# Petri Net Model Cost Extension based on Process Mining
## *Cost Data Description and Analysis*

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Abstract: Organizations always look for enhancing their efficiency and competitiveness by improving their business processes. Business Process Management includes techniques allowing continuous business process improvement. Process mining is a mature technology allowing to extract knowledge from event logs. Process model extension is a process mining technique covering different perspectives of the business process. Furthermore, financial cost incurred during business process execution is one of the relevant information needed by decision makers to take the appropriate improvement decisions in terms of cost reduction. Thus, we proposed a solution allowing Petri Net model extension with cost information using process mining extension technique. However, the proposed solution simply provides cost information by associating them to the corresponding elements of the Petri Net model, which is not sufficient for decision making support. In this paper, we propose several improvements and extensions of the proposed solution in order to enhance the provided decision making support. These proposals include cost data structuring, description and analysis with respect to the recommendations drawn from talks with experts.

# 1 INTRODUCTION

Efficiency and competitiveness are the main concerns of all organizations (Briol, 2008). The Business Process Management (BPM) approach has been highly considered for its potential of, continuously, enhancing organizations' business processes (BPs). Process Mining (PM) is a BPM technique used to analyze BPs based on Event Logs (ELs) commonly available in today's information systems. Among the PM techniques, the extension technique enables process model enhancement with useful information. Moreover, organizations are always concerned with reduction of costs incurred during the execution of their BPs. Management Accounting (MA) is the field dealing with how cost and other information should be used for planning, controlling, continuous improvement and decision making (Weygandt, Kimmel and Kieso, 2010; Hansen and Mowen, 2006). Furthermore, associating cost data to the corresponding elements of the BP model enables decision makers to easily have accurate cost information about each element. In (Thabet, A. Ghannouchi and H. Ben Ghezala, 2014a), we studied the issue of BP model extension with cost information based on PM. Then, we started by proposing a solution for cost extension of Petri Net (PN) models based on PM extension technique. A PN is a directed bipartite graph populated by places and transitions connected by arcs. Although the proposed solution is a new way of providing BP cost information, but improving cost data handling would further facilitate decision making for BP improvement in terms of cost reduction.

In the remainder of this paper, we specify the considered research questions in Section 2. In Section 3, we present related works to the research questions. Section 4 summarizes the talks we conducted with experts and present the enhanced solution design. Section 5 deals with the enhanced solution implementation. In Section 6, we illustrate the test of the enhanced solution. Finally, in Section 7, we summarize the main contributions and present the future works.

# 2 RESEARCH QUESTIONS

The main research goal of our work is to extend BP model with cost information using the PM extension


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technique in order to support decision makers to improve their BPs in terms of incurred cost reduction. Based on cost annotated ELs (Nauta, 2011), the solution we proposed in (Thabet, A. Ghannouchi and H. Ben Ghezala, 2014a; 2014b) performs a PN model cost extension including cost information extraction, calculation and association to each transition of the PN model.

However, as we aim at providing better support for decision makers, the proposed solution may be improved at different levels, mainly, in terms of cost data structure, description and analysis. In this paper, we consider the following main research questions:

- What are the suited improvements we should adopt for the proposed solution -at the levels of cost data structure, description and analysis- so that it provides better decision making support for BP cost reduction?
- What are the suited ways to bring these improvements to the proposed solution?



## 3 RELATED WORKS

Nauta (2011) proposed an architecture to support cost-awareness in PM. Nauta's approach, mainly, allows to annotate initial EL with cost information based on a cost model created using information provided by management accountants, the BP and the organizational models. Then, the cost annotated EL is used to generate cost reports (Nauta, 2011). However, cost reports are not sufficient for a better decision making support.

This work have been pursued by a current PhD project named "Cost-aware BPM" started in 2012 (Wynn, 2012). The authors propose a cost mining framework to support MA decisions on cost control for monitoring, predicting and reporting. The proposed framework allows customizable cost reports generation and cost prediction (Wynn, Low and Nauta, 2013). The cost prediction looks for cost patterns so that it would be possible to predict cost consumption of an ongoing BP (Wynn, et al., 2014). The cost prediction is based on a cost extension of the transition system approach (van der Aalst, Schonenberg and Song, 2011) to produce a cost-annotated transition system. However, the authors focus on interpretation of the generated cost-annotated transition system without explaining the method used to deduce cost patterns and also without giving details about the way the transition system-which is used in to predict current case time completion- was extended for cost prediction.

