Combination of Process Mining and Simulation Techniques for Business Process Redesign: A Methodological Approach

Santiago Aguirre, Carlos Parra, and Jorge Alvarado

Industrial Engineering Department, Pontificia Universidad Javeriana,
Bogotá, Colombia
{saguirre,carlos.parra,jorge.alvarado}@javeriana.edu.co

Abstract. Organizations of all sizes are currently supporting their performance on information systems that record the real execution of their business processes in event logs. Process mining tools analyze the log to provide insight on the real problems of the process, as part of the diagnostic phase. Nonetheless, to complete the lifecycle of a process, the latter has to be redesigned, a task for which simulation techniques can be used in combination with process mining, in order to evaluate different improvement alternatives before they are put in practice. In this context, the current work presents a methodological approach to the integration of process mining and simulation techniques in a process redesign project.

Keywords: process mining, data mining, simulation, process redesign, BPM.

1 Introduction

Information systems have become the backbone of most organizations. Without them, companies could not sell products or services, purchase materials, pay suppliers or submit their tax reports. These systems record valuable information about process execution on event logs containing activities, originators, timestamps and case data. This information can be extracted and analyzed to produce useful knowledge for organizations to diagnose and improve their business processes. This is called process mining [1] .

Process mining is a discipline that aims to discover, monitor and improve business processes by extracting knowledge from information systems event logs [2], making use of data mining techniques. Event logs record information about real business process execution and are available in Process Aware Information Systems (PAIS) such as BPM, ERP, CRM, Workflow Management Systems, etc. [3]. Process mining is, therefore, a recent discipline that lies between data mining and process modeling and analysis [1].

The ultimate goal of process mining is to generate useful knowledge for organizations to understand and improve their business processes mainly through the application of data-mining-based tools. Figure 1 shows the three components of process mining [2]: Discovery, Conformance and Enhancement.

P. Cudre-Mauroux, P. Ceravolo, and D. Gašević (Eds.): SIMPDA 2012, LNBIP 162, pp. 24–43, 2013.

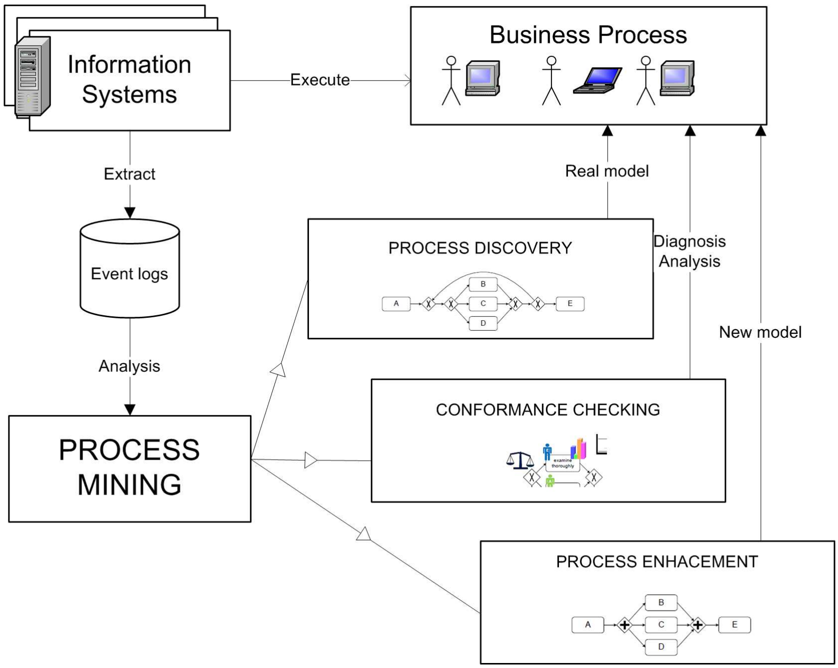

Fig. 1. Process mining components

Table 1 details the organizational enhancement possibilities offered by process mining through its three components.

For its part, Business Process Simulation provides techniques for testing solutions before their actual implementation. Both simulation and process mining contribute to Business Process Lifecycle [9] (Figure 2), which starts with business process design based on customer and stakeholder requirements. Next, the implementation stage comprises business rules and policy definition as well as computer platform configuration. Then, the process enters its actual execution stage. Later, in the monitoring and analysis stage, the process is optimized by measuring and analyzing its performance indicators. Table 2 details the contribution of simulation and process mining to each stage of the cycle.

According to the authors of the Process Mining Manifesto[1], one of the challenges that must be addressed to improve the usability of process mining is its integration with other methodologies and analysis techniques. A clear example is provided by simulation tools, which are likely to complement process diagnosis and analysis by testing alternative process mining implementation scenarios as part of the business process lifecycle.

