A Guidance System for Business Process Flexibility

Asma Mejri[1], Sonia Ayachi Ghannouchi[1,2] and Ricardo Martinho[3,4]
[1]*Laboratory RIADI-GDL, ENSI, Mannouba 2010, Tunisia*
[2]*High Institute on Management of Sousse, Tunisia*
[3]*School of Technology and Management, Polytechnic Institute of Leiria, Portugal*
[4]*Center for Health Technology and Services Research (CINTESIS), Portugal*

Keywords: Flexibility, Guidance, BPM, Emergency Care Process, BPMS, Paradigm.

Abstract: During the last decades, flexibility has gained a strong presence, in a variety of disciplines, mainly in the BPM field. The real challenge for BPM consists in providing modeling paradigms and BPMSs with adequate information and features to deal with the often conflicting requirements of flexibility. In this setting, we focus on providing a guidance approach for enhancing business process flexibility. Our purpose is therefore to perceive which modeling paradigm(s) and/or business process management system(s) (BPMS(s)) are the most adequate to the specific organization needs in terms of flexibility. This approach was implemented in a plug-in named BPFlexGuide. To evaluate this approach, we have studied the emergency care (EC) process. Users interested in the EC process were guided to use the AristaFlow BPM suite BPMS. The results of this study would help designers to choose the best paradigms and BPMS that best fit their needs on flexibility.

1 INTRODUCTION

In the past decades, flexibility has gained a strong presence in various fields, notably in the BPM discipline. Flexibility is a must, because continuously changing conditions compel organizations to rapidly and flexibly adapt their business processes (BPs). Thus, the real challenge for BPM consists in providing modeling paradigms and BPMSs with adequate information and features to deal with the often conflicting requirements of flexibility. Indeed, several paradigms have emerged.

In this paper, we are going to select the most popular paradigms which are the rule-based, constraint based, case handling and adaptive process management. The adaptive paradigm represents one of the paradigms that enable users to make structural process changes to support the handling of exceptions, the evolution of BPs and user support in exceptional situations (Schonenberg et al., 2008). A constraint-based paradigm makes it possible to execute both allowed and optional scenarios in BPs (Pesic, 2008). A paradigm is called rule-based if the logic of its control flow, data flow and resource allocation is expressed by means of business rules, which are recognized as powerful representation forms that can potentially define the semantics of BP models and business vocabulary (Sun et al., 2006). The case handling paradigm supports flexible and knowledge intensive BPs (Van der Aalst et al., 2005). Each of these paradigms has its specific characteristics which are adjusted to specific organization's needs.

On the other hand, users have to be aware of how their flexibility needs can be addressed by the aforementioned paradigms, and then which BPMSs better match these (often combined) paradigms to execute and manage BP models and corresponding instances. Moreover, process engineers, who often decide which BPMS to adapt to their organizations, do not know upfront most known BPMSs nor their (flexibility) characteristics. Even if they could collect some information from the Internet it would be very difficult to come up with a scoring mode that could easily perform a match between their BPs' flexibility needs and the best choice for a BPMS. We propose in this paper the BPFlexGuide guidance system for choosing the best-suited BPMSs and BP modeling paradigm to an organization's BPs.

With our system, process engineers will be able to input their organization's needs in terms of BP flexibility, and take a ranked and properly scored list of recommended BPMSs and modeling paradigms. They can also benefit, with our system, from fully characterized BPMSs in terms of flexibility, which will allow them to analyze and improve decision making regarding particular characteristics that can only be observed in some of their BPs. To accomplish these main objectives of our BPFlexGuide guidance

Mejri, A., Ghannouch, S. and Martinho, R.
A Guidance System for Business Process Flexibility.
DOI: 10.5220/0006316902100217
In *Proceedings of the 12th International Conference on Evaluation of Novel Approaches to Software Engineering (ENASE 2017)*, pages 210-217
ISBN: 978-989-758-250-9

system, we performed the following main research tasks:

- Compare existing BPMSs regarding flexibility: This includes weighting the different flexibility criteria;
- Measure the ability of existing BP modeling paradigms to deal with flexibility;
- Implement a system that guides the users to choose the most appropriate BPMS and modeling paradigms;
- Evaluate the system using a flexible process (in healthcare domain).

