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Collaborative Business Process Modeling Approaches: A Review

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Abstract—**Recently, Collaborative Business Process modeling (cBPM) has become very popular due to modern Business Process Management trend. It expands to cover business processes across the organizational boundaries and, thus, emerges the need of collaborative business process modeling. Business process modeling (BPM) requires many complex iterations and communications between the domain specialists and business analysts. Collaborative business processes are the facilitators for organizations to develop flexible and dynamic collaborations to adapt to the changing conditions and stay competitive in the global market. The main aim of the paper is to review the cBPM approaches and provide a comparison among them to highlight their limitations and challenges.**

Keywords- collaborative business process modeling; business process management; survey

I. INTRODUCTION

A business process can be defined as a sequence of related activities in a business context with purpose of obtaining certain output. It should enhance the value of the business for clients or organizations [2]. An organization can be analyzed based on the defined business processes. Business Process Management approach is used for the management, transformation and improvement of the organizational operation [5]. Business Process Modeling (BPM) is an essential component of Business Process Management. Existing BPM approaches are based on various methods and description languages, most of which are based on textual programming languages or graphical representations. BPM approaches have emerged to become relevant and important part of conceptual modeling [1]. They provide the basis for various phases in the lifecycle of Business Process Management, such as implementation, execution, monitoring, controlling and enhancement of business processes [3].

In the past few years enterprises have undergone meticulous revolution due to the new challenges of globalization, mass customization and unstable demand. To remain competitive in the global market, enterprises must have the ability to standardize, describe and adapt the way they react to different types of business opportunities. To support this global collaboration, enterprises need to include internal and external systems, resources and partners. To achieve these objectives they need business processes that conduct collaborative businesses across multiple organizations.

A collaborative business process can be defined as a relevant business process across multiple participating organizations that are integrated for efficient functioning of businesses in the global market [4]. Consequently, in the context of Business Process Management, collaboration support features in process modeling and its respective tools have become an important research topic. A significant effort has been placed on research related to modeling of processes. The main concern is focused on the nature of the modeling task and how to support people with collaborative tools in their modeling accomplishments [6]. Collaborative Business Process Modeling (cBPM) has been investigated by very few studies and those studies have been exclusively based on prototype implementations of tools and experimental research [7]. In this study our aim is to review the state-of the-art of cBPM. The main focus of our study is to explore existing approaches that support collaborative business process modeling. We further discuss the issues and future challenges in cBPM.

We further provide a brief background in Section II. Then we discuss significant cBPM approaches in Section III. In Section IV, we provide discussion about relevant issues. Finally, we conclude the paper in Section V.

II. RESEARCH BACKGROUND

A. Business Process Modeling

Since the late 1990s, business process management has been customary in both industry products and academic prototypes. In business process management life cycle, BPM is the first and foremost imperative step [9]. It intends to separate process logic from application logic, such that the underlying business process can be automated [10]. To support business processes and information systems conceptualization, communication, understanding, analysis, design and their improvement, models are very useful [11]. BPM is used to identify and describe business processes [12]. A. Lindsay, et al. describe BPM as a series of snapshots of actual business processes that are perceived at different points in time [13]. BPM is essential for the analysis, evaluation and improvement of business processes. It is used to structure processes, such that the existing and alternative task sequences can be analyzed systematically and comprehensively [14]. In addition, BPM is a useful tool to capture structure and formalize knowledge about business processes [15]. To capture various aspects of business processes, a number of BPM techniques were introduced. The

authors of [16] suggest that business process models are mainly used to learn about processes, to make decisions about them and to help developing software applications that support the operations of these business processes.

Various BPM techniques are preferred for various purposes depending on the particular constructs [17]. The most common diagrammatic techniques for BPM are flowcharts, IDEF and Petri nets (PN). In addition, Discrete Event Specification (DEVS), State Charts, Activity Cyclic Diagram (ACD), Integrated Enterprise modeling (IEM), Role Activity Diagrams (RADs) and GRAI Methods are used as well. However, there are also a number of standards for Business Process Modeling, i.e. [18] Business Process Modeling Notation (BPMN) maintained by OMG, Business Process Execution Language for Web Services (BPEL4WS), Web Services Description Languages (WSDL), Event-Driven Process Chains (EPC), XML Process Definition Language (XPDL) and Unified Modeling Language (UML). Majority of the business community uses simple diagrammatic modeling techniques.