Most simulation techniques have been applied to production and logistics, where process routes are predefined and can therefore be more easily modeled. However, in service processes such as complaint appraisal and response, there

Table 1. Process Mining components and their applications

Component	*Application*
Process Discovery	*Finding out how the process actually runs.* Process mining algorithms applied to the analysis of event logs allow organizations to clearly see and model the real execution of a process in terms of either a Petri net or BPMN notation. The point here is that process mining describes the real situation and is not based on people's (subjective) perception [4].
Conformance Checking	*Determining whether the process complies with regulations and procedures.* The real execution model of a business process can be compared to documented procedure protocols in order to determine its conformance with established standards, regulations and policies. Process mining has proved useful for detecting potential sources of fraud and non-compliance [5].
Process Enhacement	*Analyzing the social interaction of the process.* Through the application of process mining techniques, it is possible to assess the social network supporting the process, in order to analyze interactions between individuals and discover loops that may delay its execution [6]. These techniques are also used to interpret roles in the process as an example group of users involved only in one task. *Discovering bottlenecks (bottlenecks).* These techniques allow finding actual bottlenecks on which action can be taken to improve process implementation. *Predicting specific time cycles.* Certain data mining techniques such as decision trees facilitate the prediction of the remaining execution time of a running process [7], [8].

can be many variations or process routes depending on the type of complaint. For this reason, it is important to start by analyzing the information system's event log in order to reach a realistic model, rather than an idealized version of the process. The necessary parameters to build such a model can be supplied by process mining.

Furthermore, a series of methodological approaches have been developed for business process redesign and for the application of simulation and process mining. BP trends [10] proposes five general stages for a process redesign effort: 1) Project Understanding, 2) Business Process Analysis, 3) Business Process Redesign, 4) Business Process Redesign Implementation and 5) Redesigned Business Process Roll Out. Although this methodology constitutes a valuable approach, it needs to be complemented with specific tools such as simulation and process mining.

The current paper presents a methodological approach to process redesign, based on a combination of simulation techniques and both data and process mining tools, together with those of the understanding phase of the BP trends

Table 2. Contributions of simulation and process mining to Business Process Lifecycle

Phase	Contribution of process mining	Contribution of simulation
Re(Design)	The real process model, which is discovered by process mining techniques, is an important input for process design or redesign.	Through simulation it is possible to perform “what if” analyses of the different process design or redesign options.
Implementation and Execution	In the implementation phase, process mining is used to verify that the process complies with business policies and rules. It is also possible to predict the remaining execution time of a running case.	Having been tested and improved through simulation, business processes are implemented in this phase.
Monitoring and analysis	In the analysis phase, process mining is used for identifying loops and bottlenecks, and for further checking for conformance with business rules.	Simulation allows business process analysis to eliminate bottlenecks and improve throughput times.

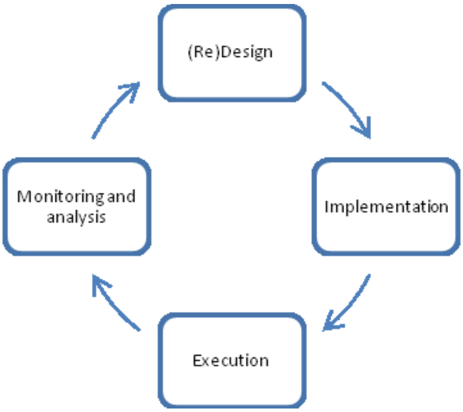

Fig. 2. Business Process Lifecycle

Business Process Redesign methodology [10]. Section 2 contains a complete review of the state of the art and related works. Section 3 provides a detailed explanation of the methodological approach and Section 4 describes the case study to which the method was applied. Finally, Section 5 draws the conclusions and future work.

2 Literature Review and Related Works

The literature review focuses on previous methodological developments intended not only for the application of process mining to business process improvement, but for the combination of process mining and simulation as well.

2.1 Methodologies for Process Mining

Bozcaya [11] proposed a methodology for applying process mining to business process diagnosis, based on three perspectives: control flow, performance and organizational analysis. The method in question starts with Log preparation, which includes event log extraction, interpretation and transformation, in order to determine the activities and their sequence. The next step is to inspect and clean the event log data to eliminate cases with missing data. Once the log has been cleaned, the control flow analysis is performed for conformance checking against procedures through the application of discovery techniques like alpha, fuzzy of genetic algorithms.

As a next step, these same authors propose performance analysis in order to discover business process bottlenecks and delays. Finally, the social network algorithms are used to apply an organizational analysis aimed not only at determining role interactions involved in process execution, but at discovering loops that might be delaying process cycling time. This method was applied to a case study and constitutes an important step ahead in the diagnostic phase of process redesign. Nevertheless, this phase needs to be complemented with the understanding (planning), redesign (to-be) and implementation stages of a complete business process redesign cycle.

Rebuge and Ferreira [12] developed a methodological approach to business process analysis in the health care sector. They start by describing the complexity of business processes in this sector, which are inherently dynamic, multidisciplinary and highly variable. Therefore, process mining techniques are the most suitable ones for diagnosing and analyzing these processes.

These researchers describe their method as an extension of Bozcaya's one [11], on which they based their work, including the sequence cluster analysis applied by this author after the log inspection phase. Rebuge and Ferreira [12] actually focus on this cluster technique, which is aimed at discovering process flow patterns. When applied to the emergency care process of a hospital, this method allowed identifying all variations and deviations from the internal protocols and guidelines of the institution, thus demonstrating the usefulness of process mining for diagnosis and analysis in these cases. As to future work, they suggest complementing the method with additional steps such as the use of heuristics for determining the number of clusters, on the one hand, and the establishment of measures for evaluating the quality of the results, on the other hand.

2.2 Process Mining and Simulation

The literature on this topic presents research works and case studies in which process mining and simulation are used in combination. Rozinat [4] uses process mining techniques to discover business processes and, based on past executions, analyzes how data attributes influence decisions on said processes. This analysis allows finding each event's probabilities and frequencies, based on which a model is constructed and represented by a Colored Petri Net (CPN), in order to simulate different resource usage optimization and throughput time reducing alternatives.