The remainder of this paper is organized as follows. Section 2 presents basic concepts, including flexibility in BPM, a summary on Regev et al.'s BP flexibility taxonomy and most relevant related work. Our research method is described in Section 3 and in section 4 we reveal our main elements and artifacts derived from this method. The BPFlexGuide implementation details with ProM are presented in Section 5, and in Section 6 we apply our approach to a case study. Section 7 concludes the paper.

2 RELATED WORK

Guidance addresses the issue of guiding either users and/or developers, practitioners and/or academicians, and/or modelers during the different steps of the BPM life-cycle. The concept of guidance has hence been researched in the BPM community in the context of proposing principles and guidelines, providing recommendation systems or decision support systems.

In (Mendling et al., 2010), authors propose a set of seven process modeling guidelines. These guidelines directly aim to bring support to process modelers. In (Thomas et al., 2014), authors propose a set of ten principles that characterize BPM as a research domain and guide its successful use in organizational practice.

On the other hand, authors propose recommendation systems, in (Barba et al., 2013), (Schonenberg et al., 2008), (Setiawan et al., 2011), (Conforti et al., 2015), (Huang et al., 2012), (Koschmider et al., 2011), (Mertens et al., 2014). For example, in (Barba et al., 2013), the recommendation system is based on a constraint-based approach for planning and scheduling the BP activities and considers both the control-flow and the resource perspective. Recommendations, in (Schonenberg et al., 2008), are given in order to assist users in selecting activities, during process executions, by giving recommendations on possible next steps.

Authors, in (Conforti et al., 2015), propose a recommendation system that supports process participants in taking risk-informed decisions, with the goal of reducing risks that may arise during process execution. A system for supporting users at modeling time was presented in (Koschmider et al., 2011). It provides information that facilitates the decision for the right recommendation which is based on the user profile. Consequently, users can follow up recommendations that are ranked, based on different criteria. In order to provide guidance to users during process execution, a recommendation system was proposed in (Mertens et al., 2014). Their main contribution consists of a robust process engine that can deal with changes that are held in very dynamic and complex environment, at run-time.

Other research efforts were engaged in developing decision support systems. For instance, authors, in (Cingil et al., 2012), have developed a decision support system that includes a relational database to keep the predefined relations, its descriptions, the inputs for weights, its grades and calculated scores. Besides, authors have proposed in (Yao and Kumar, 2013) a clinical decision support system that provides decision support, in order to get adaptable clinical pathways. These pathways are selected during BPs execution and are based on rules that encapsulate medical knowledge and patient conditions that are constantly changing. In most of these approaches, the focus on flexibility and user assistance can be observed. But, they do not support, in a straightforward way, BP flexibility. Moreover, the need for increased attention to flexibility, the competing paradigms and the wide variety of BPMSs has been recognized by both academia and industry. Though, to the best of our knowledge, none of the research works directly targets the development of a guidance system that takes into account flexibility and the multitude of paradigms and BPMSs. Upon the recognition of such scarcity, there is an urgent need to propose a guidance approach and develop the corresponding tool in order to guide users to choose the most convenient paradigms and BPMSs, according to their particular needs in terms of flexibility. An overview on our guidance approach will be the main focus of the next section.

3 PROPOSED TWO-STEP RESEARCH APPROACH

In this section we describe our research approach, which is based on two steps: (1) a general classification of BPMSs and process modeling paradigms; (2)

the proposal of a guidance procedure that foresees inputs from users regarding their needs in terms of BP flexibility, and later guiding them to choose the best-suited BPMS for their organizations.

