A Multi-criteria Evaluation Framework for Selecting Sensitive Business Processes Modeling Formalism

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Keywords: Knowledge Management, Sensitive Business Process, Business Process Modeling, Business Process Meta-model.

Abstract: Sensitive business process (SBP) modeling has become primary concern for any successful organization to improve the management of their individual and collective crucial knowledge on which it is necessary to capitalize. This paper presents a multi-perspective evaluation framework for assessing the expressiveness of current widely used BPM formalisms, in order to select the most suitable for the SBP representation and improve the identification of crucial knowledge that is mobilized by these processes. Furthermore, the result of the evaluation led us to justify the choice of the better one positioned nowadays, the standard BPMN 2.0. Besides, we have illustrated the practical applicability of this notation on a medical process in the context of the association of protection of the motor disabled people of Sfax-Tunisia (ASHMS).

1 INTRODUCTION

Today's organizations has been characterized by collaborative, highly dynamic, complex and knowledge-intensive actions. In order to improve competitive advantage, they have been increasingly conscious of the necessity to formalize and capitalize knowledge produced and mobilized by their business processes (BPs). According to this view, business process modeling (BPM) has become crucial concern for successful organizations to improve the identification, acquisition, storage, dissemination, sharing, creation and (re) use of their individual and organizational knowledge.

Considering the large amount of knowledge to be preserved and enhanced, such organizations must first identify and model the SBPs which are likely to mobilize crucial knowledge on which it is necessary to capitalize. In fact, the more organization's BPs are sensitive, the more they can mobilize crucial knowledge. Few existing research on Knowledge Management (KM)-BPM focusing on the identification, analysis and modeling of SBPs in order to localize and identify the crucial knowledge. We quote: the Global Analysis METHodology (GAMETH) proposed by Grundstein (2000), the identifying crucial knowledge methodology (Saad et al., 2009) and the Sensitive Organization's Process Identification Methodology (Turki et al., 2014a). However, these methods do not explicitly and conveniently address the critical operation of « SBPs modeling ». A SBP typically lacks a description and a representation that allow to explicit the rich semantics embedded into a SBP. So, the specification of a precise conceptualization, with a subjacent representation notation, that explicitly and adequately integrate the knowledge dimension within their actions and other relevant SBP aspects, is still an open issue. In fact, a SBP has its own characteristics that distinguish them from classical BPs. In fact, a SBP commonly mobilizes a high number of critical activities with very specific knowledge « crucial knowledge» (tacit and explicit). It presents a diversity of knowledge sources and possesses a high degree of dynamism in the objectives' change and high complexity.

Some conventional graphical BPM formalisms, include, amongst others, Event Driven Process Chain (EPC) (Korheer and List, 2006), Business Process Modeling Notation (BPMN 2.0) (OMG, 2011a), Unified Modeling Language (UML 2.0) activity diagram (OMG, 2011b), Specification Language (PSL) (Schlenoff et al., 2000), Process Business Process Modeling Ontology (BPMO) (Cabral et al., 2009) and Role Activity Diagram (RAD) (Weidong and Weihui, 2008), have been adapted to allow the representation of the intrinsic

Ben Hassen M., Turki M. and Gargouri F.
A Multi-criteria Evaluation Framework for Selecting Sensitive Business Processes Modeling Formalism.
DOI: 10.5220/0006222500840097
In *Proceedings of the Sixth International Symposium on Business Modeling and Software Design (BMSD 2016)*, pages 84-97
ISBN: 978-989-758-190-8

elements of knowledge within BPs. But, these languages/notations do not include all the required features to describe a SBP. In addition, the literature shows a set of approaches dedicated to knowledge highly intensive processes (KIPs) representation, originate from the knowledge modeling context, including the Business Process Knowledge Method (BPKM) (Papavassiliou and Mentzas, 2003), DECOR (Abecker, 2001), CommonKADS (Schreiber et al., 2002), Knowledge Transfer Agent (KTA) Modeling Method (Strohmaier et al., 2007), PROMOTE (Woitsch and Karagiannis, 2005), the work of Donadel (Donadel, 2007), DCR Graphs (Hildebrandt and Mukkamala, 2010), Knowledge Modeling Description Language (KMDL 2.2) (Gronau et al., 2005) (Arbeitsbericht, 2009), GPO-WM (Heisig, 2006), Oliveira's methodology (Oliveira, 2009), and the Notation for Knowledge-Intensive Processes (NKIP) (Netto et al., 2013), etc. However, none of these proposals, as shown in (Ben Hassen et al., 2015a), adequately addresses all the relevant SBP elements.

In order to address existing limitations and improve the SBP representation, we proposed, in previous work (Ben Hassen et al., 2015a) (Ben Hassen et al., 2015b), the Business Process Meta-Model for Knowledge Identification (BPM4KI) BPM4KI comprises concepts from several perspectives that are crucial for a complete understanding, characterization and representation of a SBP, namely the functional perspective, the organizational perspective, the behavioral perspective, the informational perspective, the intentional perspective and the knowledge perspective. The generic meta-model we have developed is semantically rich and well founded on COOP, a core ontology of organization's processes proposed by Turki et al. (2014b) which is useful to characterize the concepts useful for the analysis and identification of SBPs. Furthermore, BPM4KI serves as a comprehensive evaluation framework of the expressiveness and adequacy of current widely-used BPM formalisms, to check their suitability to cover all the relevant elements of a SBP. Precisely, the (objective) evaluation facilitates selecting and justifying the most appropriate BPM formalism for the representation of SBP taking its semantic dimensions into account.

The overall goal of the present work is to carry out an evaluation of which BPM4KI elements are potentially supported by the above-mentioned language meta-models. Besides, it presents a practical example using the best evaluated formalism. Furthermore, it points alternatives for representing elements that not adequately addressed yet.

The remainder of the paper is structured as follows. Section 2 presents the core concepts that describe Sensitive Business Process and related work about modeling SBP. Section 3 presents the main characteristics of current formalisms for BPM, evaluates their suitability to support the representation of all relevant SBP elements. Section 4 presents a practical example. Section 5 concludes the paper and underlines some future research topics.

