Research challenges in Business Process Adaptability

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ABSTRACT

Modern software systems are more and more deployed within moving and continuously changing contexts. It is not easy to consider all the possible contexts configurations/variances at priori, or it is quite cumbersome and error prone to list and program all this variability points at development time. For such a reason different research trends try to develop mechanisms to express, analyse and support the dynamic adaptation of a software system while it is running.

Business Processes show today similar characteristics. In order to keep their competitiveness and quality for products and services, organizations need to be able to adapt to changing contexts. Changes have to be reflected in the software systems supporting the corresponding organizational activities.

In this paper we report the results of a systematic literature review on Business Process Adaptation. The reviewing process lead us to consider 84 papers from the main digital libraries indexing computer science conferences and journals. From the reading and the systematic analysis of these papers we derived some research trends and challenges which have been considered relevant to be able to cover the main sources of adaptation in the definition of effective Business Processes.

Keywords

Business Process, Adaptability, Systematic Litterature Review

1. INTRODUCTION

Within the software development community terms like flexibility, adaptability and variability all indicate the need to derive software systems which are not static, and that instead embed mechanisms permitting to react to changes occurring in the running environments, or which make easier the definition of strategies able to provide solutions in different contexts [1].

This trend is today perceived by complex organizations which more and more operate in quickly changing markets, and then need to adapt in order to provide high quality products and services to their customers. Within an organization a first step toward flexibility is the possibility to explicitly abstract and represent, via some formal or semi-formal notation, its internal and external Business Processes (BPs).

A BP defines how an organization as a whole structures its activities in order to reach its objectives. The explicit representation of BP, for instance using BPMN 2.0 [7], and the adoption of BP management systems is certainly a first step toward an increased consciousness of the organization activities, and will certainly permit to improve its reactivity to possible changes. Modeling approaches permits to model an organization as a composition of cooperating components similarly to what is typically done for software systems.

This paper reports the results of a Systematic Literature Review (SRL) complemented by a manual search on not indexed scientific events. The objective is to try to organize this wide knowledge base in order to identify the research challenges that the community should target, with respect to the subject of BP Adaptability. The survey has been conducted applying a rigorous approach as described in the following sections. In particular, Section 2 reports related literature in the area of BP management and adaptability, whereas Section 3 describes the methodology and the organization of the survey we conducted. Then Section 4 reports and discusses the results we obtained, and finally Section 5 draws some conclusion and opportunities for future works.

2. BACKGROUND

Business Process Management - A BP is a collection of related and structured activities undertaken by one or more organizations in order to pursue some particular goal. Within an organization a BP results in the provisioning of services or in the production of goods for internal or external stakeholders. Moreover BPs are often interrelated since the execution of a BP often results in the activation of related BPs within the same or other organizations [11]. Starting from a BP, its instance represents a concrete case in the operational business of an organization, consisting of activity instances [25].

Business Process Management (BPM) has been presented as a key factor to guarantee the success of Information and Technology infrastructure permitting to align organizational
strategies and business objectives. The BP life-cycle, is constituted by many different phases as illustrated in [23, 25]. In general we can distinguish among the design/modeling phase, the analysis phase, the enactment/execution phase, and the monitoring/improvement phase. For what concerns the design/modeling phase different classes of languages have been taken into account. These are related to the level of rigor, going from graphical models (i.e. BPMN 2.0 [7] and Event-Driven Process Chains [13]), with a precise syntax and with a semantics given in natural language, to mathematical models (i.e. Yet Another Work-flow Language [22]) for which the semantics is provided thanks to well founded mathematical theories [24]. BP analysis is deeply linked with the design phase and can be carried on via informal (i.e. workshops or focus group) and/or formal approaches (i.e. model checking). The enactment and execution phases require system support with reference to specific type of information systems which allows for the separation of process logic and application code (i.e. Service Oriented Architecture [4]). Finally, the monitoring and control phase imply the collection of measures for executed BP instances in term of functional and non-functional parameters. This techniques can also give the possibility to apply BP mining techniques [19].

**Business Process Adaptation** - Among the key business success factors we can find the need for effective BPs modeling, and BP instance generation able to accommodate to changes in the environment in which they operate. For example, new laws, new business strategy, or adoption of emerging technologies [20]. Different terms are typically used to describe adaptation when it affects the BP. Among the other we refer to the following taxonomy that use the term flexibility as a synonymous for adaptability [16].