## 4 SOLUTION DESIGN

In the following, we give an overview about the conclusions drawn from talks with experts, the enhanced approach and the enhanced cost data structure based on these conclusions.

### 4.1 Talks with Experts

In order to find out the appropriate improvements to adopt for the first version of the proposed solution, we organized appointments for talks with experts in MA and BPM. These talks were driven by a question-based guide and led us to the following main recommendations:

- Cost data structure: (1) cost types differ from an organization to another and (2) it is important to take into account resource, time and data attributes.
- Cost data description: cost data could be described using tables and graphics in order to be represented based on other related factors.
- Cost data analysis: interest to analyze cost data in such a way to find out what are the factors influencing cost values.

### 4.2 Approach Overview

As shown in Figure 1, the inputs of the proposed approach are: the PN model and the corresponding cost annotated EL produced by Nauta's approach. The first step of the approach is the extension of the PN with cost data. This step includes cost data extraction from a cost annotated EL, PN model loading and cost data association to the corresponding transition of the PN model. The output of this step is a cost extended PN model. Next, the PN model is displayed along with the associated cost perspective. The next step of the approach is to handle the cost extended PN model in such a way to further support decision makers in BP cost reduction. For each selected transition, cost data can be handled in two ways: cost data description and analysis. Cost data description allows decision makers to get insight about each transition of the PN model from a cost point of view. Cost data analysis provides knowledge about the factors influencing cost values for each transition of the PN model.

#### 4.2.1 Cost Data Description

Cost data description is improved using customizable tables and graphics. On one hand, tables are used to present cost values computed according to the user selected computation mode(s) and cost type(s) for each transition of the PN. On the other hand, graphics are used to present different views of average cost values based on different factors for each transition of the PN model. The considered views are as follows:

- Cost/Cases view: represents the average cost data and user-defined cost data based on BP cases. This enables decision makers to visualize the average cost evolution over BP cases compared with the user-estimated cost, for each transition.
- Cost/Resources view: represents the average cost value of transition instances executed by each resource. This enables decision makers to visualize the average cost value for each resource involved in the considered transition execution.
- Cost/Cost Types view: represents the average cost value per cost type. This allows decision makers to visualize the distribution of average cost values by cost types.

Thus, on one hand, the proposed approach allows users to easily customize cost data description directly on the PN model for each selected transition using tables and graphics while in the approach proposed by (Nauta, 2011; Wynn, Low and Nauta, 2013; 2014), only resource-related cost information can be visualized and are in the form of separate tables or graphs. On the other hand, the proposed approach includes views allowing users to visualize graphically the relationship between cost estimated values and the actual ones which is not considered in related works, namely, (Nauta, 2011; Wynn, Low and Nauta, 2013; 2014).

### 4.2.2 Cost Data Analysis

We extended the proposed approach with two methods for cost data analysis. We started by focusing on the resource attribute as it is obvious that resources, involved in the execution of a task, influence the incurred cost of that task. We proposed a resource classification method based on transition average cost. The method consists in classifying resources into two groups by comparing resource-based average cost of a given transition with a user-defined cost value. Afterwards, we proposed a cost data analysis based on more than one attribute. The goal is to extract knowledge about which transition-related attributes influence transition cost values, and how. Furthermore, Machine Learning (ML) techniques can be used to discover structural patterns in data, based on a set of training instances. ML classification technique can determine classes of instances based on their attributes (Rozinat, 2010; Witten, Eibe and Hall, 2011; Han, Kamber and Pei, 2012). Therefore, using a ML classification algorithm, we can extract knowledge about the influence of selected attributes on transition cost values. The inputs of a classification algorithm are: training examples, attributes and classes. In our case, for each transition of the PN model, training examples are the transition-related instances contained in the cost annotated EL. The attributes to be analyzed are the transition-related attributes including: resource, time and data attributes. The classes are: C1 (respectively C2) represents transition instances having an average cost value higher (respectively lower) than a user-estimated cost value. The outputs are the inferred structural patterns represented in different forms such as classification rules.

