Collaborative Business Process Management – A Literature-based Analysis of Methods for Supporting Model Understandability

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Abstract. Due to the growing amount of cooperative business scenarios, collaborative Business Process Management (cBPM) has emerged. The increased number of stakeholders with minor expertise in process modeling leads to a high relevance of model understandability in cBPM contexts. Despite extensive works in the research fields of cBPM and model understandability in BPM, there is no analysis and comprehensive overview of methods supporting process model understandability in cBPM scenarios. To address this research gap, this paper presents the results of a literature review. The paper identifies concepts for supporting model understandability in BPM, provides an overview of methods implementing these concepts, and discusses the methods' applicability in cBPM. The four concepts process model transformation, process model visualization, process model description, and modeling support are introduced. Subsequently, 69 methods are classified and discussed in the context of cBPM. Results contribute to revealing existing academic voids and can guide practitioners in cBPM scenarios.

Keywords: Business Process Management, Collaborative Business Process Management, Model Understandability, Literature Review

1 Introduction

Business Process Management (BPM) is a discipline that combines computer science and management science and has gained a considerable amount of attention over the last decades [1, 2]. The growing importance of cooperation due to globalization and the trend of blurring organizational boundaries lead to collaboration in BPM [1, 3–5]. *Collaborative Business Process Management* (cBPM) is concerned with the management of business processes across organizational boundaries [4]. Since cBPM integrates different collaborating organizations [5, 6], the number of stakeholders involved in business process modeling activities is high. However, since not all relevant stakeholders are experienced in process modeling and the particular notations [7], the models might not be fully understood by all stakeholders [8]. Clearly, there exists a gap between modeling experts and inexperienced stakeholders like domain experts [8–10]. This gap needs to be bridged to guarantee success in cBPM projects [11–13].

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For addressing this knowledge gap, a considerable amount of research in the field of business process model understandability has been conducted [14, 15]. Many of these contributions are experimental works focusing on factors that influence model understandability [14]. Researchers investigate factors of modeling languages, model characteristics, model content related factors or personal factors that influence model understandability [7, 16–19]. For example, Figl et al. investigate the influences of routing symbols of modeling languages on process model understandability [19]. Reijers and Mendling observed that model characteristics such as the average connectors degree or the overall density of a model affect its understandability [7]. Furthermore, Mendling and Strembeck found out that long element labels influence model understandability negatively [16].

Researchers recognize the relevance of cBPM on the one hand and model understandability in the context of BPM on the other hand. However, there is currently no review that analyzes methods implementing concepts for supporting model understandability in BPM and evaluates the methods' suitability for cBPM. This paper's objective is to identify existing methods in the intersection of the topics model understandability and BPM and to discuss the general applicability of these methods in the context of cBPM. Therefore, we have performed a structured literature analysis and address the following research question: *What are methods supporting model understandability in BPM and to what extent are they applicable to cBPM?* Our results provide a comprehensive overview of the last decade's academic work on the topic of model understandability in BPM and a discussion on the usage in cBPM. Practitioners can use it as guidance for identifying potential methods supporting their business. Academics can rely on our work to identify academic voids and plan future research.

The remainder of this paper is structured as follows: Section 2 presents the underlying research background on cBPM and model understandability. In Section 3, we describe the applied research method. We derive concepts for supporting model understandability and provide an overview of methods that implement these concepts in Section 4. In Section 5, we combine model understandability and cBPM by discussing the methods' applicability for cBPM. Finally, in Section 6, we draw a conclusion and present potential future work.

2 Research Background

2.1 BPM and cBPM

BPM is concerned with operational business processes and their management, improvement [2], re-design, analysis, or support with information systems (IS) [18]. An increasing importance of global value chains leads to a trend of blurring organizational boundaries in the context of BPM [3, 4]. Against this background, cBPM is an expansion of BPM that strives to cover business processes across inter-organizational boundaries [20].

cBPM can be described as the management of (collaborative) business processes across organizational boundaries involving actors from inside or from outside an organization [4]. Hence, in comparison to traditional BPM, cBPM incorporates an *increased number of stakeholders* since it affects not only a single organization but also at least one additional organization [5]. Besides, since organizations with a similar business model rather tend to compete than to collaborate, the *group of stakeholders possesses a high degree of heterogeneity.*

Consequently, the collaboration comprises organizations with different product portfolios and from different domains, which strive to deliver more value to their customers. Due to the increased number of stakeholders, the higher degree of heterogeneity, and the resulting need for coordination, cBPM has to cope with *more complex business processes* [3]. Increased complexity in the execution of business models also affects the modeling and thus results in *more complex process models* in cBPM [3]. Process models have to capture the more sophisticated control flow relations in these business processes and have to integrate different modeling conventions in the participating organizations [3].

