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Evaluation of process modeling paradigms enabling flexibility

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Abstract

Many process modeling paradigms enabling flexibility have been proposed over the last decades, creating a demand for theory to assist in the comparison and evaluation of these paradigms. This paper comparatively assesses four popular process modeling paradigms in order to provide insights on the extent of flexibility they provide. Our study also reveals and compares flexibility in eight Business Process Management Systems (BPMS), based on a questionnaire proposed to senior researchers and developers of these systems.

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Keywords: comparative study ; process modeling paradigms ; questionnaire ; flexibility ; BPMS

1. Introduction

Flexibility is important, because continuously changing conditions force organizations to rapidly and flexibly adapt their processes. Flexibility is defined as a key consideration of effective processes. It is their ability to deal with both foreseen and unforeseen changes in the context or environment in which they operate [1].
Thus the real challenge for business process models consists in providing information systems with adequate information to deal with the often conflicting requirements of flexibility.

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To overcome the limitations caused by traditional and rigid business process modeling and execution approaches, several alternative paradigms have emerged. The most popular ones are the rule-based, constraint based, case handling and adaptive process modeling.

In this paper we deal with these four paradigms. We aim at comparing them using the taxonomy of flexibility in business processes proposed by Regev et al. in [2]. Here, the authors define business process flexibility as the capability of implementing changes in a business process model and/or instances by changing only those parts that need to be changed, while keeping other parts stable.

The aim of this paper is, therefore, to shed some light over the following challenges:

- Compare existing BPMS regarding flexibility. This includes weighting the different flexibility criteria.
- Measure the ability of existing business process modeling paradigms to deal with flexibility.

The remainder of this chapter is structured as follows: Section 2 includes an introduction to flexibility in Business Process Management (BPM), a summary on Regev et al.'s taxonomy and modelling paradigms, as well as related work regarding reviews on flexibility. In Section 3, we present the questionnaire provided to the selected BPMS's senior researchers and developers, and their flexibility scores against Regev et al.'s taxonomy. Based on this taxonomy, we also performed in section 4 a comparison between four alternative process modeling paradigms. We conclude with a summary and outlook on future work.

2. An overview on flexibility in BPM

This section deals with the importance of flexibility in BPM, the taxonomy of Regev et al., the modelling paradigms which enable flexibility and related work on these subjects.

2.1. Flexibility in BPM

The field of BPM has gained the attention of organizations. BPM includes methods, techniques, and tools to support the design, enactment, management, and analysis of operational business processes [4].

Flexibility has also been following the evolution of BPM, especially because of its ability to adapt business processes to predicted and unpredicted real-world changing scenarios. Therefore, it allows reducing the gap between process models and instances digitally registered among BPMSs, and what is happening in the real world, during the execution of a business process. Several flexibility taxonomies have been proposed, including the ones by Schonenberg et al. [1], Regev et al. [2] and Nurcan et al. [5].

In this paper, we will mainly refer to the flexibility taxonomy proposed by Regev et al. [2], which is summarized in the next section.

2.2. Taxonomy of Regev et al.

Regev et al. presented in [2] a taxonomy of flexibility in business processes. It includes three orthogonal (combinable) dimensions:

- the *abstraction level of change*, which refers to changes that can occur at the process type/model or instance levels, or both;
- the *subject of change*, which concerns the various elements of a process that can be changed (essentially, these include sub-processes, activities, data in-puts and outputs, decision, fork and join control-flow elements, resources and tools/systems that support the execution of a process);
- the *properties of change*, which includes extent, duration, swiftness and anticipation of change. Extent of change refers to the amount of change realized, either being applied to an existing process model (incremental change), or abolishing it and creating a completely new one. Duration of change refers to how long a certain change will last: temporarily (only lasts for a period of time), or permanent (lasts until the next change). Swiftness of change reflects the choice between an immediate propagation of change over the existing process instances (including the running ones), or a deferred propagation affecting only new instances of the changed process. The anticipation of change refers to planned, previously modelled and expected changes, or ad-hoc, unforeseen ones.

In this paper, we adopt this taxonomy since it provides a means for classifying flexibility with respect to the types of changes it foresees. We find it also generic enough to allow us to define the flexibility criteria we will use to analyze and compare the selected BPMSs.

2.3. Process modeling paradigms

Literature provides various process modeling paradigms that we classify into: constraint-based, rule-based, case handling and adaptive process modeling paradigms. Each category has its underlying approach that may be examined in terms of its appropriateness to flexible process modeling and execution.