Figures 1 and 2 present the main activities developed within these major two steps. These activities can be summarized as follows:

- Classification of BPMSs
  - Identification of flexibility criteria: we began by identifying a set of criteria that we derived from Regev et al.'s taxonomy, in order to evaluate flexibility within BPMSs. From this activity we have specified eleven Flexibility Criteria (FC) (detailed in the next section);
  - Development of the questionnaire "'Evaluation of Business Process Management Systems (BPMS)"': here, we developed a questionnaire for BPMS developers and researchers to answer, based on their advanced knowledge of the BPMSs they develop and research upon. We also selected these BPMSs taking into account their prominence in literature, as well as their ability to support BP flexibility. We could then analyse the answers to the questionnaires and classify BPMSs accordingly, regarding their support on flexibility and modeling paradigms;
- Proposal of a guidance procedure
  - User's BP flexibility needs: here we have to identify flexibility needs from the users of our BPFlexGuide system. This step implied efforts of mapping the well-known flexibility taxonomy of Regev et al. into a set of questions to be understood by general users without a profound knowledge of BP flexibility;
  - Similarity study: here we compare the obtained answers from the users' needs questionnaire and the previous classification of BPMSs, in order to derive a score in terms of flexibility;
  - Specific classification: we then classify and sort the BPMSs and modeling paradigms with an algorithm (detailed in the next section), and present the associated recommendations to users.

In the next section, we provide the results and calculations derived from each of these research activities.

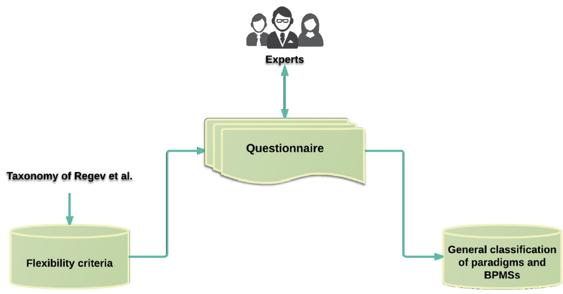

Figure 1: Overview of step 1 of our research method.

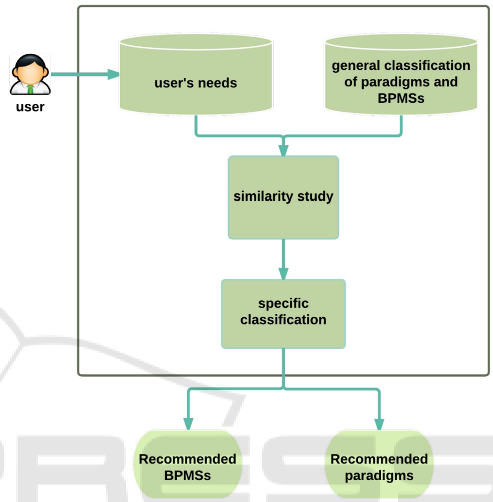

Figure 2: Overview of step 2 of our research method.

4 BASIC ELEMENTS OF OUR TWO-STEP RESEARCH APPROACH

We present in this section the main elements on which our research is based. These include the identification of flexibility criteria for evaluating BPMSs, the design of the questionnaire and obtained answers, and the calculations and developed algorithms to assess the BPMSs to users' needs regarding BPs flexibility.

4.1 BP Flexibility Criteria

We began by identifying a set of criteria that we derived from Regev et al.'s taxonomy, in order to evaluate flexibility within the selected BPMSs. We have specified eleven Flexibility Criteria (FC), which concern the following questions:

- FC1: To which extent do the BPMS modelers describe the process control flow?
- FC2: To which extent does the BPMS support descriptive modeling and execution of process activ-

ities?

