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A Software Platform for Processes-Based Cost Analysis in the Assembly Industry

Erik Sigcha[1], Eliezer Colina-Morles[2], Villie Morocho[1], and Lorena Siguenza-Guzman[1](✉)

[1] Department of Computer Sciences, Faculty of Engineering, University of Cuenca, Cuenca, Ecuador
{erik.sigchaq,villie.morocho,lorena.siguenza}@ucuenca.edu.ec

[2] Research Department, University of Cuenca, Cuenca, Ecuador
eliezer.colina@ucuenca.edu.ec

Abstract. Processes and resources management are important current discussions related to decision making in the industrial field. This fact motivates companies to search for management models to improve their processes and services continuously. In order to achieve this purpose, approaches such as Business Process Management (BPM) and Time-Driven Activity-based Costing (TDABC) are used as bases for models design. This article describes the validation process of a software platform constructed using Business Process Model and Notation (BPMN) and TDABC paradigms aimed at analyzing processes costs in assembly companies. This work contemplates a description of the methodologies applied, functionalities implemented and validations steps performed. The platform also serves to generate process diagnosis in assembly companies prior to full BPM implementation.

Keywords: BPMN · TDABC · Process · Cost · Management

1 Introduction

The high competitiveness level that currently exists in the assembly industry moves companies to concentrate efforts in efficiently managing their resources, seeking a direct impact in achieving objectives such as minimizing costs and maximizing profits. AQ1 Thus, strategic management models or methods to optimize the use of their resources are especially important. Two essential aspects, which are part of the strategic management of resources to improve services and process, are the process and cost management. Among the techniques applied to perform process management, BPM comprises a set of principles, methods, and tools whose objectives are to create process-oriented organizations and to optimize their operation through the management of activities carried out internally [1]. Regarding cost management in companies, accounting is an essential mean to determine economic and financial states. In this area, accounting has been in constant evolution, contributing with several costing techniques

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over time. TDABC is a costing system developed in 2004 which appropriately reflects the diversity of processes in companies, and provides accurate information about their costs [2]. TDABC calculations are based on two parameters: the unit cost of resource used and the estimated time needed to perform an activity [2].

Nevertheless, despite the two methods being complementary, only a few published studies are related to the simultaneous implementation of BPMN and TDABC regarding software tools aimed at analyzing the state of processes and costs in assembly companies [3]. One example is the development of a module called TD-ABC-D, presented in [4] and [5], oriented to costs management in university libraries. However, this software focuses on processes within service institutions rather than manufacturing companies. A study reported in [6] introduces the analysis and design of a software platform for processes and costs management but does not deepen on the TDABC costing approach. As a continuation of the before mentioned work, [7] presents the methodologies applied during the implementation of the platform for calculating process costs.

In the same context, this article describes the software architecture, features, and functionalities of a software platform for processes-based cost analysis in assembly companies. It also reviews the way this platform was tested and validated to analyze processes status within a real assembly company. This company, classified as a middle size enterprise, has more than 100 employees and assembles televisions with a production around of 40 K units/year. The remainder of this document is as follows; Sect. 2 summarises the previous work. The software platform and its functionalities are described in Sect. 3. Section 4 contains a detailed description of the validation steps performed on the platform. Finally, Sect. 5 is reserved for conclusions and discussion of future work.

2 Related Work

Information about the analysis and design phases of this work can be found in [6], where the BPMN standard was used for process modeling. To estimate process costs, TDABC was established as a base methodology for performing calculations. Figure 1 presents the steps executed to estimate costs per process or sub-process within an assembly company [8].

2.1 Conceptual Data Model

The conceptual data model, illustrated in Fig. 2, is a schema of entities whose contents and relationships are stored in the platform's database and provides data about elements participating in the costing process. The *Processes* entity allows having a referential map containing the main processes performed in an assembly company. *Sub-processes* are grouped in higher-level processes, and permit obtaining costs according to the referential processes map of an assembly company [8], which conventionally classify as operational, strategic and support processes [9]. Finally, the *Resources* entity