2 SENSITIVE BUSINESS PROCESSES

2.1 SBP Fundamentals

According to Ben Hassen et al. (2015b), a SBP represents the core process of organization which constitutes the heart of the organization's activities. It is commonly mobilizes very specific knowledge «crucial knowledge» (i.e. the most valuable/important knowledge on which it is necessary to capitalize). It includes a high number of critical activities which mobilizes and produces different types of knowledge: (i) imperfect individual and collective knowledge (tacit and/or explicit) (i.e. missing, poorly mastered, incomplete, uncertain, etc.) which are necessary for solving critical determining problems; (ii) a great amount of heterogeneous knowledge recorded on diverse knowledge sources (dispersed and sometimes lacking accessibility); (iii) expertise and/or rare knowledge held by a very small number of experts; flexible knowledge owned by experts; (iv) very important tacit organizational knowledge (like competences, abilities and practical experiences).

Moreover, it contains activities that valorize the acquisition, storage, dissemination, sharing, and creation and (re) use of individual and organizational (tacit and explicit) knowledge, in the sense that it mobilizes a large diversity of knowledge sources consigning a great amount of very important heterogeneous knowledge. Its execution involves a large number of business domains/competencies (in terms of internal and external organization unit/agents operating in the BP), having distinct experience and expertise levels. Furthermore, it include a high number of organizational collaborative activities that mobilize, exchange, share and generate new individual and collective knowledge that is created by dynamic conversion of existing ones in the process in order to achieve organizational objectives. So, it depends on

knowledge flows and transfer of data, information and knowledge objects between communicating process participants. Other typical characteristics of SBPs presented in Ben Hassen et al. (2015b) includes: (i) A SBP is unstructured or semi-structured. Yet, a flexible process typically contains a very dynamic and unpredictable control-flow, comprising complex activities (individual and /or collective) that may frequently change over time or at design-and run-time. The process agents (e.g. experts) is often not able to predetermine the overall process structure in terms of the activities to be executed and their ordering, the data and knowledge sources to be exploited and the roles and resources required for process progression and completion. (ii) It is driven by constraints and rules. Indeed, process participants may be influenced by or may have to comply with constraints and rules that drive organizational actions performance and decision making. (iii) It possesses a high degree of dynamism in the objectives' change associated to it, essentially, in decision making context. The change of organizational objective leads to a new organizational distal intention (which is necessary to control the SBP) and influences experts' decision making. (iv) Its contribution to reach strategic objectives of the organization is very important. Also, their realization duration and cost are important.

According to above mentioned, representing and organizing the knowledge involved in SBPs is very complex, especially when applying traditional approaches. However, it is difficult to find out an approach/formalism that addresses all or at least most of these characteristics in the representation of a SBP model. Nevertheless, the Object Management Group (OMG, 2011a) states that, in addition to underlining the concepts inherent to a domain, a notation enhances the clarity of the models and allows the ability of communicating the concepts uniformly. The selection and adoption of a suitable BPM formalism for representing SBP models is still an open issue, allowing the knowledge mobilized and generated by the BP instances to be located, identified, modeled, stored and reused. In this context, several BPM approaches and notations are found in literature as likely to represent SBP.

2.2 Related Work: SBP Modeling Approaches

Although there is abundance of BPM formalisms and despite their diversity, only a few were applicable for SBP modeling. Some traditional workflows/BPM formalisms that are widely-followed in current research and practice scenarios (such as BPMN, EPC, UML AD), have been adapted to allow the representation of the intrinsic elements of knowledge within BPs. However, they were not meant for SBPs, since they focus on the representation of "deterministic" process, composed by a well- structured control flow among its activities, low uncertainty and complexity (that is, the existence of few and pre-defined exceptions). Besides, these notations can be used to implicitly identify certain issues related to knowledge flows, such as the information sources that are required, generated, or modified by an activity.

Moreover, some authors have attempted to develop approaches for the representation of processes with high knowledge intensity (KIP) (Gronau et al., 2005) (called also Process-oriented knowledge modeling approaches) where basic phenomenon is knowledge. In these processes, the principal success factor is adequate modeling of knowledge conversions. It is noteworthy that SBP shares many common characteristics with KIP approaches. In fact, KIPs are processes whose conduct and execution are heavily dependent on knowledge workers performing various interconnected knowledge intensive decision making tasks. KIPs are genuinely knowledge, information and data centric and require substantial flexibility at design- and run-time. These approaches that focus on KM within the BP level have not been widely adopted by organizations and are still very incipient. Also, they have limited capabilities, in the sense that they do not conveniently include process perspective, as well as they do not provide an opportunity to clearly distinguish between data, information and knowledge.

The CommonKADS (Schreiber et al., 2002) approach focuses on knowledge representation. Various stages of modeling attempt to establish a structured approach so that knowledge can be managed with the support of technical and engineering tools. Three basic points characterize these demands: the details of the skills involved in process execution, the representation of the processes through artifacts and semantic analysis, and the opportunities for improvement regarding the process and use of knowledge. The BPKM-Business Process Knowledge Method (Papavassiliou and Mentzas, 2003) provides a methodological guidance for the implementation of BP-oriented KM. It presents a meta-model for integrating BPM aspects with KM. This meta-model transcribes the four perspectives of a workflow: task, organizational, logical and data. It was extended to

include KM tasks that support BPs represented by the elements: knowledge management task, knowledge object and knowledge archive. Two other approaches of knowledge representation are the Knowledge Transfer Agent (KTA) Modeling Method (Strohmaier et al., 2007) and the DECOR approach (Abecker, 2001). The first describes how to create knowledge transferring models. The method consists of modeling and analyzing in three distinct levels of detail. The DECOR Project delivers context-sensitive organizational knowledge and has its focus in representing processes knowledge across diagrams embedded in organizational memory. It aims to structure the BP, the dynamic context, contextual information and the representations of memories embedded in the production process. In the method proposed by Donadel (2007) aims to support the management of knowledge resources related to BPs. The organizational value chain is mapped and the knowledge aspects that may influence the organizational processes are represented. The aforesaid knowledge oriented approaches do not explicitly differentiate between tacit and explicit which is relevant in SBPs due to, for instance, the high degree of tacit knowledge developed and exchanged among agents through inter-organizational collaboration. And most of them do not provide special attention to the graphical notation for BP representation.