- FC3: To which extent does the BPMS support descriptive modeling and execution of the preconditions of the activities?
- FC4: To which extent does the BPMS support descriptive modeling and execution of data/information exchanged between process activities?
- FC5: To which extent does the BPMS support descriptive modeling and execution of roles associated to process activities?
- FC6: Does the BPMS support changes to process models which will affect all new process instances?
- FC7: Does the BPMS support changes at the instance level, and that will only affect certain selected instances, in order to accommodate exceptional situations?
- FC8: Can the BPMS support incremental change and/or revolutionary change?
- FC9: How would the duration of change that the BPMS support be characterized: temporary and/or permanent?
- FC10: Is the BPMS able to deal with immediate and/or deferred change?
- FC11: Can the BPMS support planned / ad-hoc changes?

It is important to mention that all FCs have the same weight. We have specified for each FCs a scale in order to get consistent results. FC1, FC2, FC3, FC4 and FC5 range from 0 (not descriptive) to 5 (very descriptive). FC6 and FC7 can be 1 (yes) or 0 (No). FC8, FC9, FC10 and FC11 can take 1 (if it satisfies one of the characteristics describing this criteria) , 0 (if it doesn't satisfy none of the characteristics) or 2 (if it doesn't satisfy both characteristics).

4.2 Questionnaire for BPMS Providers

The questionnaire has been designed in order to evaluate flexibility in BPMSs from a provider point of view. The questionnaire was specifically designed to seek responses from the most senior personnel responsible for the development of the selected BPMSs. We had it filled out by eight senior developers/researchers that provides us with answers for eight BPMSs (or modeling tools): DECLARE, ESProNa, Jrules, AristaFlow BPM suite, PhilhamonicFlows, jBPM, ProdProc and FLOWer. Most of the BPMSs from which we got answers were developed in the context of research projects. Others were developed by professional developers from the industry. Table 1 contains the responses for each BPMSs. According to the questionnaire's results, Table 2 summarizes the answers to the following question: "<What is (are) your BPMS(s) underlying modeling/execution paradigm(s)?"> From Table 2, we can conclude that, from the selected BPMSs, most of them support constraint-based modeling (5 out of 8) and also 5 out of 8 are mono-paradigm oriented. We can also observe that 2 out of 3 multi-paradigm systems combine the constraint and rule based paradigms.

4.3 Match between Users' BP Flexibility Needs and BPMSs' Announced Flexibility

We aim at comparing the elements of the users' needs in terms of flexibility in BPs and the elements of the responses of the questionnaire presented in Table 1. Our study is based on a similarity metric in order to measure distance, more specifically the overlap metric. According to (Raj Kumar, 2012), the overlap metric simply tests for equality between two values, so that different values get distance 1 whereas equal values get distance 0:

Definition the overlap distance

$$d_{overlap}(x,y) = 1\, when\, x \neq y$$
$$d_{overlap}(x,y) = 0\, when\, x = y$$

4.4 Algorithm of Specific Classification of BPMSs

In order to calculate this similarity score for each BPMS, we follow the methodology that includes the following steps: (1) Compare the users' flexibility criteria with the different BPMS flexibility criteria. (2) Attribute a calculated similarity score for each criterion. The score is 0 or 1, where 0 indicates no similarity and 1 indicates identical elements. (3) Sum all the criteria to obtain a similarity score SIM for the considered BPMS. The next step consists in comparing the calculated scores for each BPMS in order to sort them.

Algorithm 1. *We consider two sets S and U. S is the set of the different BPMSs. Each S_i consists of the values taken by the flexibility criteria for a given BPMS. U is the set of the criteria entered by the user. Let n be the number of studied systems, NCR be the number of studied flexibility criteria.*

Furthermore let $S = (S_1, S_2, S_3, ..., S_n)$

$U = (FCU_1, FCU_2, FCU_3, ..., FCU_{NCR})$

Table 1: Responses of the questionnaire for each BPMS.