The *constraint-based paradigm* focuses on constraints as rules that have to be followed during the process execution. Possible executions of constraint-based process models are specified implicitly as all executions that satisfy the model constraints. This makes unnecessary to explicitly predict and model all possible execution paths in advance, which proves to be helpful for certain domains [6].

The main concept in the *case handling paradigm i*s the case, and not process activities or paths. The case is the ‘‘product’’ which is manufactured, and at any time workers should be aware of this context. Case handling is a paradigm for supporting flexible and knowledge-intensive processes by strongly integrating them with data [7].

A paradigm is called *rule-based* if the logic of its control flow, data flow and resource allocation is declaratively expressed by means of business rules. Business rules are recognized as powerful representation forms that can potentially define the semantics of business process models and business vocabulary [8].

The *adaptive process management* paradigm can be seen as an evolutionary technique, solidly based on traditional workflow, while extending it with features to dynamically and safely adapt the process definition at any point in time [9].

2.4. Related work

Evaluation of flexibility in the business process domain has a rich research background. Günther et al. focus on the adaptive process management and case handling paradigms. The authors compare both approaches with respect to their strong and weak points [9].

In [10], the authors considered a number of software tools and examined their suitability for BPM. The tools have been evaluated on their modelling capabilities, simulation capabilities and possibilities for output analysis. In [11], the research work investigates to which degree current case handling systems (FLOWer and Activity Manager) are able to support Product Based Workflow Design. This method takes a static description of an (information) product as a starting point to derive an improved process design. In [12], the authors present a critical analysis of a number of existing process-oriented approaches by discussing their efficiency against the knowledge-intensive processes requirements. In [13], the authors evaluated selected approaches and systems regarding their ability to deal with process changes. These authors consider different characteristics against which they compare BPM systems or tools or paradigms. In this paper, we are comparing eight BPMSs and eventually paradigms. These BPM systems and paradigms are evaluated on their flexibility using the taxonomy of Regev et al. In [23], Martinho et al. propose a framework to model controlled flexibility in software process models, based on the same taxonomy of Regev et al. presented in [2].

3. Questionnaire and selected BPMSs

We proposed the use of the Regev et al.’s taxonomy as the starting point for evaluating BPMSs. In this section, we present the questionnaire we used on BPMSs senior researchers and developers, the selected BPMSs and the flexibility criteria that we used in order to compare them.

3.1. Questionnaire: evaluation of flexibility in BPMSs

We have developed a questionnaire to evaluate flexibility in BPMSs from a practitioner point of view. The questionnaire, entitled “evaluation of flexibility in business process management systems”, contains five parts, namely: Information about the BPMS, Flexibility support (regarding the taxonomy of Regev et al.) : Abstraction level of change, Subjects of change and Properties of change and Application domains of the BPMS

The questionnaire was specifically designed to seek responses from the most senior personnel responsible for the development of the different BPMSs. It was sent to these experts of BPMSs. We have collected the responses of this questionnaire. These responses are presented in section 4.1.

3.2. A review of selected BPMS

In this section we present different BPMSs on which we got responses from our flexibility questionnaire. These BPMSs have a great impact in the business process management research area. Following is a brief description of each of these BPMSs.

DECLARE system provides a broad range of functionalities ranging from design, enactment and dynamic change to verification, discovery and recommendation [14]. It is based on the declarative process modeling language "declare" that combines a formal semantic grounded in Linear Temporal Logic (LTL) on finite traces [15]. It was first introduced by Pesic and Van der Aalst in [16].

ESProNa (Engine for Semantic Process Navigation) is a declarative business process modelling system. It uses constraints for representing inter-process dependencies and constraint propagation for finding which processes are executable in user selected scenarios or given ones [17].

JRules/JSolver is a business rule management system (BRMS). It enables business users and developers to manage business rules directly with various levels of implication, from limited review to complete control over the specification, creation, testing, and deployment of business rules [18].

Based on a conceptual framework for dynamic process changes, on novel process support functions, and on advanced implementation concepts, ADEPT2 enables the realization of adaptive process-aware information systems [19].

The PHILharmonicFlows framework (Process, Humans and Information Linkage for harmonic Business Flows) is a framework targeting on comprehensive support of object-aware processes. It comprises both modeling and runtime environment enabling full lifecycle support for object-aware processes [7].

Product and Production Process Modeling and Configuration (ProdProc) is a developed system in a research project in [20]. Constraint programming techniques were exploited in the development of ProdProc in order to guide the configuration of a product and its production process given the respective ProdProc model [20].

JBoss jBPM is a workflow management system that was considered for the purposes of the patterns-based evaluation [21].

FLOWer is a case-handling system developed by Pallas Athena in The Netherlands. It focuses on handling the case as a whole, and not only on the routing of activities. This routing is merely regarded as derivative [22].