B. Collaborative Business Process Modeling (cBPM)

cBPM describes the joint effort of a team of people to create a business process model. This team of modelers shares an interest in creating a business process model and individuals contribute to the outcome by working together as a team [50]. cBPM can be described as a framework of BPM and is adapted in such a way that it can be utilized as a tool for the exploration of collaborative business field [19]. It involves a cooperative creation of models, integration of different perspectives on a process and shared understanding of models. It targets creating a fruitful environment for joint ventures, fostering strategic discussions about developing markets and emerging business models. In the Business Process Management field, we need novel modeling methods that support describing of "collaborative processes". Business processes are inherently characterized by a higher degree of collaboration. Collaboration in the modeling task itself remains widely unaddressed [20].

There are various techniques used for modeling business processes such as PN, UML, IDEF3 and architecture of integrated information systems (ARIS), etc. These techniques, however, are inadequate for describing collaborative practices. This is so because they are incapable of representing multiple actors participating in each collaborative task while keeping consistency of the overall processes [20]. Some business process languages, such as WS-BPEL [23] and Business Process Modeling Notation (BPMN) [24], have been proposed to support the modeling of collaborative business processes, and are being adopted as industry standards.

The authors of [8] proposed a collaborative modeling architecture based on design science approach [25]. This architecture is a combination of business needs and applicable knowledge. They defined applicable knowledge as derivation from theory and empirical findings of modeling studies using conventional means. To discover business needs they conducted interviews with IT consultants from four different companies. In their study they included only those problems that appeared twice in respondents' artifacts. Afterwards, they used applicable knowledge to elaborate those problems. After results analysis, they developed architecture for collaborative modeling. The architecture consists of three levels: language, pragmatic, and social. In the language level, syntactic and semantic levels are revealed in the initial coding phase. They are further divided into natural language and modeling language domains. This division is based on the type of language used to describe the business process. On the pragmatic level, activities are classified as "understanding" and "organizing the modeling process". "Understanding" activities were further split into "understanding language" and "understanding text". The latter can be divided into "setting the agenda" and "negotiation'. The social level consists of rules for acceptance and rejection by negotiation.

In the design circle they developed two artifacts, the architecture (COMA) and a tool that implements this architecture. Their approach was driven by theoretical insights and interpretation of group modeling behavior. In the relevance circle they identified business needs and assessed the degree to which it fulfils these needs; they put the artifact to a practical test. In the rigor circle, they confirmed the knowledge about the existing means to solve typical problems in collaborative modeling. They found significant positive impact on five out of ten problems. They mentioned that further research is needed in both areas where it proved useful and in which it was not helpful in solving problems. In their opinion to meet the concerns of all collaborators, collaboration is a close form of working together. It requires the meaning of terms and desired output to be negotiated. Project management was also mentioned as an important issue that requires further research.

III. COLLABORATIVE BUSINESS PROCESS MODELING APPROACHES

Many efforts have been made to define a best fit methodology for cBPM phenomena. Most of them are based on traditional modeling approaches. A number of extensions to those approaches were developed, as further discussed in detail.

A. Extension of UML

Most of the efforts made to provide support for collaboration in modeling languages are by extending UML. Authors of [20] developed a new method for modeling collaborative processes i.e. Collaborative Process Modeling (CPM). CPM method supports development and verification of collaborative process models. CPM is based on manufacturing industries. It originates from the need to capture collaborative processes among its components for better understanding and definition of supporting functions of a system. For modeling purposes of collaborative processes, they categorized them in two types, i.e. intra- and inter-collaboration. Intra- is co-operation of different groups within the organization and inter- is between different organizations. CPM involves modeling of collaborative processes among multiple actors with different affiliations. The characteristics of CPM are that it is process-oriented, it is based on UML activity diagrams notation, and consists of eight elements, as shown in Figure 1. It is easily understandable because it uses different symbols for inter- and intra-collaboration processes. Different processes carried out

by different actors can be modeled into one single CPM Model and each participant is easily identified in model.

Symbol	Description	Symbol	Description
Actor_IDs	Intra-collaboration process		Horizontal and vertical synchronization
Actor_IDs	Inter-collaboration process		Process transition
Actor_ID	Normal process		Resource
	Decision		Reference note

Figure 1. CPM Elements [20].

Generated models can be transformed into marked graph models in order to apply analytical methods for PN. CPM does not have any elements to directly represent the state of processes or system. However, it is noted that state transitions can be captured by understanding the flow among processes. Regarding the transformation to PN, it is impossible to get direct mapping of all CPM elements into PN because it has only four components. For that purpose they first define marked graph building blocks (MGBB) with the combinatorial use of SPN components. They defined five transformation rules for this purpose.