	DECLARE	ESProNa	JRules	AristaFlowBPM suite	PHiharmonicFlows	ProdProc	jBPM	FLOWer
FC1	2	3	4	4	2	2	5	1
FC2	5	3	4	5	3	4	5	2
FC3	2	4	3	3	5	4	3	2
FC4	2	3	1	5	5	3	5	2
FC5	2	3	2	5	4	3	3	2
FC6	0	0	1	1	1	1	1	1
FC7	1	1	1	1	1	0	1	1
FC8	1	1	1	2	1	0	2	2
FC9	1	1	1	2	1	1	1	1
FC10	1	1	1	2	1	1	1	1
FC11	1	2	1	2	1	0	2	1

Table 2: BPMS classification according to their modeling paradigms.

BPMS / Paradigm	Constraint based	Rule based	Case handling	Adaptive Process management	Total
DECLARE	yes	yes			2
EsProNa	yes				1
Jrules	yes	yes			2
AritaFlow BPM suite				yes	1
Philharmonic Flows			yes		1
ProdProc	yes				1
jBPM		yes			1
Flower	yes		yes		2
Total	5	3	2	1	

$S_i = (FC_{1i}, FC_{2i}, FC_{3i}, ..., FC_{NCRi})$.

We define the similarity score for each system as follows: $SIM_i = \sum_{j=1}^{NCR} sim_{ij}$

where $sim_{ij} = d_{overlap}(FCU_j, FC_{ji})$ Next, we do the sorting of the S_i according to the calculated similarities. $SORT_S = sort_i^n \{SIM_i\}$ where $i \in [1,n]$

4.5 Algorithm of Classification of Paradigms

We consider the following steps in order to calculate the paradigms flexibility measurement score for each paradigm:

- Calculate for each BPMS the similarity score (SIM) (as done in the algorithm for classification of BPMSs).
- Sum the similarity scores if the BPMS belongs to the paradigm.
- Compare the flexibility measurement scores of the different paradigms.

Algorithm

Algorithm 2. *Here we consider an additional set P of considered paradigms. Let n be the number of studied systems, m the number of studied paradigms, NCR be the number of studied flexibility criteria.*

Furthermore let $S = (S_1, S_2, S_3, ..., S_n)$

$U = (FCU_1, FCU_2, FCU_3, ..., FCU_{NCR})$

$S_i = (FC_{1i}, FC_{2i}, FC_{3i}, ..., FC_{NCRi})$.

$P = (P_1, P_2, P_3, .., P_m)$.

Each S_i belongs to one or more paradigms. We define the paradigms' flexibility measurement score (PFMS) for each paradigm as follows:

$$PFMS_j = \sum_{k=1}^{n} SS_k where SS_k = \begin{Bmatrix} SIM_k & if S_k \in P_j \\ 0 & otherwise \end{Bmatrix} \quad (1)$$

Next, we do the sorting of the S_i according to the calculated similarities. $SORT_P = sort_j^m \{PFMS_j\}$ $where j \in [1,m]$

5 IMPLEMENTATION

The approach conducted in this research work is supported and tested by a corresponding tool implementation. Therefore, we did not develop a tool from scratch. Whereas, we expanded it upon an existing open-source solution which is the ProM tool, in its latest version 6.4 (Verbeek et al., 2010a).

The starting point is a spreadsheet-based (MSExcel) document that contains the results of the ques-

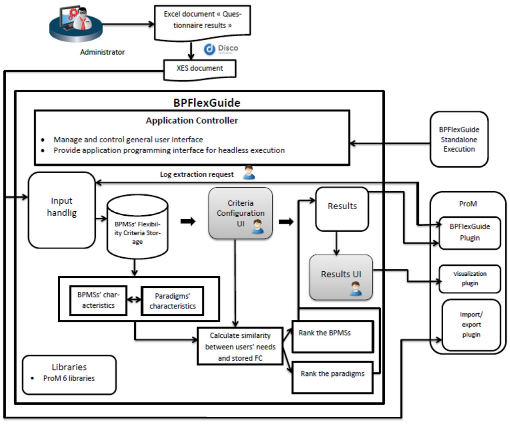

Figure 3: BPFlexGuide architecture.

