4. Example 2 of association rules

We can see in figure 4 that quail\_KPI2 is consequent in the rule form, which can be used to determine another measurement that should be associated with it to have a high level of satisfaction.

Those rules can be used to see what other KPIs should be taken into account to promote a high satisfaction with the quail\_KPI2.

This analysis of frequent items aims to find all interesting rules that correlate the presence of one set of items with that of another set of items.

## 8 Conclusion

Regarding the research questions addressed in this work, not only we track the process behavior and we derive qualitative and quantitative key performance indicators but we also understand all necessary concepts involved in the BP and incorporate domain knowledge of the field. We also, extract implicit information from them and their relationships with other indicators. This information can assist process analysis in the evaluation of KPIs, as well as in the optimization of the associated BPs. An example of implementation of our proposed contribution as well as its validation on a real case study in the healthcare domain is presented.

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