3.3. The flexibility criteria

In this section we identify 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: Does the BPMS support changes to process models which will affect all new process instances?
- FC2: Does the BPMS support changes at the instance level, and that will only affect certain selected instances, in order to accommodate exceptional situations?
- FC3: To which extent does the BPMS modelers have to describe the process control flow?
- FC4: To which extent does the BPMS support descriptive modeling and execution of process activities?
- FC5: To which extent does the BPMS support descriptive modeling and execution of the preconditions of the activities?
- FC6: To which extent does the BPMS support descriptive modeling and execution of data/information exchanged between process activities?
- FC7: To which extent does the BPMS support descriptive modeling and execution of roles associated to process activities?

- 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's important to mention that all FCs have the same weight. We have specified for each FCs a scale in order to get consistent results.

4. Flexibility scores on the selected BPMSs

4.1. Determination of flexibility scores

We have collected the responses of the questionnaire for the different BPMSs. Table 1 contains these responses. These responses are presented using the scales that we have specified.

Table 1. Responses of the questionnaire for each BPMS.

	DECLARE	ESProNa	JRules/ JSolver	ADEPT 2	PHiharmonicFlows	PordProc	jBPM	FLOWer
FC1	0	0	1	1	1	1	1	1
FC2	1	1	1	1	1	0	1	1
FC3	2	3	4	4	2	2	5	1
FC4	5	3	4	5	3	4	5	2
FC5	2	4	3	3	5	4	3	2
FC6	2	3	1	5	5	3	5	2
FC7	2	3	2	5	4	3	3	2
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	2	2
FC11	1	2	1	2	1	0	2	1

From these scores, we can observe that ProdProc supports only changes caused by modifications of the process type/model, while ESProNa and DECLARE support changes only at the instance level. In ADEPT2, PHIharminicFlows, jBPM and JRules BPMSs, process changes can take place at both the type as well as the instance level. The ADEPT2 interviewee said "Our system is very flexible in this respect. It allows for changes of single instances (e.g. to deal with exceptions) as well as changes of a process model at the type level and the propagation of these changes to all of selected process instances of this type". According to the PHILharmonicFlows interviewee, "Changes in PHILharmonicFlows are less required compared to ADEPT2; instead PHILharmonicFlows inherently allows for more execution paths that may be flexibly chosen by users".

FLOWer supports changes at the instance level: according to the interviewee, "changes are till a certain level: only constraint and mapping changes are concerned". FLOWer supports also changes caused by the modification of the process type/model.

Regarding the subject of change, the ESPRoNa interviewee said when explaining the behavioral perspective : "In ESPRoNa only the default-path through a process model is modelled and the preconditions are modelled inside the process-perspectives, the user sometimes cannot see this when only looking/concentrating to the flow as it is implicit in that situation".

ADEPT2 offers powerful concepts for supporting the five perspectives which allow a comprehensive description of the business processes. It is the most scored BPMS, supporting all the subjects of change defined in the taxonomy of Regev et al..

In PHILharmonicFlows, the behavioral perspective (FC5) of the software system is represented in two different levels of granularity: micro and macro process types. Also, by modeling the object types and their relations, fundamental insights into information perspective (FC6) can be obtained using PHILharmonicFlows [26]. Additionally, the organizational perspective (FC7) of the software system is represented using user roles and types.

The functional (FC3) and operational (FC4) perspectives are well defined in JRules, unlike the informational (FC6) and organizational perspectives (FC7). For DECLARE, the major efforts have been put into the development and improvement of the description of the activities executed during the process (FC4).

ProdProc provides a basic support to the definition of the information which shall be exchanged between activities and to describe the different roles (FC6 and FC7), while the functional perspective is limited (FC3). In addition, models in ProdProc do not simply represent a single production process. Instead, it represents a configurable production process, whose configuration can lead to the definition of different executable processes (FC4) [22].

jBPM offers powerful concepts for supporting the operational (FC4), the behavioral (FC5) and informational (FC6) perspectives. It offers also an important definition for the organizational and functional perspectives. FLOWer provides a basic support for the five perspectives.

In JRules, the policy manager makes incremental changes (the extent property of change from Regev et al,'s taxonomy). The revolutionary change is identified by DECLARE, ESProNa and PHILharmonicFlows BPMS. Both the incremental and revolutionary changes are provided in ADEPT2, jBPM and FLOWer. In ProdProc, no specific support is provided for explicitly representing the extent of change (FC8).

Concerning the duration of change (FC9), the permanent change is supported by all evaluated BPMS. However, ADEPT2 allows also for temporary changes.