Maruster [13]proposes a process redesign methodology based on the combination of process mining and simulation techniques, and presents its application to three case studies. Mainly supported by CPN simulation, the method consists of three phases: process performance variable definition, process analysis (as-is), and process redesign (to-be). This approach constitutes an important step forward in the integration of different tools in this field. However, it focuses on CPN simulation, thus tending to underscore the understanding phase, which is seen, according to Harmon [10], as the first stage of any process redesign project.

The current work focuses on complementing the methodology proposed by Maruster [13], by emphasizing the project understanding phase, featured by process scope analysis, process redesign goal setting and performance gap analysis. According to Vander Alast [1] one of the reasons why process mining has not been widely applied is the lack of a comprehensive methodology that is capable of linking organization Key Process Indicators (KPIs) with actual analysis and redesign efforts. The methodology proposed in this paper intends to close this gap by linking business priorities to process analysis and redesign using process mining and simulation tools. Just as well, it shows how data mining tools (e.g., decision trees) can be combined with simulation in a process redesign project. Part of this method was applied to the case study described in Section 4[1] .

3 The Redesign Project: A Methodological Approach

Including process mining and simulation tools, the development of the current methodology took into consideration both BPtrends method [10] and Maruster's [3] approach. It comprises the following phases:

- *Phase I: Project Understanding.* The goal of this phase is to gain consensus over the problem to be solved, the scope of the project and the desired goals as stated in terms of the business process indicators.
- *Phase II: Project Understanding.* The goal of this phase is to gain consensus over the problem to be solved, the scope of the project and the desired goals as stated in terms of the business process indicators.
- *Phase III: Business Process Redesign (to-be).* This phase is intended to develop and simulate the corresponding business process improvement alternatives.

[1] Some data about this case study has been modified forprivacy reasons.

– *Phase IV: Implementation.* The goal of the implementation phase is to put in operation the amendments in question through changes in procedures, job descriptions and work assignments.

Figure 3 and Table 3 explain the activities and tools that describe the proposed methodology.

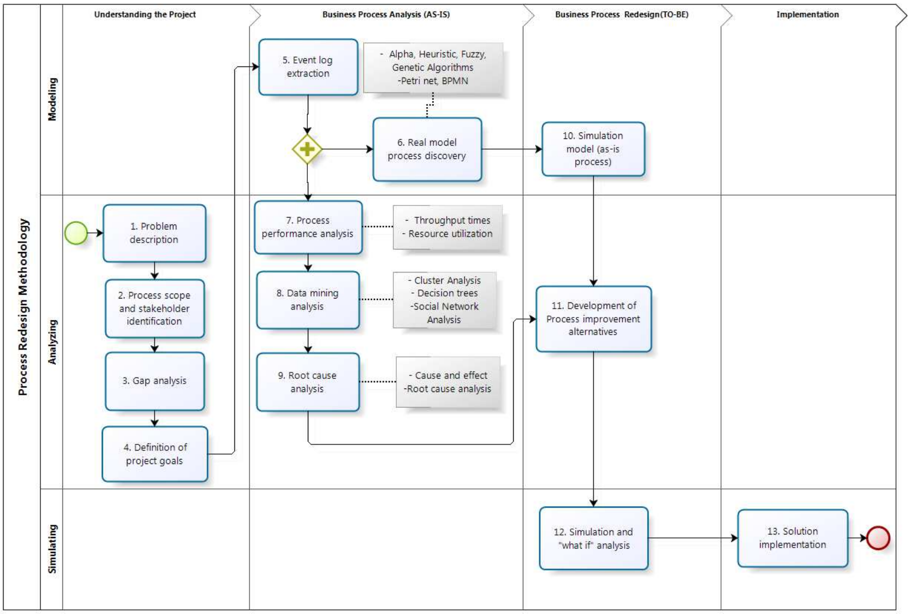

Fig. 3. Proposed methodology with phases, activities and tools

Table 3. Description of the phases and activities of the proposed methodology

Phase /Activity	***Description***	***Tools***
	Phase I: Project Understanding	
1. Problem Description	The purpose of problem description is to understand and gain consensus on the reasons why the process needs to be improved (customer complains, compliance requirements, costs, throughput times).	-Process Performance Indicators.

Table 3. (*Continued*)

Phase /Activity	***Description***	***Tools***
2. Process scope and stakeholder identificatio	During this phase, the source, input, output and customer of the process are identified. The process stakeholders are established and interviewed to gain a better understanding of the performance desired for the process.	-Process scope diagram -Stakeholders diagram
3. Gap Analysis	The gap analysis identifies the actual process performance indicators (as-is) and establishes the desired process performance indicators (to –be) based on process vision, benchmarking and stakeholder expectations.	-Gap analysis -Benchmarking -Process Performance Indicators
4. Definition of Project Goals	The desired amendments of the to-be process turn to be the project goals.	
Phase II: Business Process Analysis (AS – IS)		
5. Event log extraction	The event log of the actual execution of the business process must be extracted from the information system (ERP, CRM, BPMS). Then, the event log is cleaned from missing data and transformed, so that it can be analyzed with data mining and process mining packages.	-Disco® software -PROM® software -SPSS statistical package
6. Real model process discovery	Through the application of process mining algorithms such as alpha mining [14], heuristic mining [15] or genetic mining [16], it is possible to automatically discover the actual process model from the event log using ProM or Disco software functionalities. This model can be represented in a Petri net, or through BPMN notation. The real process model allows visualizing bottlenecks, loops or lack of compliance.	-Disco® software -PROM® software Process mining algorithms (alpha, heuristics, genetic), Petri nets, BPMN.