Furthermore, knowledge is modeled using another specific knowledge modeling notations (e.g., KMDL, GPO-WM, Oliveira) and only few of them include process perspective (e.g., PROMOTE, RAD)). The Knowledge Modeling Description Language (KMDL) (Gronau et al., 2005) (Arbeitsbericht, 2009) formalizes KIPs with a focus on certain knowledge-specific characteristics in order to identify process improvements in these processes. It represents both tacit and explicit knowledge of the process. Thus, the different possibilities of knowledge conversion can be modeled and the flow of knowledge between actors is depicted. However, this notation does not distinguish between data and information, and does not address the representation of artefacts and dynamic aspects of BP and modeling agents. Besides, it is hard to understand and to apply for the purpose of facilitating the involvement of modeling participants. Method for integration of KM into BPs (GPO-WM) (Heisig, 2006) describes and evaluates the current state of handling core knowledge domains, to gather improvement ideas for systematic knowledge handling and to integrate selected KM methods and tools into existing BPs. The notation does not allow the modeling of knowledge conversions. The abovementioned proposals focus on storing and sharing knowledge. Thus, they lack the ability to model in an adequate manner the decisions, actions and measures, which are causing a sequence of processes. Most of these methods are convenient only for knowledge management experts and require additional training for non-experts. The method for integrated modeling of BPs and knowledge flow based on a Role Activity diagram (RAD) (Weidong and Weihui, 2008) provides integration of BPs and knowledge flow and helps KM build on existing process management efforts. This method does not differentiate between tacit and explicit knowledge and does not present different types of knowledge conversion–that are relevant in SBP. Also, it does not present and separate data and information from knowledge. Supulniece et al. (2010) argued an extension of BP models with the knowledge dimension in order to take advantage of some opportunities such as identifying, planning and managing required knowledge for the role that participates in a particular activity; evaluate the amount of lost knowledge if a person would leave the organization; improve understanding about the knowledge usefulness, validity and relevance for particular activities; enable competence requirements management and proactive training. They extended BPMN incorporating concepts defined by KMDL (Gronau et al., 2005), where three different objects: knowledge objects, information objects and data objects were used. However, the proposed approach does not present knowledge flow between process participants; it lacks information about the knowledge structure; it does not integrate and separate the different knowledge types (like experience, basic knowledge, general knowledge) and it does not explicitly represent the tacit knowledge that is owned by a particular person. Recently, Netto et al. (2013) proposed KIPN, a notation for building KIPs graphical model that promotes the cognitively-effective understanding of this process. KIPN covers all characteristics defined by the knowledge-intensive processes ontology (KIPO) (França et al., 2012). It comprises a set of diagrams to represent the main dimensions within a KIP: the KIP, socialization, decision and good diagrams. In KIPN, activities are detailed through socializations. The agents interact and collaborate, contributing to the creation and acquisition of knowledge. Agents' contribution is represented by innovation, intention, belief, desire, feeling, experience and mental image elements, that are

difficult to be predicted and then modeled. The notation is able represent tacit knowledge through informal exchange and mental image elements, but it still does not capture explicitly the knowledge conversion. Moreover, NKIP is very incipient, hard to understand, not yet used and applicable for KIP modeling in current research and practice scenarios and not adopted by any available modeling tools.

Despite it mobilizes crucial knowledge within an organization and their key role for organizational KM, existing BPM approaches/notations have shortcomings concerning their ability to explicitly incorporate the knowledge dimension within BPs models as well as relevant issues at the intersection of KM and BPM. None of those proposals conveniently includes or addresses all or at least most of the SBPs important characteristics presented previously (critical activities (individual and/or collective), intensive acquisition, sharing, storage and (re)use of knowledge in challenging activities, large number of agents (external and internal) who have various business domains and different knowledge levels, high degree of tacit knowledge mobilized and exchanged among many experts, diversity of information and knowledge sources involved, high degree of collaboration (intra/inter-organizational) among agents/experts, dynamic conversion of knowledge, flexibility and dynamic aspects, deliberate actions, the influence of (distal) intentions in achieving objective and decision making, etc.). This leads to ambiguity and misunderstanding of the developed SBPs models.

2.3 SBPs Specification

In our previous research (Ben Hassen et al., 2015a), we have proposed a semantically rich conceptualization for describing a SBP organized in a meta-model, the Business Process Meta-model for Knowledge Identification (BPM4KI), which integrates all aforementioned perspectives. This meta-model intends to develop a rich and expressive graphical representation of SBPs in order to improve the localization and identification of crucial knowledge. BPM4KI is a well-founded meta-model whose concepts and relationships are semantically enriched by the core ontology organization's processes (COOP) (Turki et al., 2014b). BPM4KI covers all relevant aspects of BPM and KM within a SBP, and is composed by six perspectives:

(i) Functional Perspective, represents the BP elements which are being performed. The main concept that reflects this dimension is *Action*. It includes: *Individual Action*, *Collective Action*, *Action of Organization*, *Inter Organizational Action*, *Organizational Action /Activity*, *Organizational Individual Action*, *Task*, *Organizational Unit Action*, *Organizational Sub Process*, *Organizational Critical Activity*, *Organizational Intensive Activity* and *Organizational Collaborative Activity*.

(ii) Organizational Perspective, represents the different participants (the organizational resources) invoked in the execution of process elements as well as their affiliation. It display the process flows between different organizations and participants involved. The basic element of this perspective is *Agentive Entity* and includes: *Collective*, *Organization*, *Organization Unit*, *Human*, *Expert*, *Internal Agent*, and *External Agent*.