Additionally, in contrast to traditional BPM, *privacy* plays a more important role in cBPM since confidential information of one organization must not cross organizational boundaries [20]. Therefore, certain information in process models must be kept secret to cooperating organizations [20].

In consequence, it is especially challenging in the context of cBPM to reach a common understanding of the process models among relevant stakeholders [21]. Although model understandability is relevant in traditional BPM, the mentioned reasons increase its importance in cBPM, but likewise, impede its achievement.

2.2 From Model Quality to Model Understandability

Business process models as central artifacts in BPM [2, 5] are the basis for the development of process-oriented IS [22, 23]. Process models have to possess high quality to obtain IS of high quality [24–26]. Model understandability can be considered as a factor of model quality [14, 15]. Some quality frameworks [27, 28] include the dimension *pragmatic quality*. Pragmatic quality is concerned with the degree to which a model is correctly interpreted or understood by an end-user or stakeholder [27, 29]. Accordingly, understandability is often referred to as a factor of pragmatic quality [14, 15, 25, 30, 31].

Pragmatic quality is defined as the “correspondence between the model and the […] interpretation of the model” [29, p. 94]. So-called *pragmatic means*, introduced by Lindland et al. [27], can be applied to reach the goal of pragmatic quality, i.e. understanding a model. In this sense, pragmatic means make a model more understandable [27, 29]. Pragmatic means are model animation, model simulation, model visualization, model transformation, model filtering, model abstraction, model translation, model explanation, as well as aesthetics for diagram layout, model paraphrasing, and participant training [27, 32]. Based on pragmatic means, we derive concepts that support model understandability and analyze methods that implement these concepts.

3 Research Method

The literature-based analysis conducted in this work is based on the approaches for systematic literature reviews proposed by Webster and Watson [33] and vom Brocke et al. [34]. To further define the scope [34] and to articulate the contribution of the work in detail [33], vom Brocke et al. [34] propose the application of the taxonomy for literature reviews by Cooper [35]. The paper's taxonomy is visualized in Table 1. The gray cells in the table below represent the focus of this literature analysis.

Table 1. Classification (gray cells) of the present literature-based analysis following [34]

<table>
<tr><th>Characteristic</th><th colspan="6">Categories</th></tr>
<tr><td>focus (1)</td><td>research outcomes</td><td colspan="2">research methods</td><td colspan="2">theories</td><td>applications/practices</td></tr>
<tr><td>goal (2)</td><td colspan="2">integration</td><td colspan="2">criticism</td><td colspan="2">central issues</td></tr>
<tr><td>organization (3)</td><td colspan="2">historical</td><td colspan="2">conceptual</td><td colspan="2">Methodological</td></tr>
<tr><td>perspective (4)</td><td colspan="3">neutral representation</td><td colspan="3">espousal of position</td></tr>
<tr><td>audience (5)</td><td>specialized scholars</td><td colspan="2">general scholar</td><td colspan="2">practitioners</td><td>general public</td></tr>
<tr><td>coverage (6)</td><td>exhaustive</td><td colspan="2">exhaustive and selective</td><td colspan="2">representative</td><td>central/pivotal</td></tr>
</table>

This paper's search process follows the guidelines for literature reviews as proposed by vom Brocke et al. [34]. The approach includes the four phases: journal search, database search, keyword search and backward and forward search. Webster and Watson [33] propose a topic-based search across all relevant journals. Since it includes a large number of electronic articles and provide access to leading IS journals, Elsevier Scopus was selected as database.

To search for relevant publications, the search string in Figure 1 was used[1]. The search string comprises three constituents: Terms from the cBPM literature, terms related to pragmatic means respectively model understandability, and additional terms that are used to further limit the scope on process modeling respectively conceptual modeling. The search string was applied on the 24th October of 2016 and led to 2448 results.

After this keyword search, the results were evaluated regarding their relevance [34]. For this purpose, vom Brocke et al. [34] propose an analysis of the titles, abstracts or full texts of the search results. A title-based analysis of the total results led to 102 results considered as relevant. Based on their abstracts, these 102 publications were then analyzed in detail concerning their relevance for answering the research question. This procedure led to 43 relevant methods from 43 publications.

In addition to a keyword search, Webster and Watson [33] recommend a forward and backward search based on the evaluated results of the keyword search. Using the results of the keyword search, a one-level backward and forward search was conducted, which included referencing and referenced works of the 43 publications that were

[1] The search string uses the syntax of Elsevier Scopus. It includes the Boolean operators OR and AND. The * is a wildcard symbol. The search was limited to the following subject areas which are considered as being relevant: Computer Science, Engineering, Mathematics, Decision Sciences, Multidisciplinary and Business, Management and Accounting.

considered as relevant. Performing the backward search and the forward search with the database Google Scholar led to 26 additional methods from 14 publications. Our literature search finally resulted in 69 methods from 57 publications that were considered relevant.