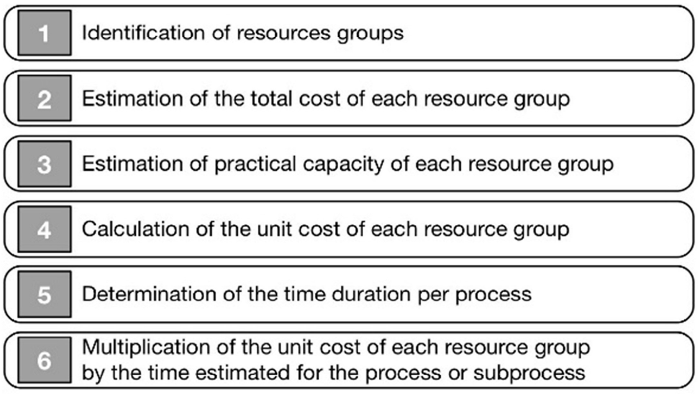

Fig. 1. Steps for estimating process cost using TDABC [8]

contains information about all the resources owned by a company. Among the required information are hours of availability, description, costs, practical capacity and type of resource (human, technological or material). This entity relates to the resource groups' identification step in the TDABC methodology, so accounting data of resources expenses is required as input for this data structure.

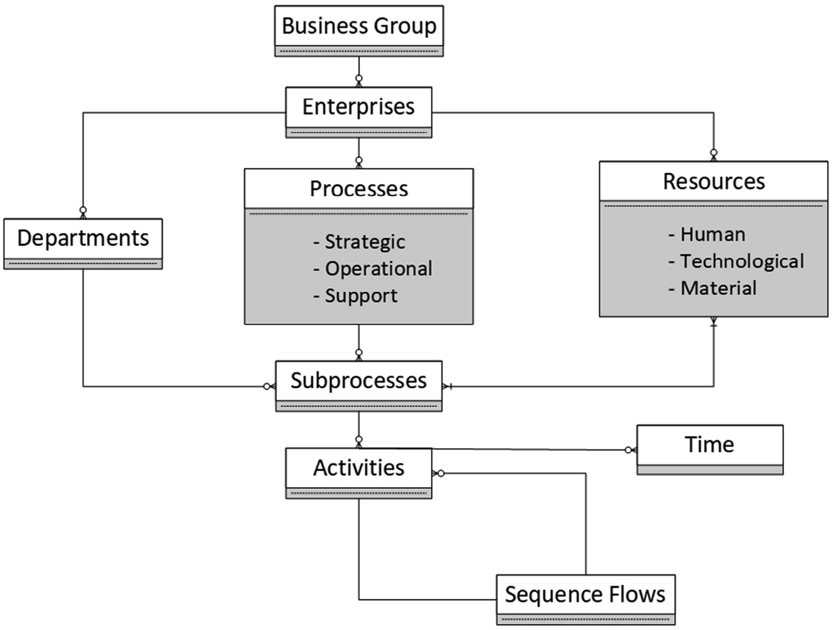

Fig. 2. Conceptual data model for process and costs analysis

3 Platform for Processes-Based Cost Analysis

The platform for processes-based costs analysis was developed as a web application using the Java programming language to support management and analysis of processes and costs in assembly companies. The software architecture, functionalities implemented and costs estimation functions are detailed next.

3.1 Software Architecture

The software architecture, depicted in Fig. 3, is based on the model-view-controller, MVC, architecture pattern and presents the information flow processed by the platform. The *Data Sources* block presents the methods used to obtain information about the company from process files and models, and the resource groups identified, which are essential information sources to perform TDABC. In the *Storage* block, the data entry in a database is shown. The database was constructed using the conceptual model depicted Fig. 2. The *Processing* block presents the elements of the MVC architecture, which is in charge of managing and processing the information contained in the database. Within the processing block, the Model sub-block contains structures to manipulate data using a programming language object. The Controller sub-block is responsible for executing the CRUD (an acronym for "Create, Read, Update and Delete") operations on the database. This sub-block records and offers the functionalities to perform the calculations and the platform's logic. Among these functionalities, BPMN is the structure employed to obtain the time of each sub-process diagram, and the TDABC functions are used to estimate costs per process. The View sub-block provides structures for the user interfaces and other functionalities, such as HTML pages, JavaScript code and style sheets, which allows the user to visualize information in a well-structured manner. In the *Data Visualization* block, the information is displayed to the user through interfaces and the data obtained in the Processing block. This allows the user to visualize an analysis of the process information, process representations with the BPMN standard and times and costs by processes in a company.