- **Flexibility by Design.** It is the ability to incorporate alternatives execution path at design-time.
- **Flexibility by Deviation.** It is the ability for a BP instance to deviate at run-time from the prescribed execution path.
- **Flexibility by Underspecification.** It is the ability to execute an incomplete BP specification at run-time.
- **Flexibility by Change.** It is the ability to modify a BP definition at run-time such that one or all of currently execution BP instances are migrated to a new BP.

We can also classify adaptation according to the phase of the BPM life-cycle in which it occurs [17]. Therefore we can have: (i) adaptation by design is possible during design/modeling phase before the BP execution; (ii) adaptation by deviation and by underspecification is possible during the enactment/execution phase. In the latter case adaptation affects active instances of BP. Of course the intersection is not empty and adaptation by change can refer to more than one phase.

Such different type of adaptability can occur due to internal (i.e. changing strategic goal the BP has to be reviewed, or errors/exceptions in the IT supporting system have to be considered) or external issues (i.e. changing in law or observed events from other IT system) [21]. Finally, we can observe (i) momentary changes that impact only on process instances (i.e. in case of emergency BP perform dedicated tasks); and (ii) evolutionary changes that impact on the BP model (i.e. new business strategy) and the constraints/rules that the model must satisfy (i.e. change in law).

### 3. METHODOLOGY

**Research Method Overview.** To conduct our study and derive the reported results we applied the instructions for Systematic Literature Review in the domain of Software Engineering suggested in [8]. The approach relies on the following three steps.

1. **Planning the SLR.** We collected the need for the review starting from the requirements of the review we were conducting, this requires to identify the sources of studies, the inclusion and/or exclusion criteria and the keywords to extract data from the papers. According to the needs we defined research questions and strategies for data extraction and synthesis. The development of the review protocol is also part of the planning.

2. **Conducting the SLR.** Starting from the defined search strategies we run the SLR using the identified knowledge sources. This activity permits to identify and select the studies that provide direct evidence of a correlation with the specified research questions. Then information needed to address the research questions are collected through the careful reading and evaluation of the papers content. Finally, collected data are synthesized to derive some general insight on the topic and the formulated results are graphically shown.

3. **Reporting the SLR.** As soon as collection and synthesis of data are completed, it is important to effectively communicate the results illustrating how the various steps have been characterized.

**Planning SLR in Business Process Adaptability.** The need of this SLR arises from the need of researchers to summarize all existing information about BP adaptation. Researchers on this area need to understand why, where and how BPs have to be adapted. Up to now no SLR has been published yet, with respect to the topic under analysis. To do that we evaluated only primary studies published in this area (i.e. survey papers have not been included in our work).

**Research Questions.** In order to conduct the SLR and according to the mentioned objectives we tried to identify the research questions which could be more relevant for the interested reader. The result of this activity is summarized in the five research questions shown in Table 1. Questions are related to the discovery of why, where and how BP adaptation is needed. Questions are also formulated to identify
which phases of the BPM life-cycle have been affected by the adaptation, and at the same time what are the needs rising from adaptation that affect the BPM life-cycle. We were also looking for existing BP adaptation approaches, techniques and tools as well as real case studies to understand the benefits of the adaptation in practice.

**Review Protocol.** We implemented our review protocol according to Kichenham’s indications [8]. At first 70 papers were identified and selected through the automatic search in digital libraries. Successively we refined the result through a manual search in conferences proceedings and journal which in some case where not indexed in the digital library. This activity permitted to identify 14 additional papers. Finally, we analysed the related works and reference section of the selected papers. This step permits on one side to add papers to the already identified set and on the other side, most importantly, permit to assess if the search activity produced reliable results. In case this step would lead to the identification of many papers missing in the already defined set, the revision of the search criteria would have been necessary. In our case this step did not highlighted the need to include further relevant papers. Therefore the execution of the review protocol resulted in the identification of 84 papers. Successively for each paper included in the set we applied the inclusion and exclusion criteria listed in Table 3.

An important aspect of any SLR work refers to the identification of the information sources used to automatically identify relevant papers. In our work we choose to include the most used digital libraries in computer science. Then a search was performed on each of them using a complex search string adapted according to the specific syntax and interaction mechanisms of each digital library. Table 2 reports, using an intuitive text based syntax, the selection criteria we formulated to retrieve relevant papers. In summary, the query we formulated should permit to retrieve those papers which contain a word related to BP in the title and mention some kind of adaptation in the abstract.