In (Nauta, 2011; Wynn, Low and Nauta, 2013; 2014), cost data analysis consists in predicting costs of ongoing cases. This supports decision makers to take decisions in order to reduce incurred costs of the ongoing case. However, cost data analysis we propose supports decision makers to find out which factors influence cost values for each selected transition. Thus, this supports them to take the appropriate decisions in order to improve the whole BP from a cost point of view.

## 4.3 Petri Net Meta-model Extension with Cost Data Structure

The Petri Net Markup Language (PNML) is a proposal of an XML-based interchange format for PNs and has been defined as an international standard (ISO/IEC 15909 series) which defines a meta-model of four packages: PNML core model, Place/Transition Nets, Symmetric Nets and High-level Petri Net Graphs. PNML core model package can represent any kind of PN (LIP6, 2012; 2013; Hillah, et al., 2009). Therefore, in our work, we consider the PNML core model package as the PN meta-model. Figure 2 shows the UML (Unified Modeling Language) class diagram representing the PNML core model extended with the cost data structure. The PNML Core Model package contains classes and their relationships representing the considered PN meta-model. More details about the PNML Core Model structure are available in (Hillah, et al., 2009; Thabet, A. Ghannouchi and H. Ben Ghezala, 2014). The Cost Extraction and Analysis package contains classes and their relationships representing the cost data structure.