Data sources analysis and structuring had been manual tasks since the information had to be collected through interviews, observations and analysis of physical documentation to be formatted later as inputs required by the software. This step can be automated by capturing resources and activities information from accounting software and technological equipment within the assembly companies, as suggested in Fig. 3.

3.2 Platform Functionalities

The functionalities of the platform for processes-based costs analysis are the following:

Process Data Management. These functions and interfaces allow the user to create, update, visualize and delete information of processes, sub-processes, and activities. The main feature of this set of functions is using a diagram editor, based on the BPMN 2.0 standard, for process information input. Figure 4 shows a screenshot of the User Interface developed to manage process data using a BPMN diagram editor.

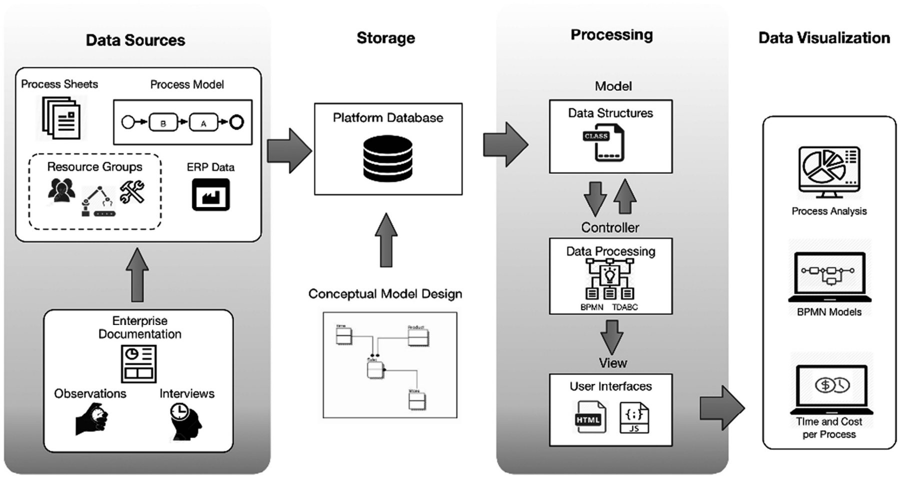

Fig. 3. Software architecture platform for process and cost analysis in the assembly industry.

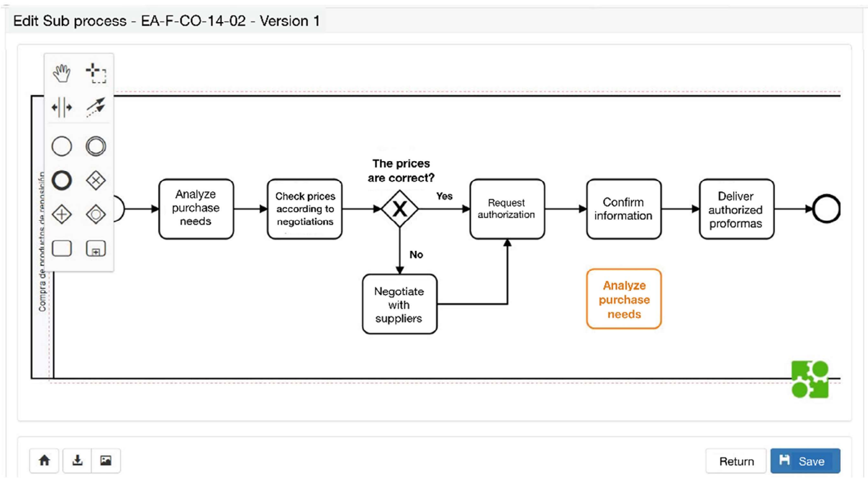

Fig. 4. Screenshot of the process edition UI

Business Data Management. Includes a set of forms and functions that allows entering, modifying, viewing and deleting information from entities belonging to the company (i.e., departments, resources or staff). To accelerate the implementation of these functionalities, the Java Server Faces (JSF) framework was used. JSF allows automatically generating interfaces and programming functions to perform the CRUD operations on database records. Figure 5 contains a screenshot of the user interfaces implemented to manage information of resources.