tionnaire (which were presented in Tables 1 and 2). In order to allow for further implementation in the ProM tool, it has to be transformed to a data structure that conforms to the eXtensible Event Stream (XES) format (Verbeek et al., 2010b). XES is an XML-based format for storing structured data such as event logs and the standard input format for ProM (as of Version 6). The conversion is performed in the first stage using Disco1: another import and data-exchange ProM plugin (Günther and Rozinat, 2012). As shown in Figure 3, this XES document serves as an input to our BPFlexGuide. When starting BPFlexGuide, an internal repository of all the BPMSs' flexibility criteria is constructed. This is done when extracting the BPMSs' flexibility criteria for each BPMS from the XES document. The BPMSs' flexibility criteria have been implemented as classes. The configuration of all the BPMSs and the paradigms is then conducted.

Next, the user can pick, from a list, the flexibility criterion which best fits her/his needs on flexibility. The provided user interface allows configuring user needs on flexibility (based on the taxonomy of Regev et al. (Regev et al., 2006)). Her/his choices are then stored.

We have implemented the algorithms presented in the previous section. The result of the execution of these algorithms is the ranking of the different BPMSs and of the modeling paradigms. Finally, these results are shown to the user. In case the same ranking is obtained for two BPMSs, the user picks one of them.

6 CASE STUDY RESULTS

Adopting BPM technology in the healthcare sector is starting to address some of the characteristics of healthcare processes, including their high degree of flexibility (Lenz and Reichert, 2007). Hence, healthcare domain requires high flexibility (Kirchner et al., 2013). Therefore, this section shows the result of the BPFlexGuide plugin applied to the EC process. The goal of the case study was to elicit flexibility needs of an EC process and to help users to select most adequate paradigms and BPMSs that best suit the needs in terms of flexibility.

6.1 Eliciting Flexibility Needs in the Emergency Care Process

In this work, we are going to consider the EC process which initiates with the patient registration and ends with her/his discharge of the emergency department of Farhat Hached hospital. The EC process was analyzed and modeled at first in (Kirchner et al., 2013), using the BPMN language.

The main technique used to elicit flexibility needs on the EC process was interviews. The target group of the respondents of these interviews was professionals who are working in the EC process. Table 3 resumes the answers of the respondents towards the taxonomy of Regev et al.. Regarding the abstraction level of modeling, when asking physicians this question "¡Do changes affect all the patients or only one patient?"¿. They held that the changes concern neither only one patient nor all the patients. Regarding the dimensions, our study focused on the five known dimensions defined in the Regev et al.'s taxonomy which are the functional, operational, behavioral, informational and organizational dimensions. Interviewees believe that it would be useful to know about the functional perspective. For instance, it would be important to introduce or remove some activities of the EC process.

Concerning the operational dimension, interviewees think that a change in the process level does not require the review of the implementation of applications of information technology that are used in the emergency department. Respondents answered that changing the order of activities can affect changes in the EC process. Thus, they affirm that it is very useful to focus on the behavioral perspective when modeling the EC process. For the informational perspective, respondents believe that it would be very important that changes concern the emergence of new types of information or data that can be exchanged between the different actors involved in the EC process. Concerning the organizational perspective, interviewees see that it would be useful that the changes also concern the roles associated to process activities. Concerning the properties of change, according to interviewees, changes in the model concern the entire model in some cases. For instance, the model could be totally changed through the effective implementation of

Table 3: Flexibility needs of the EC process, according to Regev et al.'s taxonomy.

Criteria	Responses
FC1	2
FC2	0
FC3	3
FC4	4
FC5	3
FC6	0
FC7	0
FC8	2
FC9	1
FC10	1
FC11	2

the disaster plan.

Changes can also concern a part of the model. This can occur, for example, in the cases of contagious or mental diseases. Regarding the duration of change, changes in the EC process should be temporary. They should occur in a limited interval of time (even for months). Because of patient's needs of immediate care, the changes should be immediate. They should not be delayed in time. In addition, interviewees believe that the plans must be developed and must be planned well in advance. However, actions can occur at unexpected times. To sum, regarding the anticipation of change, both planned and ad-hoc change has to be provided.