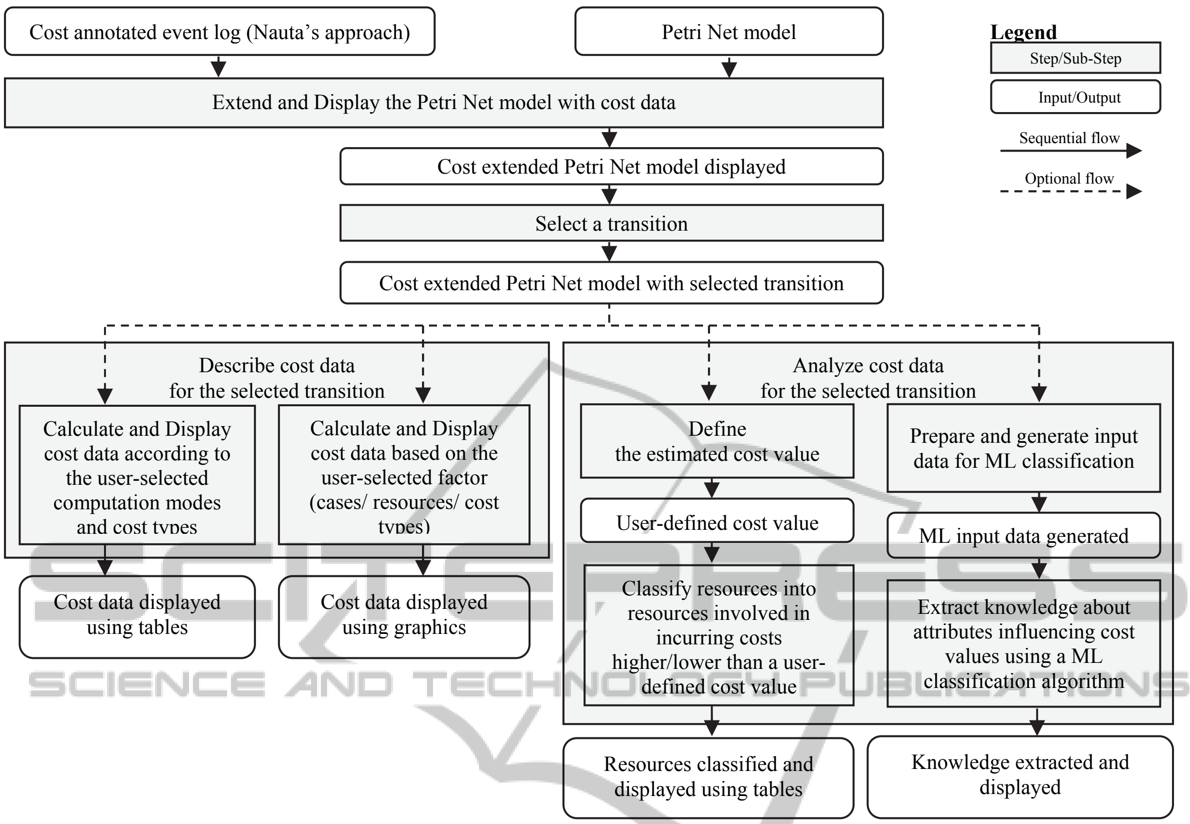



Figure 1: Overview about the proposed approach.

The cost data structure consists of the dark-colored classes and their corresponding relationships. The Cost class represents the cost concept which is described by its value and its currency. The Task Cost class represents the cost of a task in the cost annotated EL. A task is considered as the equivalent of a transition in the PNML model. Thus, the Task Cost class is associated to the Transition class. A task cost consists of the costs of the corresponding task instances (Task Instance Cost class). The Task Instance Cost class contains information about the task instance and its cost. In order to be able to describe and analyze cost data as detailed in Section 4.2.1 and Section 4.2.2, we should memorize resource, time and data attributes for each task instance. Each task instance is performed by one or more resources, has start and end times and could include other data attributes. Thus, we defined Resource, Time and Data Attribute classes and associate them to the Task Instance Cost class. Moreover, a task instance cost is composed of several elementary costs (Elementary Cost class). Each elementary cost has a cost type (Cost Type class). The proposed cost data structure is defined in such a way to facilitate the cost extension of the PNML core model. However, the cost data structure proposed in (Nauta, 2011; Wynn, Low and Nauta, 2013; 2014) is defined for cost annotation of an EL. Besides, the proposed cost data structure captures every useful transition-related information for cost data description and analysis while (Nauta, 2011; Wynn, Low and Nauta, 2013; 2014) focus only on resource and time information.

# 5 SOLUTION IMPLEMENTATION

In the following, implementation of the proposed solution improvements is presented.

## 5.1 Tool Architecture Overview

As shown in the left side of Table 1, the required inputs for the proposed tool are the following. (1) The PN model file (PNML) which meets the PNML core model structure; and (2) the corresponding cost annotated EL (XES) which meets the cost extended XES meta-model.

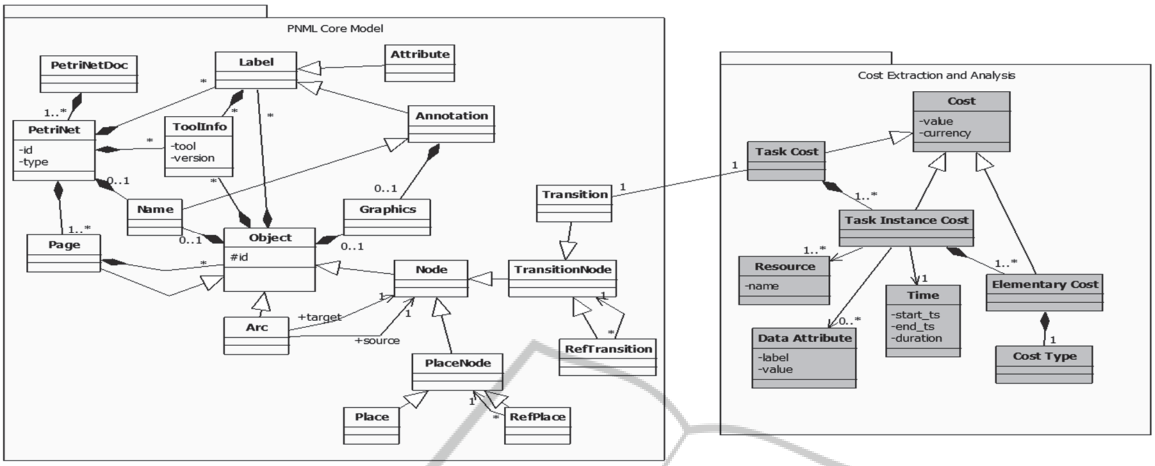



Figure 2: PNML core model extended with cost data structure.