Table 3. (*Continued*)

Phase /Activity	***Description***	***Tools***
7. Process Performance Analysis	The event log needs to be assessed through descriptive statistics in order to analyze process performance indicators such as activity times, idle times and standard deviations. Role assessment output is likely to show differences in personal productivity.	-Statistical Analysis (mean times, standard deviation). -SPSS® statistical package -Disco® software
8. Data mining Analysis	Data mining techniques are used to extract knowledge from process execution. Techniques such as decision trees are used to discover those variables that have greater incidence on process delays. Social Network is useful for analyzing role interactions between the people executing the process, with the aim of finding either functional loops or key roles within the process	-Cluster analysis, decision trees, social network analysis. -SPSS® statistical package
9. Root cause Analysis	Root cause analysis is useful to examine the causes of the main problems that have been discovered in the previous steps. This analysis is a simple way to organize and classify the list of possible causes and requires the knowledge of the people participating in the execution of the process	-Root cause diagram
Phase *III: Business Process Redesign (TO-BE)*		
10. Simulation Model	Based on the process discovered in phase 1, and on processing and waiting times calculated through the statistical analysis of the event log data, a simulation model is generated.	-Simulation -Simulation packages
11. Development of process improvement alternatives	Once the problems and causes are clear, the process improvement alternatives for the to-be process must be established to overcome the issues found in the as-is analysis phase (Phase II).	-Cost-benefit analysis

Table 3. (*Continued*)

Phase /Activity	***Description***	***Tools***
12. Simulation and "what if" analysis.	The process improvement alternatives are tested through simulation in order to decide on their actual implementation. This allows performing the "what if" analysis of different scenarios.	-Simulation -Simulation packages (Promodel, Arena, etc).
	Phase IV: Implementation	
13. Solution implementation	The process improvement alternatives selected after the simulation test are then rolled out and put in practice.	Procedures, job descriptions, work assignments.

4 Case Study: Procurement Process at a Private University

The case study to which we applied the proposed methodology consists in the procurement process of a private university that handles approximately 15,000 purchase orders every year, with an estimated budget of $ US 50 million. The normal functioning of the University and its projects depends on the efficiency of the Procurement Department in obtaining the required goods and services.

The procurement process is supported by an ERP system[2] in which the following activities are executed: purchase requisition, requisition approval, purchase order, purchase order approval, goods receipt, invoice receipt and vendor payment.

4.1 Application of the Methodological Approach

The methodology presented in the current work was applied to this case study using process mining and simulation techniques. The following is the detailed step by step explanation of the process.

A. Phase I: Understanding the Project

In this phase, the problem is described, the gap analysis between as-is and to-be is performed, and the project goals are set.

Problem Description

Despite the support of an integrated system, the procurement process in question has been presenting problems and inconveniences such as long approval waiting times and overload of "manual" documents and activities not managed by the

[2] The organization uses Oracle PeopleSoft ®.

ERP. This makes the process inefficient, as only 32% of orders are delivered within 1 month, which is the user expected time.

The users (professors, research and administrative staff) frequently present complaints about delays and excessive paperwork in the process. Although professors must make purchases for research projects having 1 or 2 year time frames, the purchase of an imported good may take more than 6 months, which certainly impacts the schedule of these projects.

Process Scope and Stakeholder Identification

Figure 4 shows the process scope diagram, where it can be seen that the main input is the requisition made by departments and areas of the university. Said requisition starts a process that finishes when the product is delivered to the areas and the supplier has been paid. There is a procedure for the order approval subprocess, but there is no business rule specifying the maximum time allowed for this step. There is also a good governance code for managing suppliers and contracts. Enablers correspond to two different resources of the process: the information system (ERP system) and the staff involved in the process.

The shaded boxes in figure 4 represent the process stakeholders: departments, suppliers, purchasing board, and both the Administrative and IT offices.

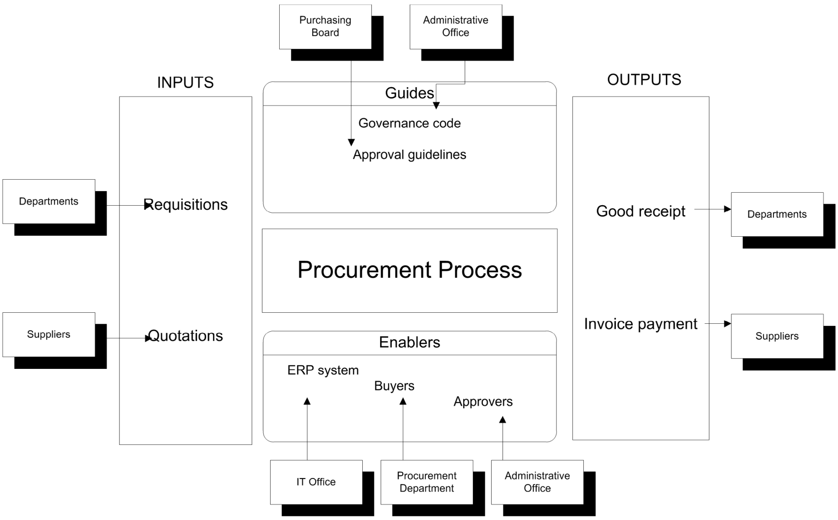

Fig. 4. Process scope analysis

Gap Analysis

The gap analysis was used to represent the current (as-is) and expected (to-be) process performances, as mediated by process redesign. In order to determine the expected performance, it is important to ask the stakeholders why the process should be improved and what the expected performance is in terms of key process indicators. Figure 5 shows the main performance and capability gaps and the tools that were used in the analysis and improvement of the process.