6.2 Applying our Guidance Approach to the EC Process

After eliciting the roles and causes for changes in the EC process, and deriving the associated flexibility needs, we used this information to advise on a possible BPMS/tool to be used. Our BPFlexGuide offers a classification of the selected paradigms: constraint-based, rule-based, case handling and adaptive process management. This classification could be general (i.e. taking into account all the dimensions) or specific (taking into account one of the three dimensions of the taxonomy of Regev et al.). Regarding the specific classification, the constraint-based paradigm was retained as the first one that is the most suitable for the EC process users' needs which are presented is the previous section. The second paradigm is the rule-based paradigm. The case handling paradigm was held as the third paradigm. Finally, the adaptive process management paradigm was classified as the last one.

Using the BPFlexGuide plugin, we have entered the flexibility needs of the EC process. The goal of the case study was to help process participants and decision makers to choose the most appropriate BPMS that best fit their needs on flexibility.

The plug-in provided, as output, a ranking of the most suitable BPMSs that can be adopted. Specifically, the BPMSs had also been ranked according to the three dimensions of the taxonomy of Regev et al.. We notice that the different BPMSs got various rankings. As a result, EC process modelers were guided to use the ADEPT2/ AristaFlow BPM suite BPMS first, jBPM and ESProNa second. In this work, we model the EC process using the AristaFlow BPM suite. The AristaFlow BPM suite allows thus for a high degree of flexibility during process execution. It provides a complete set of high-level change patterns for defining ad-hoc deviations. Users may dynamically add new activities or jump forward in the flow of control.

7 CONCLUSIONS AND FUTURE WORK

We provided in this paper a framework for guiding users to choose the most appropriate BPMSs and paradigms that fit best their needs on flexibility. In this sense, it can be used to help practitioners (i.e. process analysts, designers, engineers and users) and academics to select the BPMSs and paradigms according to their BP flexibility needs.

The proposed approach included the use of a questionnaire for BPMS providers, the classification of these BPMSs according to a flexibility taxonomy, as well as the BPFlexGuide tool that could suggest matches between flexibility needs of a process and the most suited BPMSs. We validated our approach by choosing the EC process. The reason for choosing this kind of BP is in fact due to its important need of flexibility.

The obtained results from our BPFlexGuide tool for this case study indicated that the constraint based paradigm is the most adequate modeling paradigm, and the recommended BPMS was the AristaFlow BPM suite. Consequently, we modeled the EC process with AristaFlow BPM suite BPMS. We consider that the obtained model offers in fact a high degree of flexibility.

We can conclude that these evaluation results are then promising. The advantages of such an approach consist in providing better quality models and more precisely models enabling flexibility. Although validation of our approach was achieved by using a flexible emergency care process, we intend to apply it to other BPs and organizations with different flexibility needs. Examples include, for instance, organizations from the engineering and industry fields or higher education domains. These may imply including other flexibility needs that are not covered by the BP flexibility taxonomy that we adopted in this proposal.

Many issues are still open and can be subject of future work. First, we are planning to generalize the use of the BPFlexGuide tool also to BPMS providers, in order to allow them to fully characterize their BPMSs through the use of the tool. Integrating other dimensions into the provided process guidance is technically possible. Besides, it would be more adequate to accept intermediate values between 0 and 1. This could be ameliorated using fuzzy logic. The challenges here include not to overload BPMS providers and users with flexibility criteria, and also to score BPMSs according to different BP flexibility taxonomies. Moreover, we plan to propose a post-validation approach for the BPMS recommended by our BPFlexGuide tool. This will imply measuring the flexibility of BPs modeled and executed in that recommended BPMS, by counting the number of changes that a user needs to perform in those processes (using that BPMS) to achieve the desired flexibility.

REFERENCES

Barba, I., Weber, B., Del Valle, C., and Jiménez-Ramírez, A. (2013). User recommendations for the optimized execution of business processes. *Data & Knowledge Engineering*, 86:61–84.