XES is an XML-based generic format for ELs (Hverbeek, 2012). The central part of Table 1 is a UML component diagram illustrating the internal structure of the implemented tool. The inputs are imported using graphical user interfaces (GUI package). The extraction of cost data from the cost annotated EL is performed using the Cost Extraction and Analysis package which imports the OpenXES (1.9) library. OpenXES is a reference implementation of the XES standard for storing and managing EL data (Hverbeek, 2012). The extracted cost data is structured with respect to proposed cost data structure (Figure 2). The PN model is loaded using the PNML core model package which uses the PNML framework, a prototype implementation of the international standard on PNs (LIP6, 2012; 2013). The main package ensures the association of cost data to the corresponding PN transitions and the display of the cost extended PN model using the GUI package. Then, the produced output is a cost extended PN model graphically displayed. Afterwards, cost data description and analysis can be performed using the Cost Extraction and Analysis package. Cost data description outputs can be displayed using tables or graphics while cost data analysis outputs can be in the form of tables or ARFF (Attribute-Relation File Format) files (Witten, Eibe and Hall, 2011). ARFF is the main input file format used in the Weka (Waikato Environment for Knowledge Analysis) system (Witten, Eibe and Hall, 2011). The Weka workbench is a collection of state-of-the-art ML algorithms and data pre-processing tools. It provides implementations of ML algorithms which can easily be applied to a dataset (Witten, Eibe and Hall, 2011). In our case, the dataset is presented in Section 5.4.

## 5.2 Cost Extraction and Extension Algorithms

In (Thabet, A. Ghannouchi and H. Ben Ghezala, 2014a; 2014b), we defined two different cost data structures for cost extraction and extension algorithms. This can be a waste of memory and processing time. In this paper, we define a common cost data structure in order to optimize our tool performance and to further facilitate cost data handling. The new defined cost data structure is shown in Figure 2 (Cost Extraction and Analysis package). Thus, we improved the algorithm of cost data extraction from cost annotated EL. When starting the parse of the cost annotated, a collection of task costs is initialized. For each process instance in the EL, every time a start event is found, start time data are extracted and associated to the corresponding task instance cost. For an end event, cost types-related data are extracted and associated to the corresponding task instance cost. Moreover, resource, time and other attributes data are extracted and linked to the corresponding task instance cost. Task instances costs are grouped based on task labels in order to obtain each task cost composed of its corresponding task instances costs. Each task cost is added to the task costs collection. Once the cost data is extracted from the cost annotated EL and the PN model is loaded, the latter is extended with the extracted cost data. As the extracted cost data is related to tasks in the cost annotated EL, we consider the extension of PN transitions. Thus, each task cost is associated to the corresponding transition. Then, the result is a cost extended PN model which is used to describe and analyze transition-related cost data.

### 5.3 Cost Data Description Implementation

The cost extended PN model is used to present transition-related cost data using tables and graphics. Tables are used to visualize cost data for a selected transition in the PN model. Table lines represent the user-selected computation modes (average, maximum, minimum) and its columns represent the user-selected cost types. Graphics (charts) are used to visualize cost data by different views for a selected transition in the PN model. The Cost/Cases view is presented using a 2D curve which represents the transition average cost values by BP cases. The Cost/Resources view is presented using vertical bars. Each one of them represents the average cost of task instances executed by a resource. The Cost/Cost Types view is visualized using waterfall-organized bars. Each bar represents the average cost per cost type for the transition in hand.