They concluded that modeling with CPM is straightforward and highly understandable. The involvement of different actors in each collaborative process is recognizable and analysis of model is feasible. As it is process oriented, its weakness in modeling collaborative processes is in modeling different viewpoints. CPM is a conceptual method, a tool for that has not been developed yet.

An extended version of CPM (exCPM) is proposed by the authors of [22] introducing more power for modeling and analysis of collaborative process. The exCPM consists of 10 elements and also adds Inputs, Controls, Outputs and Mechanisms (ICOM) functionality from IDEF0 [30]. ICOM is used to express the flow of data and represented with dotted arrow. States and colored tokens of PN are used in order to monitor the state of processes in real-time and to intuitively comprehend the diverse actors in collaboration respectively. One of the distinct features of exCPM is the model verification through the automatic transformation of exCPM models into SPN. In this version, they also redefined the transformation rules. To support the contribution of exCPM, it is applied to collaborative works in manufacturing or business domains. This work is still at conceptual stage.

P.Villarrel, et al. [39] proposed a method that is based on Model-Driven Architecture (MDA) that is used for design, verification and implementation of collaborative processes. In that method, collaborative processes are modeled using UML and are based on Interaction Protocols (UP-CoIBPIP) [9, 39]. BPMN language is used to represent interface process model. To describe interaction protocols, the UP-CoIBPIP language is used. Collaboration among different enterprises requires the definition of interface and integration processes that each enterprise has to implement to execute collaborative processes. By applying the MDA approach, enterprises can build and transform business process models to generate the code of B2B specifications. For the representation of collaborative processes behavior, the UP-CoIBPIP language encourages the use of interaction protocols. Other related work based on MDA proposed by authors can be found in [40]. In this work, ARIS models of cross-organizational chains are mapped into BPDM models of interface processes. They used UML2 activity diagrams and their proposed architecture uses a centralized broker to implement and govern collaborative processes. This approach encourages decentralized management of collaborative processes.

B. Extension of Petri-Nets

So far, in the area of cBPM various extensions of high level and colored stochastic PN have been successfully applied. Authors of [33] presented a process-oriented approach that is XML-net based. For the purpose of performance management of collaborative business processes, the basic Petri-net schema is combined with the graphical XML schemas. The intuitive graphical representation provides an overview of the current status of cBPM at all times via a web front-end. By utilizing XML nets, performance indicator based modeling, analysis and monitoring of business process can be enhanced. The authors demonstrated its functionality by implementing it in a software prototype called INCOME2010.

G. Jiang and B.Hu [34] proposed a model that is based on extended stochastic Petri nets (SPN). SPN face the state-space explosion problem and are not able to depict dynamic parallel mechanics. Thus, the authors added some object-oriented features and color mechanics on the basic SPN to get the extended SPN. Five more tuples were defined for that reason. The model was implemented using a programming method and a hierarchical modeling tool of a simulation environment named ExSpect (http://www.exspect.com). It describes the concurrency workflow with priorities and overcome the defects of SPN. They also used an instance with ExSpect to explain how to implement workflow process.

Another utilization of PN has been explored in [35]. The authors of this paper introduced the concept of collaborative modeling and its implementation in CoMoMod. They utilized event driven processed chains (EPC) and PN for modeling purposes. Their work provides support for simultaneous work on one process model diagram. For that reason, they grouped spatially distributed modelers, integrated communication components and usage of different modeling languages by different modelers. The developed tool is also based on Design Science approach.

The authors of [36] discussed a CPI method for the enterprise modeling. They claimed it is significant to capture intricate enterprise processes. The CPI approach objective is to furnish an extended participation of actors that have valuable insight into the enterprise operation and business processes. Their proposed method is based on SPN and DEMO (Design and Engineering Methodology for Organizations) transaction concepts [37]. The DEMO theory described two kinds of acts within organization i.e. Production act and coordination act. Transactions can be defined as a generic pattern in which two acts occur. Each transaction is carried out in three phases: order phase, execution phase and the result phase. The actor role that

initiates the transaction is called initiator and the one who carries out the production act is called executer. DEMO transaction is based on PN. Further, the authors introduced a case study where they study both the approach and the model.

C. Agent based Methodology

Some of the researchers were inspired by the semantic agents technology and utilized it to further improve the exchange of model information. According to [41], the process of collaboration is divided it into three aspects to enhance its effectiveness and efficiency. They are Information based interoperability (communication and interaction standards), Resource based coordination (controlling and scheduling of shared resources) and Business rules-based collaboration (mechanisms of process coordination). Their proposed idea used the semantic agent to facilitate business process collaboration in both human centric and application centric process environment. Semantic agents facilitate the transfer of process collaboration information among different processes. Various business process management systems accessed information from different processes captured by all agents. They are represented by process ontology. Ontology is the specific domain's conceptualization in a both human and machine-readable format. They used process description ontology to provide formal semantics to traditional process modeling methods. In that framework, they used semantic interface, agent rules and explained system infrastructure. This framework needs to be developed further in terms of ontology mapping, agent design and coordination rules.