Process and Costs Analysis. This group of functionalities allows users to obtain results of cost estimates and processes duration using the TDABC system as

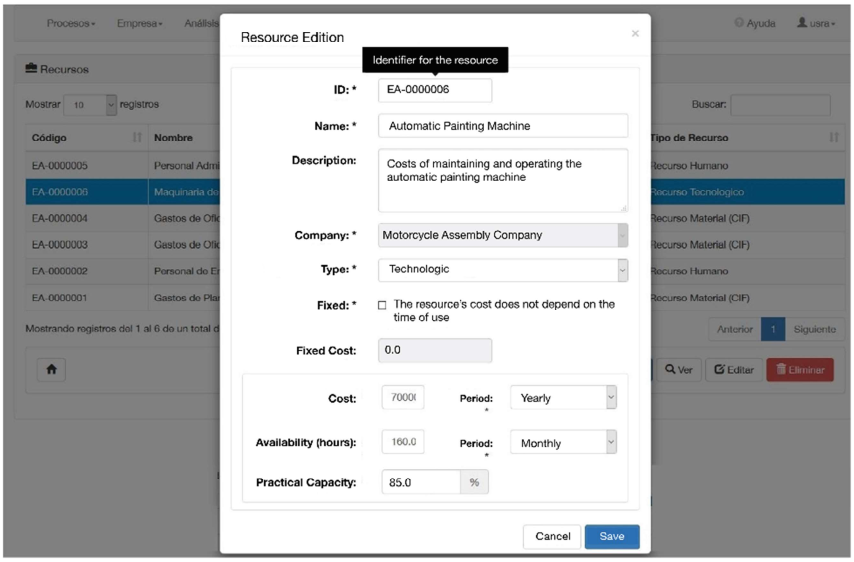

Fig. 5. Screenshot of user interfaces to edit resources data.

information reports. The reports generated by the platform are costs and times estimations by process and sub-process, costs by department, costs per production order, costs per product and generation of sub-process sheet. Figure 6 shows a screenshot of the costs and times estimation user interface.

Configuration. Constitutes a set of features to manage the general parameters of the software configuration. These include access control to the platform, user management functions, language configuration, currency and default parameters configurations.

3.3 Cost Estimation Function

Costs estimation function allows calculating the cost per process based on its activities times and resources used to perform it. This function is based upon the TDABC methodology presented in [8]. The required steps to estimate the cost per process are briefly described next. The first step to estimate process costs is to identify all expenses related to the resources used to perform the process. For this, accounting information is taken from balance sheets, income statements or accounts. Generally, these are total values for the whole company and are not grouped by resources as required by TDABC. Hence, these expense values must be classified in a way that may be assignable to company processes. For this, a classification, by cost centers, has been proposed, which was defined based on the main processes carried out in an assembly company according to a generalized process map; e.g., management, human resource management, assembly/production or sales. Once the resource groups have been identified, steps 2, 3 and 4 of the TDABC methodology are executed (see Fig. 1), which results in the unit cost ([$/min]) for each resource group identified. Figure 7 shows the sequence of steps used to estimate costs by processes using the TDABC costing.

Fig. 6. Screenshot of the costs estimation user interface.