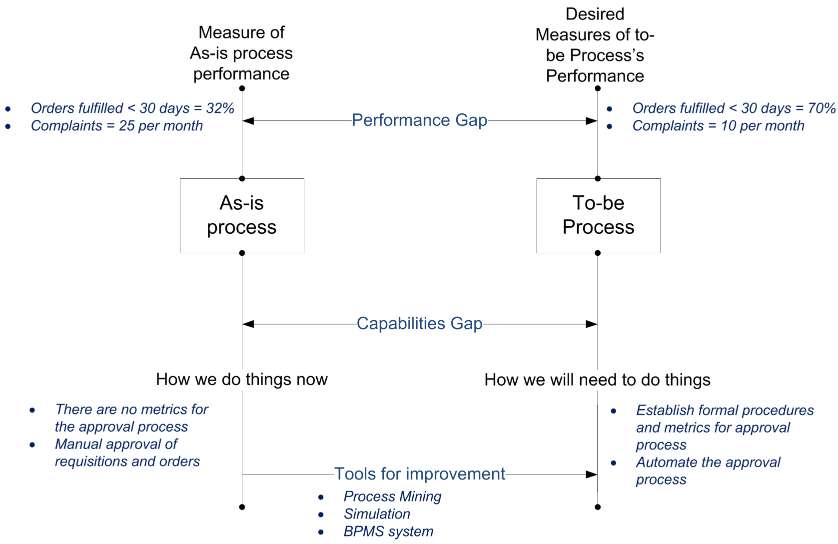

Fig. 5. Gap analysis

Definition of Project Goals

The desired amendments of the to-be process turn to be the project goals:

- Reducing cycle time to ensure that 70% of orders are delivered within 1 month.
- Reduce the number of user complaints.

B. Phase II: Analyzing Business Process (as-is)

This phase begins with event log data extraction in order to discover the real process model and to apply data mining techniques for an in-depth process analysis. The objective of this phase is to establish process improvement opportunities.

Event Log Extraction

In this phase, the event log is extracted from the ERP system. The information supplied by the log includes case id, time stamps, activities and performers (originators) of the procurement process. In addition, there is information regarding each order such as requested product or service, supplier, requesting department, cost, product family and the person approving each purchase requisition or order.

The original log contained one year of historical data, corresponding to 15,091 cases. The quality of the log was inspected in the statistical package[3] , which allowed finding some missing data and outliers. After cleaning the log, the cases were reduced to 8,987.

Process Discovery

Through the application of process mining algorithms such as alpha mining [14], heuristic mining [15] or genetic mining [16] it is possible to automatically discover the actual process model using the ProM software functionality. This model can be represented in a Petri Net, or through BPMN notation. Because of its mathematical foundations, process mining uses Petri Nets in most applications, which allows the implementation of analysis techniques [3]. Some case studies make use of Colored Petri Nets (CPN) because of their simulation capabilities in packages such as CPN tools [17]. In the current case, the alpha algorithm was used due to the low complexity of the process model and paths. For more complex processes, genetic algorithms or the heuristic mining algorithm are recommended. Figure 6 shows the studied procurement process modeled in a Petri Net.

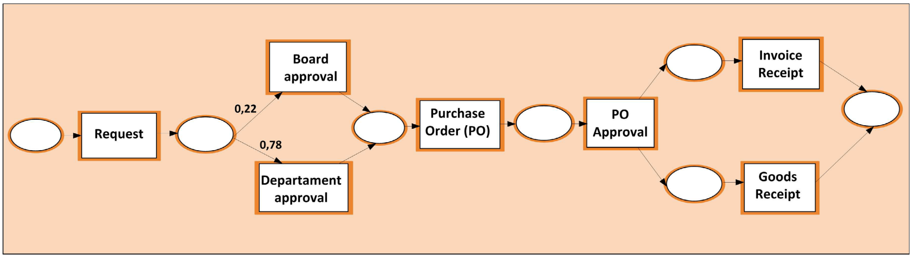

Fig. 6. Procurement process

Process Performance Analysis

The event log was assessed through descriptive statistics in order to analyze some key process indicators such as cycle time, cycle time per buyer and buyer productivity, among others. Figure 7 shows a box plot of cycle times per buyer, which exhibits a high variability in mean time cycles between buyers and, in some cases, high variability within buyers. This analysis suggests an influence of the buyer in time cycles. This influence is going to be analyzed in depth in the data mining analysis section.

[3] IBM SPSS® was used for the data mining analysis.