(iii) Behavioral perspective, basically presents the logical sequence of elements to be executed in a BP. It includes synchronization, sequence, feedback-loop, complex decision requirements, in-and ouput criteria, etc. The basic element of this perspective is *Control Object* (such as control flow elements, pre-conditions, post-conditions, triggers, performance indicators, constraints, business rules, etc.).

(iv) Informational perspective, describes the informational entities (such as data, artefacts, products and objects) which are generated, consumed, or exchanged within a process or an activity. It also includes both their structure and the relationships among them. The following concepts are related to this dimension: *Resource*, *Material Resource* (like informational and software resources), *Physical Knowledge Support*, *Event*, *Contingency*, *Input Object* (like data and information), *Output Object* (as data, information, services and results) and *Collaboration Protocol*.

(v) Intentional perspective, provides an overview perspective of the process and captures important BP context information. It describes major BP characteristics and addresses the intentional information (such as objective, strategies, quality characteristics, metrics, measurement units, the deliverables, the process type and the customer), in order to ensure the BP flexibility. It comprises: *Intention*, *Objective*, *Distal Intention*, *Collective Intention*, *Collective Distal Intention*, *Organizational Distal Intention*, *Objective*, *Individual Objective*, *Collective*

Objective, *Organizational Objective*, *Strategic Objective*, *Operational Objective*, *Deliberate Action, Culminated Process*, *Output Object* (deliverables), *Control Object* (e.g., performance measures, constraints, business rules, etc.), *Client*, *Sensitive Business Process*, *Knowledge Intensive Process*, *Inter Organizational Process*, *Internal Process*, *External Process*, *Partial External Process, Inter Fonctional Process*, *Core Process*, *Management Process*, *Strategic Process*, *Operational Process*, etc. (which are some process types).

(vi) Knowledge perspective, provides an overview perspective of the organizational and individual knowledge mobilized and created by an BP/organization as well as the knowledge flow proceeding within and between BPs/organizations. It addresses all relevant aspects related to KM (collection, organization, storage, transfer, sharing, creation and reuse among process participants). This vantage presents: *Knowledge* (as an *Immaterial Resource*), *Tacit Knowledge*, *Individual Tacit Knowledge*, *Collective Tacit Knowledge*, *Explicit Knowledge*, *Individual Explicit Knowledge*, *Collective Explicit Knowledge*, *Expert* and *Physical Knowledge Support*. It should be noted that some concepts are shared by different perspectives. For instance, *Collaborative Organizational Activity* and *Critical Organizational Activity* belong to all perspectives.

Nevertheless, BPM4KI does not provide a specific graphical notation for representing SBP. Although BPM4KI does not address the problem of representing SBP graphically, it opens a way to explore the potential of traditional BPM formalisms for it, as well as the usage of the specific process-oriented knowledge modeling/ KIP approaches. In the following section, we discuss the usage of BPM4KI concepts (which represent our evaluation framework) as a basis to model SBPs graphically.

3 A MULTI-PERSPECTIVE FRAMEWORK FOR COMPARATIVE ANALYSIS OF SBPS REPRESENTATION FORMALISMS

Based on the potential of BPM4KI to portray the essential features of SBP, this section presents a comparative analysis of different BPM formalisms to represent SBPs. Precisely, in this research work, BPM4KI acts as a multidimensional evaluation framework for assessing the suitability of six selected BPM formalisms to cover all or at least most relevant elements of a SBP. We consider guiding and justifying the choice of the most suitable formalism for SBPs representation to characterize and improve the knowledge localization.

Before we present our evaluation framework for SBP representation, we will briefly refer to some related work about BPM languages (i.e. comparison and analysis) available in the field of meta-modeling and ontology. Many frameworks ((Söderström et al., 2002); (Lin el al., 2002); (Mendling et al., 2004); (List and Korherr, 2006)) have been proposed for evaluating the suitability of some BPM languages for specific purpose, according to generic meta-models. Most of them only focus on some aspects of BPM languages. Besides, the BWW (Bunge-Wand-Weber) ontological framework (Wand and Weber., 1990) has been widely used for assessing the ontological completeness and clarity of BPM languages, include (Rosemann et al.,2006); (Recker et al., 2009); (Penicina, 2013) and (Prezel et al., 2010). Furthemore, several works addressing the integration of KM into BPs, incorporating the knowledge into BP models. França et al. (2012) proposed KIPO, a formal meta-model/ontology that highlights the key concepts and relationships characterizing KIPs and used it as a reference for evaluating the adequacy of some existing BPM languages to represent each concept. However, this meta-model is not well adapted to represent SBPs. Sultanow et al., (2012) created a systematic comparison of thirteen selected methods based on a multidimensional framework to summarize the differences, also the most suitable situation for using each method. However, this framework do not consistently support SBP model requirements and concepts. Therefore, considering existing research in the KM-BPM domain, the knowledge dimension (i.e. the knowledge required to perform activities, the knowledge created as a result of BP activities, the sources of knowledge and their localization, the explicit knowledge, the tacit knowledge, individual and collective dimension of knowledge/activities, the knowledge flows between sources and activities, the different opportunities of knowledge conversion, etc.) needed for BPM is not explicitly represented, integrated and implemented in BP meta-models.

Hence, a comprehensive evaluation framework of the representational capabilities of current BPM

formalisms for SBPs is missing.

For discussion purposes, in this paper we take the constructs from BPM4KI as a relevant set of elements that are required to precisely represent a SBP, and evaluated some existing formalisms, which are based on different fields, to verify their suitability to cover and represent each concept. The multi-dimensional evaluation provides not only a useful framework to summarize the advantages and limitations of each formalism, but also select the most suitable positioned nowadays for SBP modeling, in order to localize the knowledge mobilized and created by these processes, which may be crucial. The evaluated representation languages were UML AD, BPMN 2.0, eEPC (which are adopted by many available modeling tools in current organizations), PROMOTE, KMDL 2.2 and Oliveira's methodology.