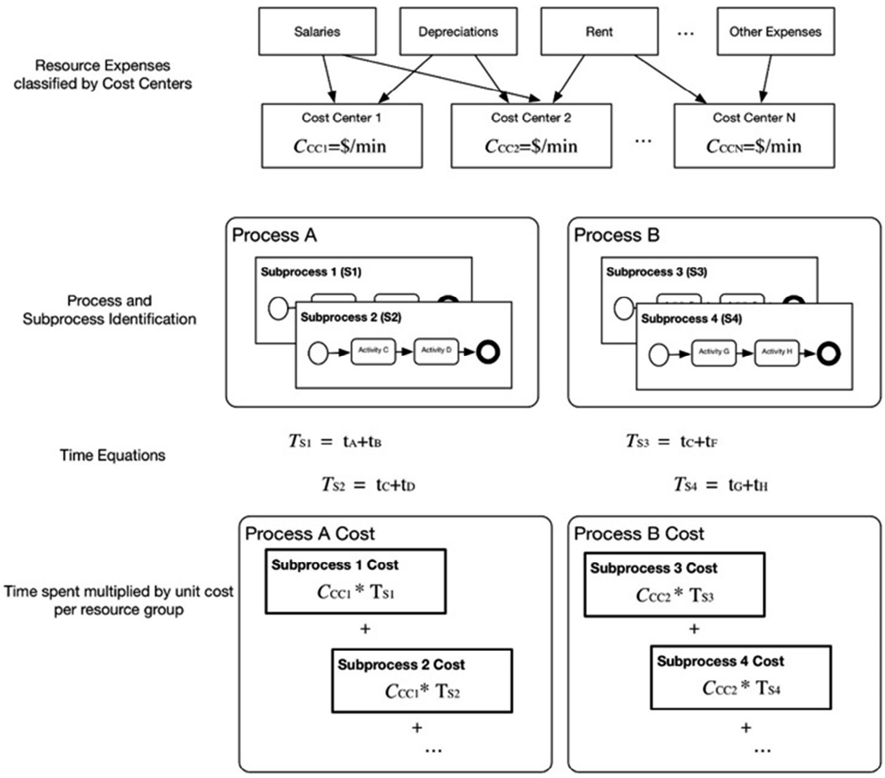

Fig. 7. TDABC applied for estimating process costs

To estimate process costs, a process identification phase is necessary to conduct through manual analysis using interviews, observations, and documentation. As a result, models and process files are obtained according to an ISO process map [9]. Once the company processes have been identified, the next step is generating time equations for each process. Since the BPMN standard has been used, a function that allows identifying activity sequences for executing a process was developed [7]. This function gives the execution time of each process, which is the objective of time equations, resulting in the second element required by TDABC. The final step in estimating process costs is to use the value of the cost unit of the resource groups and to multiply it by the time calculated with the time equations. This result in costs information for each process, sub-process and activities identified.

4 Software Validation

The platform validation considers three main aspects: data entry validations, testing of costs estimation functions and testing of process costs estimations.

4.1 Data Entry Validation

As an initial validation stage, a first partial validation was performed by entering information of 20 process sheets, collected during the process identification phase, into the platform using the functionalities of the process data management. This first data entry allows correcting some programming errors and determining the set of BPMN symbols to be implemented in the diagram editor, which are detailed in [7]. As a second stage, a new validation that comprises entry of the complete set of process models of the case study company was performed. This set contains approximately 200 process models that were entered in the platform database. This part of the validation allowed to verify if all process models were supported by the platform and could be stored using the platform database structure. Because of this validation, it was possible to test the BPMN diagram editor functionalities and to have a repository of process models in the database.

4.2 Testing of the Resources Cost Estimation Functions

These tests had the goal of verifying if the calculations performed to estimate the unit cost per resource were correctly done. To perform these tests, the JUnit[1] framework was used since it allows testing programming functions, by specifying input data, expected results and comparing these results. The function tested was the one regarding the unit cost estimation per resource; as this function executes the first four steps of the TDABC methodology (see Fig. 1). This function requires as input the resource data (name, cost per period, hours of availability per period and practical capacity percentage) and produces as output the resource cost per minute (unit cost). Data used to

[1] JUnit, https://junit.org/junit5.

perform this test comprises information of 21 resources records and were gathered from income statements and balance sheets from the case study company. An accountant expert processed the data, by using the TDABC methodology to obtain the expected unit costs, which were compared with the ones obtained from the automatized platform. Initially, small differences in the results were found due to the number of decimal digits used; but when rounding to six decimal digits, the costs estimation results were equal to the expected results.

Testing of Process Cost Estimation. The process cost estimation test verifies the correctness of costs values obtained in the platform. For this purpose, 36 process models belonging to an assembly line of a study case company were input into the software database. The study case is a middle size enterprise dedicated to the assembly of televisions. The 36 selected process models represent some of the phases required to assemble each one of the eight TV models produced by the company. Data from these process models were analyzed manually by an accountant expert to obtain estimated reference costs using the TDABC methodology [8]. Next, the cost per product functionality was used to calculate automatically the product costs grouping the process models by product. This allowed generating cost tables according to the processes involved in the production of each of the eight TV models in the assembly line. Table 1 shows an example of a cost table obtained in the platform, which includes the sub-processes and activities required to assemble a TV model, and their respective cost and times. Finally, a comparative table of platform results and expected results was developed. Table 2 shows times and costs automatically estimated by the platform, referential times and costs calculated manually (Ref. Time and Ref. Cost) and the differences between these values for all eight TV models analyzed. From Table 2, the difference values in most cases are less than 0.01%, which is justified regarding the number of decimal digits used in the platform, and in the reference calculations.