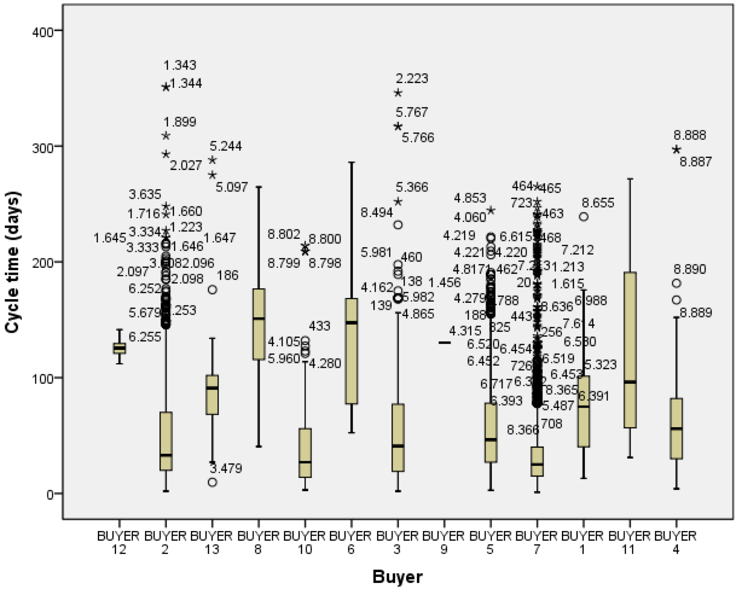

Fig. 7. Procurement cycle times per buyer

Table 4 presents some key findings of the process performance analysis.

Table 4. Key findings of the process performance analysis

The main bottleneck of the process is the purchase requisition approval subprocess
Mean cycle time is 50 days, with a standard deviation of 28 days. Only 32% of orders are delivered within 1 month.
Imports require thrice as much more time than local purchases. The minimum time required for an imported good is 40 days.
The mean cycle time per buyer is highly variable (Fig 7).

Data Mining Analysis

For a more detailed diagnosis of the purchase requisition approval subprocess, a decision tree analysis was made to discover the roles of the organization that delay the process. The database was split in three parts: training (40% of the records), validation (40% of the records) and test (20% of the records). The decision tree was growth and pruned using the classification and regression tree algorithm (CART) and Gini impurity. The CART procedure minimizes classification error given a tree size [18] Figure 8 shows the tree results in test data.

Figure 8 shows that if the order must be approved by the roles in node 2, the probability that the requisition arrives before 30 days is 1%. When the approvers are those in node 1, the odds of receiving the request within 30 days rise to 50%.

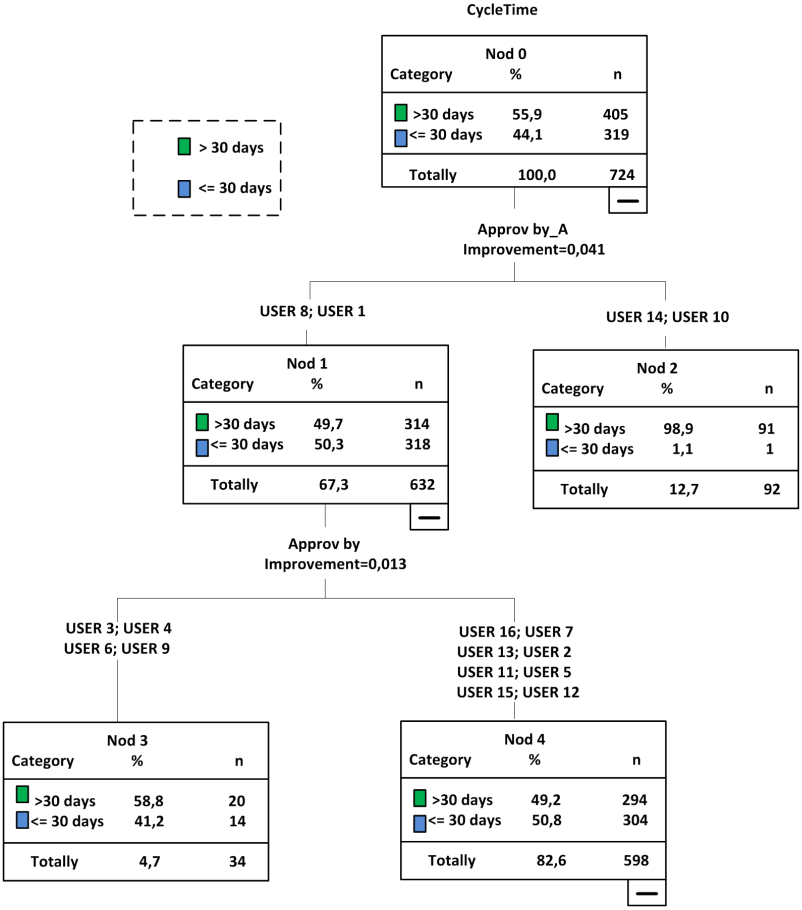

Fig. 8. Decision tree for purchase requisition approval

Table 5 presents the key findings of the purchase requisition approval decision tree analysis.

Table 5. Key findings of the purchase requisition approval decision tree analysis

The person that approves the purchase request has a significant impact on the probability of receiving the request within 30 days.

Root Cause Analysis

The *Cause and Effect* analysis was used to determine the cause of the problem. Through this tool, the roles involved in the execution of the process identified the major causes of delay in purchase requisition approval. Figure 9 shows these causes as classified by categories.