Cingil, I., Ozturan, M., and Erdem, A. S. (2012). A decision support system for evaluation of business process management systems. *International Information Institute (Tokyo). Information*, 15(2):537.

Conforti, R., de Leoni, M., La Rosa, M., van der Aalst, W. M., and ter Hofstede, A. H. (2015). A recommendation system for predicting risks across multiple business process instances. *Decision Support Systems*, 69:1–19.

Günther, C. W. and Rozinat, A. (2012). Disco: Discover your processes. *BPM (Demos)*, 940:40–44.

Huang, Z., Lu, X., and Duan, H. (2012). Using recommendation to support adaptive clinical pathways. *Journal of medical systems*, 36(3):1849–1860.

Kirchner, K., Herzberg, N., Rogge-Solti, A., and Weske, M. (2013). Embedding conformance checking in a process intelligence system in hospital environments. In *Process Support and Knowledge Representation in Health Care*, pages 126–139. Springer.

Koschmider, A., Hornung, T., and Oberweis, A. (2011). Recommendation-based editor for business process modeling. *Data & Knowledge Engineering*, 70(6):483–503.

Lenz, R. and Reichert, M. (2007). It support for healthcare processes–premises, challenges, perspectives. *Data & Knowledge Engineering*, 61(1):39–58.

Mendling, J., Reijers, H. A., and van der Aalst, W. M. (2010). Seven process modeling guidelines (7pmg). *Information and Software Technology*, 52(2):127–136.

Mertens, S., Gailly, F., and Poels, G. (2014). Generating business process recommendations with a population-based meta-heuristic. In *Business Process Management Workshops*, pages 516–528. Springer.

Pesic, M. (2008). *Constraint-based workflow management systems: shifting control to users*. PhD thesis, Technische Universiteit Eindhoven.

Raj Kumar, R. V. (2012). Classification algorithms for data mining: A survey. *International Journal of Innovations in Engineering and Technology (IJIET)*.

Regev, G., Soffer, P., and Schmidt, R. (2006). Taxonomy of flexibility in business processes. In *BPMDS*.

Schonenberg, H., Weber, B., Van Dongen, B., and Van der Aalst, W. (2008). Supporting flexible processes through recommendations based on history. In *Business process management*, pages 51–66. Springer.

Setiawan, M. A., Sadiq, S., and Kirkman, R. (2011). Facilitating business process improvement through personalized recommendation. In *Business Information Systems*, pages 136–147. Springer.

Sun, X., Liu, X.-Z., Jiao, W.-P., Huang, G., and Mei, H. (2006). A rule-based approach to supporting adaptable web service composition. *CHINESE JOURNAL OF COMPUTERS-CHINESE EDITION-*, 29(7):1084.

Thomas, K., Oliver, M., Jens, P., Maximilian, R., vom Brocke, J., Schmiedel, T., Recker, J., Trkman, P., Mertens, W., and Viaene, S. (2014). Ten principles of good business process management. *Business Process Management Journal*, 20(4):530–548.

Van der Aalst, W. M., Weske, M., and Grünbauer, D. (2005). Case handling: a new paradigm for business process support. *Data & Knowledge Engineering*, 53(2):129–162.

Verbeek, H., Buijs, J. C., Van Dongen, B. F., and Van Der Aalst, W. M. (2010a). Xes, xesame, and prom 6. In *Information Systems Evolution*, pages 60–75. Springer.

Verbeek, H. M. W., Buijs, J. C. A. M., van Dongen, B. F., and van der Aalst, W. M. P. (2010b). Prom 6: The process mining toolkit. In *Proc. of BPM Demonstration Track 2010*, volume 615, pages 34–39. CEUR-WS.org.

Yao, W. and Kumar, A. (2013). Conflexflow: Integrating flexible clinical pathways into clinical decision support systems using context and rules. *Decision Support Systems*, 55(2):499–515.