The digital libraries we used are: IEEExplore\(^1\), ACM Digital Library\(^2\), Citeseerx Library\(^3\), ScienceDirect\(^4\), Springer\(^5\) and ISI Thompson Web Of Science\(^6\).

### 4. RESULTS

In this section we report and discuss the results of the SLR according to the defined planning and review protocol. Results are represented using histograms to make them more readable.

Table 4 shows the temporal distribution of the papers within the years 2000 and 2013 classified also on the base of the publication types, which can be workshop, conference and journal. It is worthy to note that only 25% of the papers have been published in journals, and that 49% of the total was published in the last 4 years (from 2010 to 2013). Figure 1 presents a visual summary of these results, considering the total of publication by year, regardless the publication type. Our query seems to testify that the topic has received increasing interest up to 2011 while in the 2012 the interest seems to be decreased, even if this datum could be influenced by the delay in the updating process of the digital libraries, which could need up to a couple of year to stabilize. Clearly the datum for the current year (2013) cannot be considered relevant to highlight a trend.

**Q.1 - What raises the need for adaptation within the BP domain?**

\(^1\)http://ieeexplore.ieee.org

\(^2\)http://dl.acm.org

\(^3\)http://citeseerx.ist.psu.edu

\(^4\)http://www.sciencedirect.com

\(^5\)http://link.springer.com

\(^6\)http://thomsonreuters.com/web-of-science
According to the histogram presented in Figure 2 the data extraction and synthesis process found that only 43% of the papers (36) explicitly refers to the needs for BP adaptation.

Results show that in most of the cases BPs have to be adapted due to external environment changes (45%, 16 papers). This is something that happens outside the competence of the organizations involved in BP execution, for example because of a change in the law. Just to cite a few of them, relevant examples are the papers presented in [6], [10] and [14]. Some papers (17%, 6 papers) talk about internal environment changes affecting the structure of involved organization. Many papers show that exceptions due to an external or internal environment changes are the main reasons for adapting a BP (36%, 13 papers). Finally, some papers provide other possible reasons such as the change of strategic goals (8%, 3 papers), and the change in the approach to reach the goal (6%, 2 papers). Of course, most of the papers report more than one motivation for BP adaptation.

Q.2 - Which phases of the BPM life cycle requires support for adaptation?

The results shown in Figure 3 illustrate that 58% of the papers (49) relate adaptation to the BPM life-cycle.

Data extraction and synthesis found a particular interest of researchers in the enactment/execution phase where run-time adaptation techniques are proposed and applied (69%, 34 papers). Just to cite a few, relevant examples are the works presented in [2], [15] and [5]. Also modeling adaptable BPs is clearly an hot topic (43%, 21 papers). Authors contribute to extend traditional design techniques and modeling languages in order to introduce new elements to directly address adaptable issues. As well as these elements are introduced and used at design-time, they can be directly observed at run-time. Some papers (16%, 8 papers) address adaptation issues regarding the analysis of BP. In the most of the papers analysis is done as soon as adaptation is completed and it can affect both the BP model and the corresponding instances. Formal techniques of analysis are the most used in practice. There are also papers facing more than one BPM life-cycle phase; most of them (18%, 9 papers) impact both the design/modeling phase, as well as the enactment/execution phase. Generally, in these contributions it is suggested to model the BPs and some adaptation patterns that can be introduced at run-time, as soon as specific events are observed. The patterns guarantee enactment/execution correctness. Finally, the monitoring (10%, 5 papers) phase is not so much investigated and in most of the cases it is an add-on of the enactment/execution phase.

Q.3 - Which are the instruments used to express and support BP adaptation?

According to the data presented in Figure 4 data extraction and synthesis found that 81% of the papers (68) explicitly describe instruments for BPs adaptation. The term instrument here refers both to languages, approaches and tools.

Modeling languages are investigated, and in some cases extended to allow adaptation in the 28% of the considered papers (19). Just to cite a few, relevant examples are the works presented in [26], [9] and [18]. Going into detail of the different modeling languages we can refer to the Figure 5 that categorizes papers in accordance to the classification proposed in [24]. We refer to: (i) graphical models (37%, 7 papers) involving models sketching a BP using a visual diagram, they are the most used in the design phase of adaptive BPs; (ii) mathematical models (42%, 8 papers) corresponds to models in which all the elements have a mathematical or a formal underpinning, it is generally used to analyse adaptive BP during the analysis phase to verify some properties or evaluate processes performance; and (iii) script based models (21%, 4 papers) contains software-based languages supporting BP modeling and most of the time process execution with reference to adaptation.