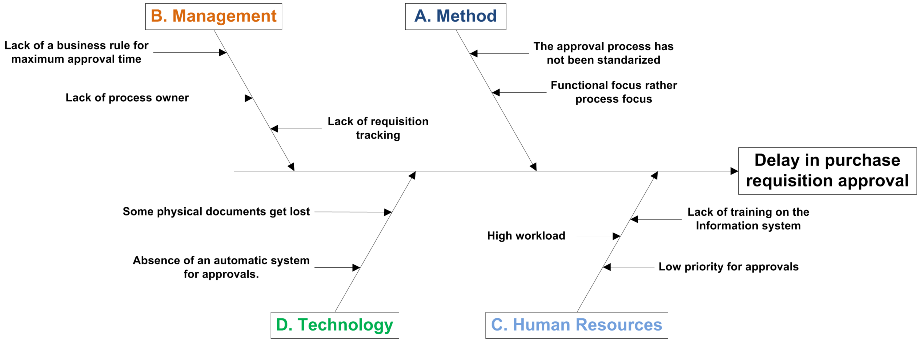

Fig. 9. Root cause analysis

Table 6 presents the key findings of this analysis.

Table 6. Key findings of this analysis

One of the main approval delay causes is that the physical documents that are handled in the process are not managed in a central repository.
Given that there is no business rule determining a time limit for approvals, approvers do not give the required priority to this process.

C. Phase III: Redesigning the Business Process (to-be)

In the redesign stage, the different process improvement options are simulated and evaluated.

Simulation Model

Based on the process discovered in phase 1, and on processing (P) and waiting times (W) calculated through the statistical analysis of the event log data, a simulation model was generated. Figure 10 shows the simulation model, which was obtained in the Process Modeler application.

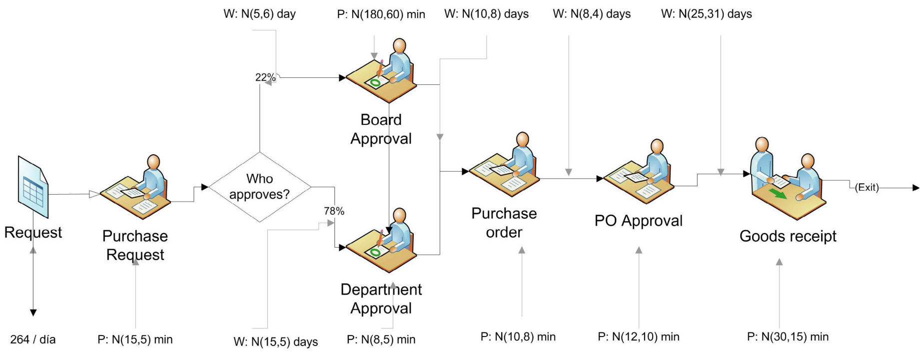

Fig. 10. Simulation model of the procurement process

Simulation of the as-is process was performed with 4,224 cases, finding and average cycle time of 50.72 days, as shown in Table 7.

Table 7. Average process cycle time

Scoreboard				
Scenario	Name	Total Exits	Average Time In System (Days)	Expected Average Time (Days)
Baseline	Request	4.224,00	50.72	30

Process Improvement Alternatives

The process improvement alternatives were defined to overcome the issues found in the as-is analysis phase. Said alternatives are shown in table 8.

Table 8. Process improvement alternatives

Process improvement alternative	
1. Removing the purchase order approval process.	Out of the 8,987 analyzed cases, no purchase order was rejected, so this control can be eliminated, the responsibility lying on the purchase requisition approval process.
2. Establishing an approval time limit business rule.	Said business rule would define that the approvers have a maximum of 5 days for purchase requisition approval.

Simulation and "what if" Analysis

The different improvement alternatives were simulated in corresponding scenarios.

- Scenario 1: Removal of the purchase order approval process.

– Scenario 2: Establishment of a business rule stating that approvers have a maximum of 5 days for purchase requisition approval.
– Scenario 3: Scenario 1 + Scenario 2

Table 9 shows the key findings of the simulation analysis

Table 9. Key findings of the simulation analysis

Table 9. Key findings of simulation and what if analysis		
Scenario 1: If the purchase order approval process was removed, the cycle time could be reduced to 43 days.		
Scoreboard		
Name	Total Exits	Average Time in System (Day)
Solicitud	4224,00	42,81
Scenario 2: If the university established a business rule specifying that approvers have a maximum of 5 days to approve purchase requisitions, the cycle time could be reduced to 43 days.		
Scoreboard		
Name	Total Exits	Average Time in System (Day)
Solicitud	4224,00	40,23
Scenario 3: Through the simultaneous implementation of scenarios 1 and 2, the cycle time could be reduced to 35 days.		
Scoreboard		
Name	Total Exits	Average Time in System (Day)
Solicitud	4224,00	34,76

D. Phase: Implementation
At this stage, the selected alternatives are implemented to improve the business process. For this case study, scenario 3 presented in Table 9 allows decreasing the cycle time to 35 minutes, thus constituting the alternative that is going to be recommended to the University for Implementation.

4.2 Lessons Learned

One of the key success factors for the implementation of the proposed methodology is the involvement of the people (users) playing a role in the actual execution of the business process. User knowledge is crucial for the interpretation of the cases, activities and variables of the process' event log, especially when it comes to preventing data misinterpretation and organizing a log that represents the actual execution of the process. Data extraction from, and cleansing of the event log is a crucial step that must be carried out in close connection with the users because they are the ones who know the real facts about outlier values and missing or wrong data.