In the context of the swiftness of change (FC10), the deferred change is supported by all evaluated BPMS. However, ADEPT2, jBPM and FLOWer allow also for the immediate change. In fact, ADEPT2 is able to apply changes immediately to all family-related process models and instances, even the running ones (includes runtime migration strategies). According to the FLOWer interviewee, "for running processes only changes can be made to the mappings and the constraints of activities. New activities and processes cannot be altered".

For the anticipation of the change (FC11), in DECLAREe, FLOWer, JRules and PHILharminicFlows BPMSs, explicit support for planned changes is provided. Nevertheless, to deal with exceptions BPMSs must support unplanned changes.

We calculated then the Flexibility Score (FS) for the different BPMSs (Table 2). To do that, we sum the different FC scores, taking into account the presented scales. FS is then calculated as follows:

$$FS = FC1 + FC2 + FC3/5 + FC4/5 + FC5/5 + FC6/5 + FC7/2 + FC8/2 + FC9/2 + FC10/2 \quad (1)$$

Table 2. Calculated FS for the different BPMSs.

BPMS	Calculated FS
DECLARE	5,6
ESProNa	6,7
JRules/JSolver	6,8
ADEPT 2 / AristaFlow BPM Suite	9,9
PHILharminicFlows	7,8
ProdProc	5
jBPM	9,7
PPM	6,8

The results in Table 2 show the perceived flexibility support for each of the BPMSs analyzed, and the corresponding total coverage of Regev et al.'s taxonomy on flexibility.

4.2. Classification of the BPMSs according to the modeling paradigms

According to the questionnaire's results, Table 3 summarizes the answers to the following question: "What is (are) your BPMS's underlying modelling/execution paradigm(s)?"

Table 3. BPMS classification.

Paradigm / BPMS	Constraint based	Rule based	Case handling	Adaptive Process Support	TOTAL
DECLARE	✔	✔			**2**
ESProNa	✔				**1**
JRules/JSolver	✔	✔			**2**
ADEPT 2				✔	**1**
PHILharminic-Flows			✔		**1**
ProdProc	✔				**1**
jBPM		✔			**1**
FLOWer	✔		✔		**2**
TOTAL	**5**	**3**	**2**	**1**	

From Table 3 results, we can conclude that, from the selected BPMSs, most of them support constraint-based modeling (5 out of 8), while also 5 out of 8 are mono-paradigm oriented. We can also observe that 2 out of 3 multi-paradigm systems com-bine the constraint- and rule-based paradigms.

4.3. Paradigms' flexibility measured score

Having presented the Flexibility Score (FS) for each of the selected BPMSs (Table 3), as well as their classification on the modeling paradigms, we now propose a combined score that correlates these two, using the following formula (weighted average):

PFMS of (paradigm) = SUM (Calculated FS of each BPMS that support the paradigm) / (sum of the BPMS that support the paradigm) (1)

Table 4. Paradigms' flexibility measured score.

Paradigm	PFMS
Constraint-based	6,18
Rule-based	7,36
Case handling	7,30
Adaptive Process Support	9,9

Table 4's results allow us to conclude that, regarding the selected BPMSs, the constraint-based modeling paradigm is the one that shows the least flexibility support regarding Regev et al.'s taxonomy. On the other hand, the adaptive process support paradigm scores higher, mainly because ADEPT2 was the only selected BPMS sup-porting this paradigm, and providing the most complete coverage on flexibility.

Nevertheless, our aim is to provide a useful combination of flexibility scores (per BPMS and per BPMS/paradigm), in order to help process engineers deciding on the most suitable BPMS, given a set of alternatives, their flexibility scores and underlying paradigms. It also allows us to derive, from a given set of most referenced BPMSs, what is the current trend regarding flexibility support per modeling paradigm. For instance, we can observe that, from the set of selected BPMSs, rule-based and case-handling systems present, in average, a better score on flexibility than constraint-based ones.

5. Conclusion and future work

This paper has presented the result of a critical and comprehensive analysis of four prominent process modeling paradigms, with focus on flexibility. We used a questionnaire to capture the perceived BPMSs' strengths and weaknesses in terms of flexibility, from their own researchers and developers. The BPMSs were selected because of their frequent usage and reference in the BPM research area.

Calculated flexibility scores rank these selected BPMSs according to Regev et al. taxonomy on flexibility, as well as their flexibility correlated with the underlying process modeling paradigm(s).

In future work, and based on this study results and derived flexibility scores, we will develop a framework to provide a guidance method for process engineers to choose the most appropriate modeling paradigm for their business processes, as well as the most suitable BPMS to support those processes.

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