### 5.4 Cost Data Analysis Implementation

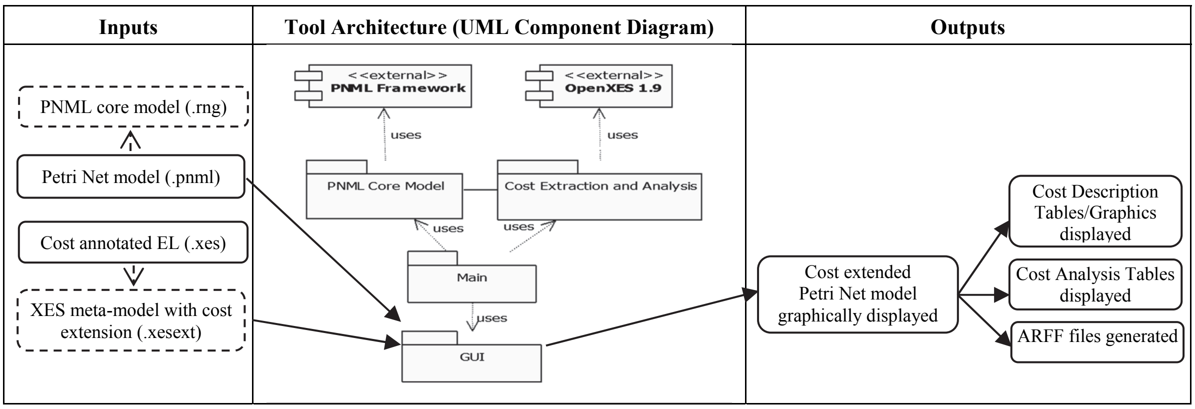
The first cost data analysis method consists in a cost-based resource classification. For each transition of the PN model, the user provides a cost type and the corresponding estimated cost value. Then, the average cost of task instances executed by each resource is calculated and compared with the estimated cost. Next, resources are classified in two groups: the first (respectively second) group includes resources which calculated average cost is higher (respectively lower) than the estimated cost. The obtained two groups are displayed using a two-column table. The second method consists in using ML classification algorithms in order to find out which factors influence transition cost values, and how. To be able to apply different classification algorithms and test their results, we considered to use the Weka system. Thus, we implemented operations generating ARFF files for the user-selected transition. For our case, each generated ARFF file consists of attributes values and classes as presented in Section 4.2.2. Thus, the generated ARFF file can be easily imported into the Weka system which allows to pre-process the input data. Then, the user selects the attributes to consider for the ML classification algorithm. Next, Weka provides several algorithms to use for extracting knowledge in different forms such as classification rules.

## 6 SOLUTION TEST

The test of the proposed solution is performed using a simple phone repair process. Details about the process example are available in (Thabet, A. Ghannouchi and H. Ben Ghezala, 2014a; 2014b). Once the PN model cost extension tool is launched, the user imports the input files: the PN model (PNML file) and the corresponding cost annotated EL file (XES file). We selected PNML and XES files of the simple phone repair process example. Then, the cost extended PN is displayed on the main tool frame (background frame of Figure 3). When right clicking on a specific transition of the PN model, two options are provided: cost data description and cost data analysis.

The cost data description is performed using user-customized table or graphics. The top left frame in Figure 3 shows the cost data description table related to the "Analyze Defect" transition. Cost data description graphics show different views about the incurred cost of each transition of the PN. The

Table 1: General architecture of the Petri Net model cost extension tool.



Cost/Cases view is illustrated by the bottom right frame in Figure 3.

This view shows (1) a curve representing the average total costs of the "Analyze Defect" transition based on BP cases and (2) a line representing the estimated cost provided by the user (17 AUD). This graphic shows that the number of cases having average costs higher than the user-estimated cost value is important which indicates that the execution of the transition incurs more costs than estimated. The Cost/Resources view is illustrated by the top right frame of Figure 3 which shows bars each of which representing the average of total costs related to "Analyze Defect" transition instances executed by a resource. This graphic shows that when the resource "Tester6" executes the considered transition the total cost is at minimum. The Cost/Cost Types view is illustrated by the bottom left frame of Figure 3 which shows that the total cost of the "Analyze Defect" transition is of 17,38 AUD and is distributed as follows: 3,10 AUD (average labour cost), 8,20 AUD (average fixed cost) and 6,07 AUD (average variable overhead). This graphic indicates that fixed and variable overhead costs represent the major part of the total cost incurred by the considered transition execution.

The cost data analysis option can be performed with two methods. The test of the first method is illustrated by Figure 4 which shows that the average total cost of "Analyze Defect" transition instances executed by "Tester6" is lower than the estimated cost value provided by the user (17 AUD). However, the other resources are involved in incurring higher total costs than the estimated one.