The sequence proposed in this methodology does not necessarily have to be executed in that same order. Tools like process performance analysis, data mining and root cause analysis can be used in any order and may be complemented with other tools like Statistical Process Control from Six Sigma or Value Stream Mapping from Lean. These tools are complementary and might be useful in complex business processes where data mining and root cause analysis are not enough for a complete as-is process analysis.

Although the currently available process mining packages have been evolving in functionality, they still need to be more user-friendly, especially regarding data display techniques. Working with state-of-the-art algorithms, ProM is particularly useful for process discovery, but the resulting petri nets are not easy to interpret by the business user. Disco from Fluxicom is emerging as a user friendly package that provides more understandable visualization and animation tools. Providing adequate functionalities for finding missing data and outliers, SPSS and SAS are helpful and robust statistical packages when it comes to event log cleaning. Data mining analyses such as cluster and decision trees can be used with these applications.

5 Conclusions and Further Research

The present paper presents a methodological approach to process redesign that combines simulation techniques, data mining and process mining tools, as well as the tools of the understanding phase of the BPtrends methodology [10]. These tools and techniques are complementary to one another, and their integration contributes to achieving the goals set for each phase of the methodology.

BPtrend tools are useful for the understanding phase of the project, in which the scope of the process is established, the gap analysis between as-is and to-be is performed, and the stakeholders agree on the expected performance of the business process.

On the other hand, specific process mining techniques such as alpha, heuristics or genetic algorithms allow both discovering the actual process model and checking for compliance with business rules and procedures. Said model is used to construct the as-is simulation model.

Data mining techniques such as decision trees and cluster analysis are useful for determining the variables that influence process cycle times and to determine the odds of executing a process within a certain time limit.

Simulation benefits greatly from process mining since the latter provides the parameters that are needed to construct the simulation model, based on the real process model. Simulation makes it possible to test different process redesign alternatives before implementing them, thus becoming a valuable decision-making tool.

A process redesign project requires more than a single tool to achieve the expected results. Although process mining provides tools for process diagnosis and analysis, it must be complemented with other methodologies and techniques such as simulation and other process improvement tools that allow understanding and planning the process redesign effort.

The methodological approach proposed in this paper needs to be validated in other case studies reaching the implementation phase, in order to assess whether it meets the expected results. Further research is needed to determine how the event log source (ERP, WFMS, CRM) determines the necessary log extraction, transformation and cleansing activities.

References

1. van der Aalst, W.M.P., et al.: Process mining manifesto. In: Daniel, F., Barkaoui, K., Dustdar, S. (eds.) BPM Workshops 2011, Part I. LNBIP, vol. 99, pp. 169–194. Springer, Heidelberg (2012)
2. Van der Aalst, W.M.P.: Process Mining: Discovery, Conformance and Enhancement of Business Process. Springer, Berlin (2011)
3. Stahl, C.: Modeling Business Process: A Petri Net-Oriented Approach. The MIT Press, Cambridge (2011)
4. Rozinat, A., Mans, R., Song, M., Van der Aalst, W.M.P.: Discovering colored petri nets from event logs. International Journal of Software Tools for Technology Transfer 10(1), 57–74 (2007)
5. Jans, M., Van der Alast, W.M.P., Werf, J., Lybaert, N., Vanhoof, K.: A business process mining application for internal transaction fraud mitigation. Expert Systems with Applications 38(3), 13351–13359 (2011)
6. Van der Aalst, W.M.P., et al.: Business process mining: an industrial application. Information Systems 32(5), 713–732 (2007)
7. Van der Aalst, W.M.P., Schonenberg, M., Song, M.: Time prediction based on process mining. Information Systems 36(2), 450–475 (2011)
8. Aguirre, S.: Aplicacion de mineria de procesos al proceso de compras de la puj (2011) (unpublished)
9. Weske, M.: Business Process Management: Concepts, Languages, Architectures, Berlin (2010)
10. Harmon, P., Davenport, T.: Business Process Change. Morgan Kaufmann, Burlington (2007)
11. Bozkaya, M., Gabriels, J., Werf, J.: Process diagnostics: A method based on process mining, information, process, and knowledge management. In: International Conference on eKNOW 2009, pp. 22–27 (2009)
12. Rebuge, A., Ferreira, D.: Business process analysis in healthcare environments: A methodology based on process mining. Information Systems 37(2), 99–116 (2012)
13. Maruster, L., Van Beest, L.: Redesigning business processes: a methodology based on simulation and process mining techniques. Knowledge and Information Systems 21(3), 267–297 (2009)
14. Van der Aalst, W.M.P., Weijters, A.J.M.M., Maruster, L.: Workflow mining: discovering process models from event logs. IEEE Transactions on Knowledge and Data Engineering 16(9), 1128–1142 (2004)
15. Weijters, A.J.M.M., Ribeiro, J.: Flexible heuristics miner. BETA working Paper Series. Eindhoven University of Technology, Eindhoven (2010)
16. Medeiros, A., Weijters, A.J.M.M., Van der Aalst, W.M.P.: Genetic process mining: An experimental evaluation. Data Mining and Knowledge Discover 14(2), 245–304 (2007)
17. Rozinat, A., Mans, R., Song, M.: Discovering simulation models. Information Systems 34(3), 305–327 (2009)
18. Shmueli, G., Patel, N., Bruce, P.: Data mining for business intelligence, Hoboken, NJ, USA (2007)