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( TITLE-ABS-KEY("collaborat*" OR “choreograph*” OR “modeling support” OR “modelling support” OR
"cooperat*" OR "interorganizational" OR "inter-organizational" OR "cross-organizational" OR "filter" OR "view"
OR "filtering" OR "visual*" OR "translat*" OR "transform*" OR "layout" OR "training" OR "workshop" OR
"explanation" OR "paraphras*" OR "simulat*" OR "execution" OR "animation") AND
TITLE-ABS-KEY("pragmatic quality" OR "clarity" OR "interpretation" OR "understand*" OR "comprehen*") AND
TITLE-ABS-KEY("process model*" OR "conceptual model*") ) AND
SUBJAREA(MULT OR COMP OR ENGI OR MATH OR BUSI OR DECI) AND ( EXCLUDE(SUBJAREA,"ENVI" )
OR EXCLUDE(SUBJAREA,"EART" ) OR EXCLUDE(SUBJAREA,"SOCI" ) OR EXCLUDE(SUBJAREA,"MEDI" )
OR EXCLUDE(SUBJAREA,"PSYC" ) OR EXCLUDE(SUBJAREA,"MATE" ) OR EXCLUDE(SUBJAREA,"CENG" )
OR EXCLUDE(SUBJAREA,"BIOC" ) OR EXCLUDE(SUBJAREA,"AGRI" ) OR EXCLUDE(SUBJAREA,"PHYS" )
OR EXCLUDE(SUBJAREA,"CHEM" ) OR EXCLUDE(SUBJAREA,"ENER" ) OR EXCLUDE(SUBJAREA,"NEUR" )
OR EXCLUDE(SUBJAREA,"ARTS" ) OR EXCLUDE(SUBJAREA,"ECON" ) OR EXCLUDE(SUBJAREA,"HEAL" )
OR EXCLUDE(SUBJAREA,"IMMU" ) OR EXCLUDE(SUBJAREA,"NURS" ) OR EXCLUDE(SUBJAREA,"PHAR" ) )
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Figure 1. Scopus search string

4 Supporting Model Understandability in BPM

4.1 Concepts for Supporting Model Understandability in BPM

Following the search process, the relevant results were synthesized and analyzed using a concept-centric matrix [33]. The concepts for this matrix were derived in two different ways: Deductively with pragmatic means and inductively based on the search results themselves. Since pragmatic means are instruments making a model more understandable, they represent appropriate concepts for classifying the search results. For clarity and for facilitating a better discrimination between the concepts, similar pragmatic means were grouped together. The relevant concepts for this literature analysis that were derived from pragmatic means in this manner are *process model transformation*, *process model visualization*, and *process model description.* Besides, the search results led to some results that are best classified as the concept *modeling support*. The pragmatic mean *participant training* stretches across all concepts. Figure 2 visualizes the concepts.

Modeling support (I). The concept *modeling support* is not directly derived from any pragmatic means. However, the analysis of the search results led to a number of methods that are best assigned to this additional concept. Correspondingly classified methods strive to support model understandability already during the construction process of the model. Consequently, this concept comprises contributions providing a new or extended modeling language [36], a special modeling tool [37], or a method that uses existing modeling notations in an innovative way [38]. Methods that integrate the use of collaborative technologies such as commenting, audio-communication, video-communication, and chatting functionalities into the modeling process are also assigned to this concept [11]. In contrast to this, methods that operate on already constructed models are not part of this concept.

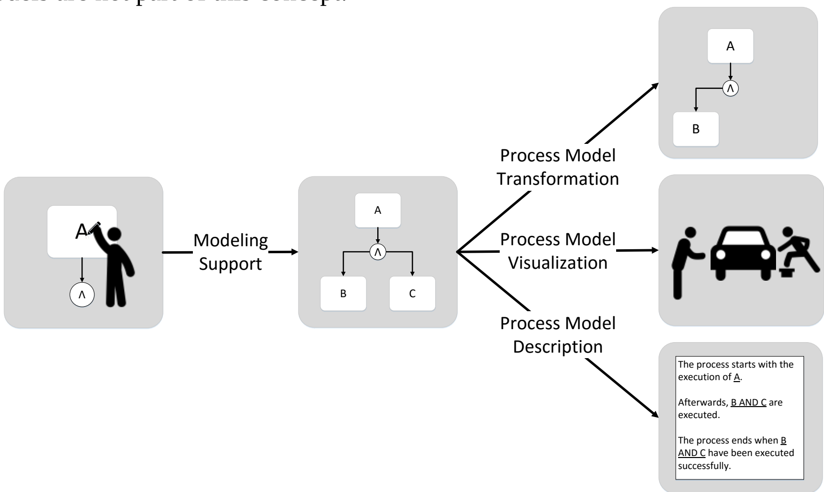

Figure 2. Concepts for supporting model understandability

Process model transformation (II). The concept *process model transformation* is derived from the pragmatic means *model transformation* and *aesthetics for diagram layout.* The means *model abstraction* and *model filtering* are also the basis for this concept since they are concerned with abstracting a model [29] or filtering out irrelevant model elements. This concept aims at the generation of specific views on models. As a result, transformation methods reduce model complexity [39], support the overall model understandability, and hence facilitate activities like the communication of the model to involved stakeholders [40].