3.1 The BPM Formalisms - An Overview

In this section, we describe the BPM formalisms which have been chosen for evaluation. Some are process oriented and some are knowledge oriented. They represent the most frequently studied BPM formalisms in scientific/professional literature and practice scenarios.

***UML 2.0 Activity Diagram (UML AD)*:** UML AD (OMG, 2011b) in the behavior category are typically used for BPM. It is mainly and originally for modeling IT systems. UML AD is a semi-formal language with the following basic graphical notations: initial node and activity final node, activity, flow/edge, fork and join, decision and merge, partition/swimlane. This diagram is more expressive for modeling data flows inside information system and is less suitable for BPM.

***Extended Event Driven Process Chain (eEPC)*:** EPC (Scheer, 2000) is a semi-formal graphical modeling language for modeling, analyzing, and redesigning BPs, easily understood and used by business people. The basic notations include events, functions and connectors. It emphases more on the operational/functional and control perspectives than data transaction perspective. The basic version of EPC was supplemented by other constructs (organizational unit, position, information object, service object and application, resulting in the extended EPC (eEPC), intended to supplement process models with organizational structure and data flow. In eEPC, knowledge is represented by two object types, knowledge category and documented knowledge, and can be model by two model types, knowledge structure diagram and knowledge map. In the first diagram, knowledge categories can be organized into subgroups based on their content. While the second depicts the distribution of various knowledge categories within an organization.

***Business Process Modeling Notation (BPMN)*:** BPMN 2.0 (OMG, 2011a) represents the most popular and widely acceptable graphical notation to represent BPs, understandable by all business stakeholders, one that has now been ratified by the OMG as a BPM standard. It divides process knowledge into broadly five categories: flow-objects, connectors, artifacts, swimlanes and data. BPMN is initiated as a standard BPM language for conventional business, B2B and services process modeling. Hence BPMN has the capabilities of handling B2B business process concepts, such as public and private processes and choreograhies, as well as advanced modeling concepts, such as exception handling and transaction compensation in addition to the traditional BP. The Collaboration and Choreography Diagrams allow modeling interaction among process' actors (between business partners, or different departments in a same company, members of a teams or even single workers and software systems), who exchange messages, while performing their tasks to reach a common objective.

***PROMOTE*:** The PROMOTE (Woitsch and Karagiannis, 2005) integrates strategic planning with the evaluation of KM and BP management and defines KM requirements on the basis of business needs. It captures, models and evaluates the knowledge in enterprises and KIPs. It provides three diagram types: a knowledge diagram, a knowledge application diagram and an evaluation diagram. This notation can specify the knowledge conversion types. But, it does not explicitly separate tacit and explicit knowledge.

***Knowledge Modeling and Description Language (KMDL)*:** is a semi-formal modeling method for the detection, visualization, analysis and evaluation of BPs and knowledge flows (Gronau et al., 2005). It increases the transparency of the existing knowledge in enterprises and optimizes the process of KIPs. This notation represents both tacit and explicit knowledge of the process, also the different types of knowledge conversion. It provides an object library containing the basic objects: information object, task, role, task requirements, person, knowledge object, type of knowledge conversion and knowledge descriptor. The current KMDL 2.2, provides three views: (1) process-based view, (2) activity-based-view (considers the knowledge con-

Table 1: Verification of BPM4KI concepts representation by BPM formalisms.

BPM4KI Concepts \ BPM		UML AD	eEPC	BPMN 2.0	PROMOTE	Oliveira	KMDL 2.2
Functional Perspective	Collective Action	-/+	-/+	-/+	-/+	-/+	-/+
	Organizational Unit Action	+	-/+	+	-/+	-/+	-/+
	Critical Organizational Activity	-/+	-/+	-/+	-/+	-/+	-/+
	Collaborative Organizational Activity	-/+	-/+	-/+	-/+	-/+	-/+
Organizational Perspective	Agentive Entity	+	-/+	+	-/+	-/+	-/+
	Collective	-/+	-/+	+	-/+	-/+	-/+
	Organizational Unit	-/+	+	+	+	-/+	-/+
	Expert	-	-	-	-	-/+	-
Behavioral Perspective	Control Object	-/+	-/+	+	-/+	-	-/+
Informational Perspective	Material Resource	-/+	-/+	+	-/+	-/+	+
	Input Object	-/+	-/+	+	-	-/+	-/+
	Output Object	-/+	+	+	-/+	-/+	+
	Contingency	-	-	-/+	-	-	-
	Collaboration Protocol	-/+	-/+	+	-	-	-/+
Intentional Perspective	Intention/Distal Intention	-	-/+	-	-	-	-
	Objective	-	-	-	-/+	-	-/+
	Sensitive Busines Process	-	-/+	-/+	-/+	-/+	-/+
	External Process	-/+	-	-/+	-	-	-
	Culminated Process	-/+	-/+	-/+	-	-/+	-/+
Knowledge Perspective	Tacit Knowledge	-	-/+	-	-/+	-	+
	Individual Tacit Knowledge	-	-	-	-	-	-
	Collective Tacit Knowledge	-	-	-	-	-	-
	Explicit Knowledge	-	-/+	-	-/+	-/+	-/+
	Individual Explicit Knowledge	-	-	-	-	-/+	-/+
	Collective Explicit Knowledge	-	-/+	-	-	-/+	-/+
	Physical Knowledge Support	-	-/+	-/+	-/+	+	+

versions during the fulfilling of a special tasks), and (3) communication-based view.

***Oliveira's Methodology*:** The Oliveira's methodology (Oliveira, 2009) is an extension of Ericsson et al., (2000) for BPM that is composed of diagrams representing a hierarchy of models. It uses constructs adapted from KMDL to model BPs, considering KM aspects.

The evaluation of the BPM formalisms was performed by three experts, who were responsible for observing how well the BPM4KI concepts could be represented in each language. The experts individually evaluated the correlation between formalism elements and meta-model concepts, considering its definitions and relationships.