Another agent-based technology was discussed in [31]. The authors proposed an extended UML-based multi agent collaboration model for task allocation in virtual enterprise (VE). It is based on Contract-Net protocol (CNP). To solve collaborative problems that exist in open distributed environment multiple agent system (MAS) is needed. To make UML fit for MAS, expansion of concurrency mechanisms and semantic elements in UML plays an important role. Various synchronous joint symbols are introduced for agent UML messages. To regulate the process of collaboration they used CNP [32]. CNP is the most widely used collaboration mechanism. The authors further describe contract net as a collection of nodes, where each node acts as role or manager of contract. To transfer message between agents shared ontology is needed. The communication language between agents can employ Knowledge Query and Manipulate Language (KQML) but the general communication protocol can be TCP/IP. They reported limitations in modeling multi agent collaboration with extended UML because of its complexity.

D. Semantic Web based Methodology

Few of the researchers incorporate web-based methodology to provide support of collaborative feature in process modeling. The approach proposed in [29] addresses the issue of dynamic collaborative business process formulation and demonstrated its feasibility. They employed Business-OWL ontology. They also introduced an algorithm for dynamic formulation of CBP that is an extension of the Hierarchal Task Network (HTN) planning algorithm. This algorithm dynamically formulates CBP definitions on-the-fly. Then, the decomposition of high-level compound tasks into low level (operational) primitive tasks is done by a novel method. The cBPM hierarchical task decompositions are stored into an ontology i.e. Business-OWL. Their proposed methodology consists of Graphical User Interface and is accessed via web browser. It captured the high-level business goals and planning criteria. The OWL language is used for the description of HTN knowledge i.e. easy for integration of web languages. Afterwards, the common B2B tasks are stored as methods within the" HTN-ontologised". The Genesis algorithm takes the high-level business goal from the GUI and decomposes them into a sequence of collaborative tasks. They claimed that this type of dynamic decomposition and sequencing of CBPs from strategic goals to operational-level tasks ready for Web Services execution has not been attempted before. Other methods [26], [27] which employed HTN for Web service compositions did not addressed the high-level business goals and collaboration criteria frequently encountered in real life. In [28] another approach is presented and their methodology is somewhat still manual, not scalable and lacks dynamic business process integration capability.

L. Boaro, et al., [42] described Development and Reasoning Environment for Annotated Models (DREAMs) Framework for improving B2B collaboration. In this framework two different actors were defined, one is a provider that represents the organization. The other is a requestor that describes the organization, which is looking for an external actor to jointly execute the business process. At provider's side, this approach utilized BPEL [43] for description of business processes. The ontology is described by WSML language [48] and XML-based language SWSAL [44] is used for annotations. At requestor side BPMN language is used to express the behavioral part of the specification. Semantic annotations are used for expressing ontological part of specification that is written in SWSAL. Semantic model checking algorithm is utilized for process verification according to specifications. They also developed a tool that is based on their framework.

IV. Issues & comparison

In cBPM a huge number of academic and industrial approaches co-exist, classified as either formal or informal. The formal ones are based on discrete mathematics. In fact, a considerable overlap exists among the many methods and languages. In the following we list the challenges and issues that we identified within cBPM:

a) The main challenges for the collaborative modeling of processes are the representation of concurrency between processes and synchronization of different processes in an organization. For concurrency purpose only one modeler can interact with the model at a time.

b) For the purpose of understanding collaborative process in an organization, the role of stakeholders is very important but they are non-technical persons. To understand the modeling approach and to describe their comments about processes in a technical way is difficult. For the effective involvement of stakeholders and other non-technical personnel, definition of overall business process modeling emerges the need of standard and simple modeling approach. Existing approaches lack simplicity and standardization. Some of them are very complex in their implementations and difficult to understand.

c) Perspective of different modeler's interaction and conflict resolution between them has not been addressed till now. Different approaches are being adapted as industry standards.
d) To facilitate collaboration different collaborative business process models are defined. The approaches are mainly from computer-oriented perspective, but there is a vast difference between human-oriented and computer-oriented processes.
e) There are many concerns regarding strategies of translation of descriptive words of non-technical individuals in models. There are also a number of problems due to heterogeneous environment of various applications in organizations. The exchange of information and data is also loosely coupled. To solve that issue, object-oriented modeling methodology of processes in collaboration environment is more appropriate. In cBPM, the deployment of object-oriented methodology is explored by [45, 46, 47]. They also showed the advantage of this methodology in representing data flows inside or outside of business processes.
f) Tracking and version management is yet another important issue in cBPM. To perceive the progress of collaboration between different organizations, the correlation and cardinality of collaborative process instances must be tracked and managed properly. The authors of [49] analyzed workflow cardinality and instance correlations based on PN. Their approach can be combined with collaborative modeling approach to handle the issue of tracking.