Table 1. Example of cost table by product.

Sub-process/Task	Time (min)	Cost ($)
Sub-process - Assembly TV Model 6		
Task – Set-Up	0,6095	0,177974
Task – Parts assembly	2,7323	0,797832
Task – Place accessories	3,0825	0,90009
Task – Connect electric system	0,7835	0,228782
Total:	7,2078	2,106048
Sub-process – Keyboards assembly TV Model 6		
Task – Receive Raw Material	0,03	0,00876
Task – Assemble accessories	2,76	0,80592
Task – Test	2	0,584
Task – Store	0,08	0,02336
Total:	4,87	1,422966

(*continued*)

Table 1. (*continued*)

Sub-process/Task	Time (min)	Cost ($)
Sub-process – Holster accessories TV Model 6		
Task – Receive remote control	0,0028	0,000818
Task – Holster	0,0152	0,004438
Task – Seal	0,0028	0,000818
Total:	0,0208	0,006078
Sub-process – Quality Control TV Model 6		
Task – Test functions and specifications	1,5015	0,438438
Task – Check product	0,5612	0,16387
Task – Fill out quality control sheet	0,2525	0,07373
Total:	2,3152	0,676479
Sub-process – Packing TV Model 6		
Task – Place packing carton and plastics	1,3567	0,396156
Task – Move to storage	0,6527	0,190588
Total:	2,0094	0,587127
TOTAL	**16,423**	**4,798**

Table 2. Comparison results of the cost estimation test

Product	Time	Cost	Ref. Time	Ref. Cost	Time Diff.	Time Diff. %	Cost Diff.	Cost Diff. %
TV Model 1	6,474500	1,891785	6,474	1,891	−0,000500	−0,000077	−0,000785	−0,000415
TV Model 2	8,434000	2,464331	8,381	2,448	−0,053000	−0,006284	−0,016331	−0,006627
TV Model 3	15,699167	4,587141	15,699	4,588	−0,000167	−0,000011	0,000859	0,000187
TV Model 4	20,320000	5,937303	20,311	5,934	−0,009000	−0,000443	−0,003303	−0,000556
TV Model 5	9,757167	2,850947	9,757	2,851	−0,000167	−0,000017	0,000053	0,000018
TV Model 6	16,423167	4,798687	16,423	4,798	−0,000167	−0,000010	−0,000687	−0,000143
TV Model 7	13,877667	4,054917	13,877	4,055	−0,000667	−0,000048	0,000083	0,000021
TV Model 8	25,663000	7,498474	25,664	7,499	0,001000	0,000039	0,000526	0,000070
Average					−0,007833	−0,000856	−0,002448	−0,000931

5 Conclusions and Future Work

This article describes a software tool and its validation for process analysis in assembly companies. The platform presented aims to provide support in obtaining an initial diagnosis, prior to the full implementation of Business Process Management or Enterprise Resource Planning, ERP, systems. The software functionalities design was inspired by the TDABC and BPMN methodologies, which are established approaches successfully applied in academic and business fields.

This work also presented a conceptual data model conceived for getting cost estimations and for modeling business processes workflows in assembly companies, based on the BPMN 2.0 standard. In addition, the conceptual data model allows obtaining data reports on costs and processes associated with departments and production lines. The software architecture showed the information analyzed and structured to implement a software platform. The architecture explained how the inputs were obtained, how they were stored and the type of analysis performed. Finally, algorithms to estimate costs and times per process have been developed with the aim of integrating TDABC and BPMN, and a set of functionalities for obtaining an initial diagnosis of the complete process, including information management for process models. These algorithms were tested and validated to verify the correctness of calculations and costs estimations, by comparing their results with referential costs per process provided by accountant experts. The resulting software, relying on open source tools, offers the possibility of taking advantage of TDABC and BPMN to determine a company's state based on its processes and resources.

Further work is considered to continue validation tasks of the platform by analyzing the processes in two more case studies. This might lead to some adjustments in the information format required for new processes and resources, and to verify the schema to store new data. This first version of the platform has some limitations, which may be solved by integrating a BPM engine or an ERP system as data sources for the platform. Therefore, it is proposed to update the architecture and data models to include this type of systems as other information sources. An additional improvement would be expanding the platform functionalities until it becomes a tool that provides full support for the automation of the BPM life-cycle [10].

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