3.2 The Evaluation

An overview of the evaluation results can be found in Table 1. Our evaluation scale ranges from comprehensively fulfilled (depicted by +), partially fulfilled (+/-) to not fulfilled (-). The evaluation is carried out from each of the six perspectives making up the BPM4KI meta-model. Results show that none

of the studied formalisms, individually, satisfies SBP modeling requirements.

Generally, the functional and the behavioral perspectives are very well represented in all BPM formalisms, while the organizational and informational perspectives are only partly supported. But a lack of the models is that the knowledge and intentional perspectives are not explicitly supported. In fact, *Expert, Individual Tacit Knowledge*, *CollectiveTacit Knowledge*, are not addressed at all, in any of the formalisms.

From the process perspective, we can conclude that the traditional BPM formalisms BPMN 2.0 and ARIS eEPC are more expressive for modeling this perspective as a whole. While BPMN offers extended notation for control flow organization, encompasses a high level of detail, numerous constructs (for modeling process logic, decision points, control flows, processes and event types, etc.) offering a very complex expressive model of BPs. In constrat, eEPC has less expressiveness than BPMN, and its constructs are considerable fewer and not so well specified as in BPMN. Furthermore, EPC process models are not intended for being detailed in order to be executed. It is a notation to model the domain aspects of BPs. The focus of the notation is mainly on domain concepts and processes representation rather than the formal specification or technical realization. Besides, the defined concepts-actions specification (Process, Activity, Sub-process, Task, function, action) defined by the selected list of formalisms do not explicitly take into account the individual/collective dimension of the actions. However, taking into consideration such a dimension is very important in our research context, given that we are interested in the localization of knowledge mobilized to realize the BP. This knowledge taken in the action may be either individual or collective/organizational (tacit or explicit).

From the knowledge perspective, knowledge modeling is possible with KMDL 2.2, Oliveira and PROMOTE (including ARIS eEPC, but it incompletely supports this dimension). However, the BP oriented knowledge modeling notation have not been widely adopted by organizations and are very incipient. At the same time they have limited capabilities: (i) They have poor capabilities of process control flow modeling (decisions, actions, control flows, etc.), also they lack the ability to model in an adequate manner the process perspectives as a whole (the structural, behavioral, organizational and informational dimensions); (ii) Information and data concepts are not distinguished; (iii) Most of them do not explicitly differentiate between tacit and explicit knowledge, which is relevant in SBPs due to, for instance, the high degree of tacit knowledge developed and exchanged among agents through inter-organizational collaboration; (iv) These notations allow modeling knowledge flow perfectly, but BP modeling with KMDL or Oliveira is challenging - understanding a model requires special thinking, learning and significant effort for analysis, design and implementation. They are convenient only for KM experts and require additional training for non-experts.

From the informational perspective, the other notations (BPMN, UML AD and ARIS eEPC) enable data and information modeling, but do not offer a strict border between these terms and are often represented by the same modeling constructs and symbols. It is noteworthy that this distinction is useful and essential for our modeling context. Data and information form the basis for knowledge generation, distribution and utilization in the context of collaboration between BP agents.

To sum up, our evaluation results showed an important loss of information in SBP representations, either because relevant concepts were not addressed by existing formalisms or because these concepts were represented in a very high abstraction level. This may lead to ambiguous and unclear SBP models. The BPMN 2.0 standard was the BPM formalism that presented the broadest coverage of the set of BPM4KI concepts, incorporating requirements for SBP modeling better than other formalisms. Therefore, we select BPMN 2.0 as a basis for representing SBPs to address our research problem, which consists in improving the localization and identification of the crucial knowledge that is mobilized by these processes.

In brief, the best characteristics of BPMN are: (i) BPMN is currently the BP notation most used among strong process modeling practitioners, very simple, easy to use and readily understandable; (ii) BPMN is a BPM standard backed up by OMG, so the language definition is based upon a meta-model built with UML, the notation which is the de facto standard for modeling software engineering artefacts; (iii) BPMN is one of the most recent BPM languages, so it is grounded on the experience of earlier BPM languages, which ontologically makes it one of the most complete BPMLs (Recker et al., 2009); (iv) BPMN is supported by almost all popular BPM tools; (v) BPMN is extensible (with standard extension mechanisms); (vi) BPMN offers a standardized bridge for the gap between the BP design and process implementation, etc.

Nevertheless, despite its strength representation,

some of its concepts should be adapted and extended to be convenient for a rich and expressive representation of SBPs. In fact, this notation does not explicitly support the key concepts of BPM4KI (as *Critical Organizational Activity*, *Individual Tacit Knowledge*, *Collective Tacit Knowledge*, *Expert*, *Knowledge Explicit Knowledge*, *Distal Intention*, *Collective Objective*, etc.). So, to overcoming the shortcomings of BPMN 2.0, this extension must take into consideration, on the one hand, the knowledge dimension, and on the other hand, integrate the new concepts of BPM4KI to represents issues relevant at the intersection of KM and BPM clearly and with a sufficient level of details.

4 CASE STUDY: A SBP MODEL REPRESENTATION

4.1 Case Study Description

In this section, we describe a case study carried out to demonstrate the feasibility, suitability, and practical utility of the evaluated approach to represent and analyze SBP. Precisely, this section illustrates a SBP model using BPMN 2.0, on top of the ARIS express tool (IDS Scheer, 2013) to evaluate its potential in providing an adequate and expressive representation of a SBP, to improve the knowledge localization and identification. The chosen process for this example reflects a medical care process in the Association of Protection of the Motor-disabled of Sfax-Tunisia (ASHMS). This organization is characterized by highly dynamic, unpredictable, complex and highly intensive knowledge actions. Particularly, we are interested in the early care of the disabled children with cerebral palsy (CP) (Ben Hassen et al., 2015b). In fact, the amount of medical knowledge mobilized and produced during this medical care process is very important, heterogeneous and recorded on various scattered sources. One part of this knowledge is embodied in the mind of health professionals. Another part, is preserved in the organizational memory as reports, medical records, data bases, therapeutic protocols and clinical practice guidelines). The created knowledge stems from the interaction of a large number of multidisciplinary healthcare professionals with heterogeneous skills, expertise and specialties (such as neonatology, neuro-pediatrics, physical therapy, orthopedics, psychiatry, physiotherapy, speech therapy, and occupational therapy) and located on geographically remote sites (University hospital of Sfax Hedi Chaker, University hospital of Sfax, Habib Bourguiba, faculty of medicine of Sfax, research laboratories, etc.). Therefore, the raised problem concerns on the one hand, the insufficiency and the difficulty to localize and understand the medical knowledge that is necessary for decision-making, and on the other hand, the loss of knowledge held by these experts during their scattering or their departure at the end of the treatment. The ASHMS risks losing the acquired know-how for good and transferring this knowledge to new novices if ever no capitalization action is considered. Thus, it should identify the so called «crucial knowledge» to reduce the costs of capitalization operation. Our main objective consists in improving the localization, identification and sharing of different types and modalities of crucial medical knowledge necessary for performing the medical care process of children with CP.