Table 1 briefly summarizes the approaches used for cBPM. Most of the research is based on academic prototypes. The approaches described in section III are based on various frameworks. Some of them are based on the activity diagrams of UML and some introduce combination of UML and PN. Some of the UML based approaches lack the elements to present states of processes and do not have analysis feature. They are dependent on the traditional approaches for the analysis purposes. PN based approaches are more complex than UML based approaches for non-technical personals. Agent-based technologies are also very complex process in terms of messages, description and expression of multi agents. Semantic web-based technologies are more focused on the strategic goals and decompose them into lower level technical tasks. However, they can only be used for web-based businesses. UML and PN based approaches are defining how collaboration should be achieved and they provide documentation of the collaborative process. However, agent-based and semantic-based approaches are performative and show how the actual collaboration will be performed.

V. CONCLUSION

cBPM plays a key role in the modern business process management field. This paper presented the state- of- art of cBPM approaches. These approaches lack standardization and simplicity in terms of their implementation and understanding of the terminologies by non-technical persons. Approaches

TABLE 1 BRIEF SUMMARY OF COLLABORATIVE MODELING APPROACHES.

Modeling Framework	Modeling Target	Tool	Modeling Scope	Limitations
Extension of UML				
CPM : Based on UML activity diagram and consists of ten elements.	Industrial Case Study	Still Conceptual Method	To get benefit of Petri-Net Analysis power transform it into Petri-Nets and in extended version of CPM they also used ICOM property of IDEF0 Collaboration between enterprise to different supplier and production enterprises available.	o Does not have element to present state of process. o Process-oriented approach, unable to present different point-of-view o Model verification and simulation is not possible. o Limited for temporal relations between entities
MDA based Combination of UML and UP-CoIBPIP used for modeling and interaction protocols.	Academic	Available	BPMN language is used for the representation of interface process model. Collaboration between different enterprise can be handled	
Based on UML 2 Activity diagram and MDA approach	Academic	Available	Encourages decentralized management of collaborative processes. Collaboration between different enterprises can be handled.	
Extension of Petri Nets				
Petri-Net Schema combined with XML	Academic	INCOME2 010 Prototype	Utilized web for interface between different partners. Utilization of performance indicator based modeling enhanced the analysis and monitoring of business process.	o Models become very complex with respect to representation of multiple actors o Models are not easily understandable by non-technical representation
Combination of stochastic Petri-Nets, coloured mechanic and object oriented features. Define five more tuples	Academic	Expect	Overcome the defect of SPN for the presentation of dynamic parallel mechanics. Collaboration between different partners can be modeled	
Combination of EPC and Petri-nets explored. Based on Design science Approach	Academic	CoMoMod	Simultaneous work of different modelers on business model and use of different languages (EPC and Petri-Net).	
Petri-Net and DEMO transactions	Industrial Case Study	Available	Participation of different actors in modeling is possible.	
Agent based Methodology				
Agent based process ontology Approach	Academic	Available	Human centric and application centric Environment	o Very complex process in terms of messages, description and expression of multi agents.
UML based multi agent collaboration model with CNP. Different symbols introduced for agent UML message	Academic	Available	Complex in virtual environment, support collaboration between different organization	
Semantic Web based Methodology				
Business OWL-ontology based introduced HTN planning algorithm	Academic	Genesis	Dynamic decomposition of tasks and collaboration between different actors available through Genesis GUI	o High complexity o Only suitable for type of businesses that are web-based / rely on web services.
DREAMs Framework BPEL used at provider side and ontology is described by WSML and BPMN.	Academic	Available	Collaborative modeling between different organizations possible. Process verification is also possible by using semantic model checking algorithm.	

such as the UML-based are uncomplicated, but they are not able to handle collaboration and states of processes in effective way. Yet, other approaches are able to support the collaboration feature in effective way, but they are more complicated. Finally, cBPM is a stimulating topic from both a practical and scientific perspective.

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