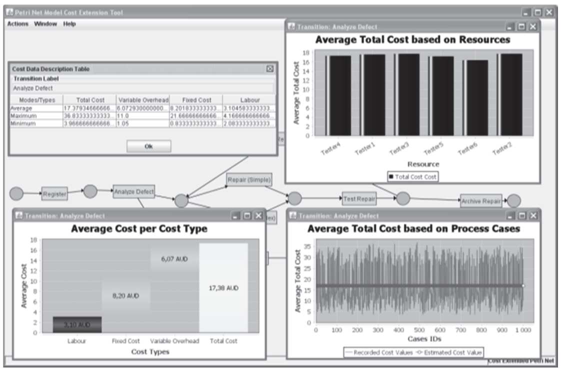



Figure 3: Displaying cost data description for the "Analyze Defect" transition.

Taking into account the cost/resource graphical view, this indicates that "Tester6" is the resource that incurs (slightly) lower total cost than the other ones, when executing "Analyze Defect" transition. This may lead decision makers to a resource-based solution to reduce the costs incurred by the execution of "Analyze Defect" transition. We tested the second method on the "Analyze Defect" transition by selecting the total cost as a cost type and 17 AUD as the estimated cost. Then, an ARFF file is automatically generated according to details presented in Section 5.4. Afterwards, the ARFF file is imported using Weka system. After pre-processing data by selecting the "resource", "duration", "phone type" and "defect type" attributes for the transition in hand, we applied different classification algorithms among which we retained the J48 algorithm (Witten, Eibe and Hall, 2011) result as it provided the highest rate of correctly classified instances (100%). The J48 extracts knowledge in the form of decision trees. We present the result in the form of classification rules:

```
If (phoneType = T1) Then
   Cost is lower
If (phoneType = T2) Then
   Cost is lower
If (phoneType = T3) Then
   Cost is higher
```

The provided result shows that if the phone type is T1 or T2, the incurred total cost of the "Analyze Defect" transition is lower than the estimated cost value. However, if the phone type is T3, the total cost exceeds the estimated cost value. The conclusion we can draw from the obtained result is that if we assume that the estimated total cost value of the transition "Analyze Defect" is 17 AUD, the total cost incurred during the execution of this transition depends on the "phone type" attribute. The influence of the other attributes on the corresponding total cost is not prominent.

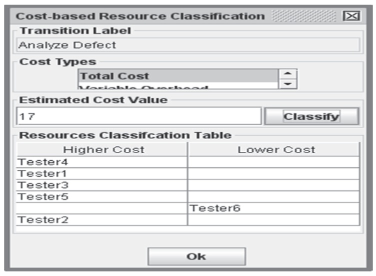



Figure 4: Resource classification based on total cost of the "Analyze Defect" transition.

This indicates to decision makers that reviewing the repair of phones with type T3 is likely to lead to a solution to reduce costs incurred by the execution of "Analyze Defect" transition. The above presented test case deals with the influence of "resource", "duration", "defect type" and "phone type" attributes on "Analyze Defect" transition cost.

# 7 CONCLUSION AND FUTURE WORKS

In (Thabet, A. Ghannouchi and H. Ben Ghezala, 2014a; 2014b), we proposed a solution for PN cost extension. In this paper, we carried out several improvements of the proposed solution according to talks with experts in MA and BPM. We improved the proposed cost data structure in order to take into account important cost-related concepts. Furthermore, we extended the proposed solution with cost data description and analysis. Cost data description allows decision makers to get insight about their BP from a cost point of view using tables and graphics. Cost data analysis supports decision makers to know which factors influence cost values and how. This contributes to support making decisions to reduce the incurred costs. Moreover, all these improvements were implemented and tested for the case of a simple phone repair process.

Currently, we are working on further improvement of cost data analysis in order to provide more accurate results for better decision making support. This will be studied in conjunction with different experts in order to validate the proposed solution. Furthermore, we are studying the generalization of the proposed approach to support cost extension of any BP model (not only PNs). Future works concern carrying out real world case studies in order to evaluate the proposed solution.