Indeed, this SBP is composed of several sub-processes which consists of a succession of many actions in the form of medical and paramedical examinations and evaluations in different specialties (like neonatology, neuro-pediatrics, physical medicine, orthopedics, psychiatry, physiotherapy and occupational therapy). The different BPs (such as process related to neonatology care, process related to neuro-pediatric care, process related to physiotherapy, etc.) require certain medical information as well as certain medical knowledge (results of para-clinical exams, hospitalization reports, patient-specific knowledge recorded in the medical case file, practice guidelines, etc.).

4.2 The SBP Modeling

In this study, we take into consideration the results of experimentation of the Sensitive Organization's Process Identification Methodology (SOPIM) proposed by Turki et al., (2014a) for the early care of children with CP. As a reminder, the proposed multi-criteria decision making methodology was conducted and validated in the ASHMS organization and aims at evaluating and identifying SBPs for knowledge localization. We have opted for the SBP «Process of neonatology consultation of a child with CP» to illustrate and evaluate the potential of BPMN 2.0 with regard to its applicability and capability of making relevant knowledge embedded in a SBP explicit. Indeed, this SBP is highly dynamic, very complex, in the sense that it involves a large number of organizational units, agents and experts (internal and external who are not affiliated to the organization) from various business/ skills often residing in different physical locations), neonatology

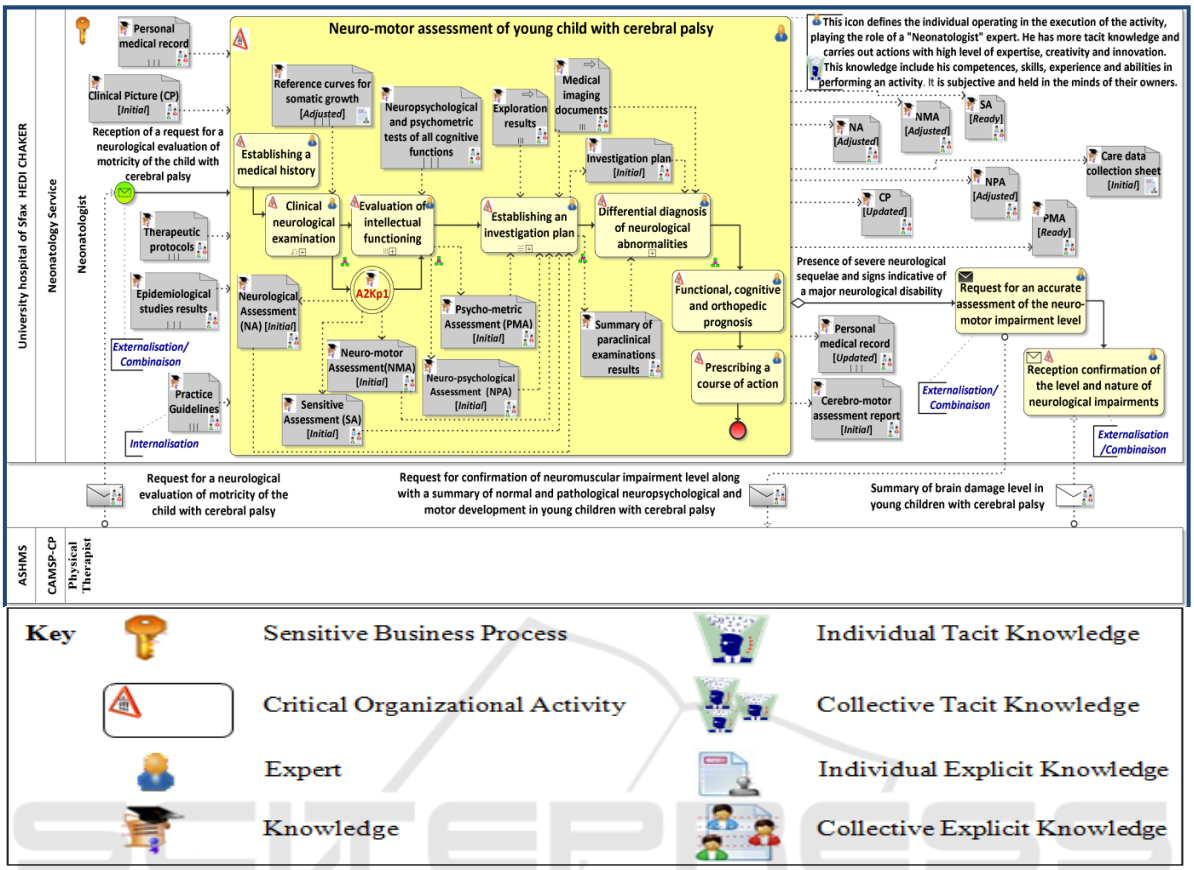

Figure 1: Fragment of SBP model in BPMN related to the neonatology consultation of a child with CP.

disciplines and critical organizational activities (individual and collective). It is very dependent on explicit knowledge sources and on tacit knowledge. In addition, it involves an intense collaboration and interaction between participants to achieve organizational objectives, make decision to deal with an unexpected situation and create value. Some of its activities are highly dependent on the experts experience, expertise and creativity.