Many papers explain that rules (called also protocol or constraint) can be used in order to derive a new version of BP (21%, 14 papers). We could introduce rules in the previous classification, but we prefer to take it out due to...
the ability of rules to be applied both at design/modeling, and execution/enactment phase.

If we consider the proposed techniques, few papers suggest to directly modify BP models manually editing it, and inserting or deleting tasks (10%, 7 papers). It is worth mentioning that in some case this is done using patterns (9%, 6 papers). Other approaches suggest to use features models and process families (9%, 6 papers). Some papers consider adaptability as just the capability of a BP to manage events (9%, 6 papers).

Less used instruments, that are not reported in Figure 4 to not overload the diagram, are: declarative modeling (7%, 5 papers), adaptation algorithms (7%, 5 papers), case-based reasoning (3%, 2 papers), meta-models for adaptation (1%, 1 paper), modularity approach (1%, 1 paper), functional programming (1%, 1 paper), and common variability languages (1%, 1 paper).

**Figure 4: Main Instruments for Adaptation (Q.3)**

**Q.4 - Are there any real experiences of BP adaptation?**

Considering the data extracted to answer Q.4 we observe that there is a general lack of real experiences on BP adaptation reported in the paper. Most of the case studies discussed in the papers are only toy examples and they do not represent real scenarios. Indeed we could identify just 3 real scenarios with respect to adaptability.

Among the most significant cases we can cite the car logistic scenario [2]. This refers to the case of the seaport of Bremen (Germany) where many vehicles need to be delivered from the manufacturer to the dealer. There are several variables and cases bringing adaptation that must be considered in this scenario. For instance in case a car is damaged during the travel it has to be repaired before delivering it.

Another interesting case is the warehouse management scenario [12]. It explains that organization, control storage and movement of goods in a warehouse is not an easy task, and these activities can be improved thanks to dynamic workflows instantiations.

Finally, the clinical scenario is shown in [3]. The authors explain that adaptation in clinical BP must not be restricted because many unexpected events can be observed. This implies users can adapt BPs during execution.

**Q.5 - What are the challenges associated with the BP adaptation?**

Applying this research question to the set of studies enabled us to comprehend the current direction within the BP adaptability field, and to provide a classification of interesting major issues which need to be further investigated. These problems represent challenges raised by academics and potential research opportunities.

- **Dynamic languages for BP modeling.** Current languages for BP modeling do not support adaptation constructs, so in most of the cases they need to be extended. This is a solution addressed by many papers, but the real challenge is to create a reference conceptual model for adaptable BP modeling so that run-time techniques can be easily defined and applied.

- **Adaptation BP running instances.** In many cases it is necessary to adapt a running BP instance. Many works propose to deviate the path of activities inserting, skipping, deleting and undoing tasks. It can be considered a good practice but, they do not consider that in critical BPs in many cases undoing a task is impossible. For example it is not possible to reverse the effects of sending a mail. What to do in such situations is not clear from the SLR, and it seems that further investigation are needed.

- **Verification of adapted BPs.** Adapted BPs must still be structurally and semantically correct. To do that many approaches have been proposed which generally foresee mapping to well-founded notations where verification algorithms can be applied. Nevertheless a related challenge refer to the possibility of efficiently verifying many adapted BP instances while the process is already running. We believe worthy to investigate techniques mixing monitoring and on-the-fly verification approaches. With respect to semantic correctness we envisage greater challenges since there is not an easy way to represent the semantic/objectives of a BP and to relate them with the activities performed by an adapted BP.

- **Evolving BPs.** When most of the running BP instances are adapted in the same way probably the BP needs to be evolved. So, a new version of BP has to be instantiated. Techniques to understand the boundary between adaptation or the need for evolution of a BP, seem to be an interesting topic to explore.

**5. CONCLUSIONS AND FUTURE WORK**

In this paper we reported the results we got from a SLR on the subject of BP adaptability. The survey has been conducted considering all the major digital libraries typically used within the computer science domain. The results show that the topic has received increasing attention from the community, nevertheless some research lines seems to be worthy to be further investigated. Remarkably we witnessed a general lack of application of research results to real
scenarios. At the same time we identified some challenges, which are not satisfactorily handled by proposed solutions. In the future we intend to extend the SLR monitoring a wider set of study enlarging the search string. Furthermore we intend to further refine the results we got from research question 5 trying to get more opinions from researchers and practitioners working on the subject.

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6. REFERENCES