# REFERENCES


Briol, P., 2008. *Ingénierie des Processus Métiers: de l'élaboration à l'exploitation*, Briol Patrice.

Han, J., Kamber M. and Pei, J., 2012. *Data Mining: Concepts and Techniques (3rd ed.)*, Elsevier. United States of America.

Hansen, D.R. and Mowen, M.M., 2006. *Cost Management: Accounting and Control*, Thomson South-Western. United States of America.

Hillah, L.M., Kindler, E., Kordon, F. and Petrucci, L., 2009. A primer on the Petri Net Markup Language and ISO/IEC 15909-2*. In *CPN'09, 10th International workshop on Practical Use of Colored Petri Nets and the CPN Tools*. Denmark.

Hverbeek, 2012. *Extensible Event Stream*. (online) Available at: <http://www.xes-standard.org> (Accessed June 2013).

IEEE Task Force on Process Mining, 2012. Process Mining Manifesto. In *BPM 2011 Workshops*. Springer.

LIP6 (Laboratoire d'Informatique de Paris 6), 2012. *PNML Framework download site*. (online) Available at: <http://pnml.lip6.fr> (Accessed July 2013).

LIP6 (Laboratoire d'Informatique de Paris 6), 2013. *PNML reference site*. (online) Available at : <http://www.pnml.org> (Accessed July 2013).

Nauta, W.E., 2011. *Towards Cost-Awareness in Process Mining*. Master's thesis. Eindhoven. (pdf) Available at: <http://alexandria.tue.nl/extra1/afstversl/wsk-i/nauta2011.pdf> (Accessed April 2012).

Process Mining Group, 2013. *Process Mining: Research, Tools and Application*. (pdf) Available at: <http://www.processmining.org> (Accessed June 2013).

Rozinat, A., 2010. *Process mining: Conformance and Extension*, PhD Thesis, University Press Facilities. Eindhoven.

Thabet, D., A. Ghannouchi, S. and H. Ben Ghezala, H., 2014a. Towards Business Process Model Extension with Cost Perspective based on Process Mining - Petri Net Model Case. In ICEIS'14, 16th International Conference on Enterprise Information Systems, SciTePress. Portugal.

Thabet, D., A. Ghannouchi, S. and H. Ben Ghezala, H., 2014b. Petri Net Model Extension with Cost Perspective based on Process Mining. In *ICMHIS'14, 9th International Colloquium of MHIS (Management High Institute of Sousse)*. Tunisia.

van der Aalst, W.M.P., 2011. *Process Mining: Discovery, Conformance and Enhancement of Business Processes*, Springer-Verlag. Berlin.

van der Aalst, W.M.P., Schonenberg, M. and Song, M., 2011. *Time prediction based on process mining*. (pdf) Information Systems. Available at: <http://wwwis.win.tue.nl/~wvdaalst/publications/p609.pdf> (Accessed July 2014).

Weygandt, J.J., Kimmel, P.D. and Kieso, D.E., 2010. *Managerial Accounting Tools for Business Decision Making*, John Wiley & Sons Inc. United States of America.

Witten, I.H., Eibe, F. and Hall, M. A., 2011. *Data Mining: Practical Machine Learning Tools and Techniques,* Elsevier. Burlington.

Wynn, M., 2012, *Dr. Moe Thandar Kyaw Wynn's homepage*. (online) Available at: <http://www.yawlfoundation.org/moe/index.html> (Accessed May 2012).

Wynn, M.T., Low, W.Z. and Nauta, W., 2013. *A Framework for Cost-Aware Process Management: Generation of Accurate and Timely Management Accounting Cost Reports*. (pdf) Conferences in Research and Practice in Information Technology. Available at: <http://crpit.com/confpapers/CRPITV143Wynn.pdf> (Accessed July 2013).

Wynn, M.T., Low, W.Z., ter Hofstede, A.H.M. and Nauta, W., 2014. *A Framework for Cost-Aware Process Management: Cost Reporting and Cost Prediction*. (pdf) Journal of Universal Computer Science. Available at: <http://www.jucs.org/jucs_20_3/a_framework_for_cost/jucs_20_03_0406_0430_wynn.pdf> (Accessed July 2014).