Figure 1 outlines a SBP model extract of the neonatology consultation process using BPMN 2.0, enriched with the knowledge dimension (modeled according to BPM4KI). As stated above, this notation does not, however, provide primitives to explicitly represent all relevant aspects related to knowledge dimension in BP models. To remedy for the shortcomings, we tried to extend this notation and started by integrating some specific graphical icons in the form of some BPMN modeling elements relating to several new BPM4KI concepts (Figure 1). The BPMN SBP model is evaluated and validated through some interviews made with 2 stakeholders: the neonatologist and the neuro-pediatrician. During our experimentation, we have identified different types of medical knowledge mobilized and created by each critical activity related to the SBP of neonatology care. We have distinguished missing or poorly mastered knowledge (individual or collective) necessary to resolve critical problems, expertise, unexplainable tacit knowledge and mastered knowledge necessary and relevant to the proper functioning and development of the activity or produced by the activity. We have also identified the different sources of knowledge, their localization, actors who hold the knowledge, the places where they are usable or used, their nature (like experience, basic knowledge, general knowledge), their degree of formalization (tacit/explicit dimension), their organizational coverage (individual/collective dimension), as well as their quality (perfect or imperfect).

For instance, the knowledge A_2K_{p1} related to « Knowledge about result of the evaluation of the clinical neurological examination, neurological abnormalities, cerebral palsy category, and clinical signs and symptoms associated of young children with cerebral palsy » is produced by the critical activity A_2 « Clinical neurological examination».

Note that this materialized/externalized knowledge is created as a result of the activity execution by the Neonatologist, during which he interacts with information (i.e. source of knowledge information) related to the child with CP (based on his previous experiences and tacit knowledge) to generate and communicate his own knowledge. A_2K_{p1} is stored in the following physical media: the neurological assessment sheet, neuropsychological assessment, the sensitive assessment sheet and the neuro-motor assessment. These physical media of knowledge are located internally within the Neonatology service in the University Hospital Hedi Chaker, precisely in the various archives drawers or patients' directories. A_2K_{p1} is of a scientific, technical and measure nature which is related to patients. It represents a collective explicit knowledge, part of which can be represented in the form of an individual explicit knowledge recorded on the care data collection sheet of the Neonatologist. This knowledge is imperfect (general, incomplete and uncertain). A_2K_{p1} is mobilized by the activity A_3 « Evaluation of intellectual functioning of young child with CP ».

It is important to mention that not all BPM4KI concepts are applicable and must be instantiated in every SBP scenario. Precisely, relevant tacit aspects could not be represented explicitly, such as: the tacit knowledge embedded in the neonatologist's mind, the knowledge conversion and the knowledge flows exchanged between communicating process participants and among activities, and the distal intentions which are responsible for making neonatologist to perform any action and achieve an organizational objective.

Therefore, the relevance of extending BP models with the knowledge dimension (according to BPM4KI meta-model) is manifold:

1. Enhance the localization and identification of the crucial knowledge mobilized and produced by the critical activities: (i) Illustrating the knowledge and its sources that are necessary for the execution of BP activities and are generated, created and/or modified as a results of activities. (ii) Illustrating the knowledge localization (where knowledge can be obtained and clearly stated) as well as experts who hold the (tacit) knowledge. (iii) Illustrating the way in which specific knowledge flows among the activities, or how a specific source is used and modified through the activities. (iv) Illustrating transfers of knowledge between sources, and among activities as well as the different opportunities of knowledge conversion. (v) Defining the knowledge that is being captured or obtained from specific sources. (vi) Giving an opportunity to improve understanding about the knowledge usefulness, validity, and relevance for particular activities in a SBP. (vi) Possibility to evaluate the amount of lost knowledge if a person-owner of knowledge- leaves the organization (i.e., to identify which tacit knowledge in which cases should be transformed into explicit knowledge).
2. A deeply characterizing of the identified knowledge to determine which ones are more crucial to be exploited: (i) Illustrating the nature and degree of formalization of knowledge. (ii) Illustrating the organizational coverage of knowledge, their quality.

5 CONCLUSION AND PERSPECTIVES

This paper presented an evaluation framework of BPM formalisms to represent the SBP, taking the conceptualization defined by BPM4KI (Ben Hassen et al., 2015a) as a baseline. Several BPM notations are reviewed, some are process oriented and some are knowledge oriented. This evaluation concluded that current BPM formalisms are not adequate for the representation of SBPs, since important SBP characteristics details could not be observed. All formalisms were very similar in the number of concepts represented, whereas ARIS eEPC and BPMN 2.0 address the highest representation coverage. In order to observe the practical applicability of the selected formalism, a SBP model of a real neonatology care process of a child with CP was illustrated using BPMN 2.0.

There are several open issues in this paper that we plan to address in the future to deepen the so-called problematic of knowledge identification mobilized by SBPs. Further work is underway to present an extended version of BPM4KI, improving the definition of some BPM4KI concepts so as to ease their understanding, as well as adding new elements to take into consideration issues relevant at the intersection of KM and BPM in greater detail. So, we consider relying on core ontologies (such as core ontology of know-how and knowing-that (COOK) (Ghrab et al., 2015) and Knowledge-Intensive Process Core Ontology (KIPCO) (França et al., 2012). Work for the medium term is to extend the proposed evaluation framework and perform further comprehensive evaluation considering several relevant criteria. Besides the six BP aspects, there are further non-functional requirements a BP meta-model should fulfill: ease of use and

understandability, ontological completeness /expressibility, extendibility/ flexibility, notations, modularity, level of details/granularity, exception handling, pattern support, tools availability, security and privacy, etc. Moreover, the evaluation of six BPM formalisms provides a good starting point that can be easily extended with both further BPM languages and supporting tools. Also, the evaluation will be carried out from each of the six perspectives making up the BPM4KI meta-model. Further down the track, we plan to propose a rigorous scientific approach for extending BPMN 2.0 for KM.

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