Process model visualization (III). The pragmatic means *visualization*, *simulation*, and *animation* are the basis for the concept *process model visualization*. This concept comprises the alternative visualization of a process model's content. In other words, elements of a process model are depicted by alternative visual representations of non-model elements that substitute the original model elements. This concept also covers process animations. The use of visualization mechanisms enables an improved and understandable process model representation [9, 10, 41]. Whereas model transformation (II) relies on restructuring or visualization with alternative model elements, model visualization makes use of non-model elements.

Process model description (IV). *Process model description* comprises the pragmatic means *model paraphrasing*, *explanation*, and *translation* [27, 32]. This concept covers textual descriptions or explanations of a process model to raise its understandability. This, for instance, includes the automatic generation of textual descriptions capturing the process logic as depicted in a process model. The generation of natural language process model descriptions with explanatory character supports model understandability as it allows focusing on process model semantics rather than syntax. In contrast to the concepts (II) and (III), this concept makes use of texts and does not incorporate graphical elements.

4.2 Methods for Supporting Model Understandability in BPM

The identified literature was classified using the concepts explained above. The classification is presented in a concept-centric matrix (see Table 2) as proposed in [33]. The previously introduced concepts are not disjunctive. Consequently, a method can be assigned to more than one concept.

Modeling support. In total, there are 35 methods supporting the modeling process, which can be divided into three different groups, namely a) tools using collaborative technologies (No. 31-33, 38-53), b) methods providing new or extended languages (No. 9, 11-13, 16, 65) and c) tools using existing modeling languages (No. 6, 8, 17, 19, 29, 55-56, 58, 60, 63). Tools using collaborative technologies facilitate process modeling with the support of collaborative technologies such as commenting or text- and/or audio-based chats for supporting model understandability. Some methods of this concept focus on new modeling languages claiming to be less complex and easy to understand. Methods using existing modeling languages try to support model understandability by employing those languages in specific ways or adapting some existing modeling methods for process modeling.

Process model transformation. In total, the literature search led to 41 methods that are concerned with process model transformation. 22 out of 41 methods focus on altering the model's physical structure (No. 1-7, 10, 11, 14, 15, 18, 23, 25, 30, 42, 49, 51-53, 64). Generally speaking, these methods abstract from insignificant process model information, i.e. they focus on relevant information and omit irrelevant parts of a process model. In contrast, 28 out of 41 methods change the model's presentation, i.e. its appearance, scheme or layout (No. 6, 14, 19, 25-27, 31-36, 42, 48, 51-53, 56-62, 66-69). A transformation of a model's presentation does not change its physical structure to highlight relevant model information [39].

Process model visualization. The concept-centric matrix indicates that nine methods enable some kind of process model visualization. In this set of methods, the simplest form of process model visualization is accomplished by the use of additional non-model images (No. 20, 26). Advanced methods (No. 33, 31, 28, 32, 55) make use of 3D virtual world environments for visualizing a process model in a real-world like representation. The visualization of the token flow (No. 37, 66) in a process model is also a relevant implementation of this concept. The displayed token flow represents the execution order of activities to aid the analysis or validation of a process model.

Process model description. Five out of 69 methods are concerned with the generation and integration of process model descriptions capturing the process logic. Methods of this concept differ in the modeling language support and in the fashion, how they create process model descriptions. Methods can be generic as well as modeling language specific. Starting with a process model, descriptions are generated and integrated either automatically based on sophisticated algorithms (No. 21-22, 25, 54) or manually following specific guidelines (No. 24).

Table 2. Concept matrix

#	Src	Method	I	II	III	IV
1	[61]	Shared Process Model		•		
2	[62]	Tailored process model abstraction		•		
3	[63]	Process model abstraction slider		•		
4	[64]	Process model abstraction with data support		•		
5	[65]	Graph-based process model refactoring (IBUPROFEN)		•		
6	[66]	Modeling with Concurrent Task Trees	•	•		
7	[67]	Semantic process model abstraction		•		
8	[68]	Ontological process modeling	•			
9	[69]	Subject-oriented business process management	•			
10	[70]	Aspect-oriented BP Modeling (AO4BPMN)		•		
11	[36]	Knowledge intensive process notation	•	•		
12	[71]	Domain specific modeling languages (DSLs4BPM)	•			
13	[72]	Lightweight process modeling	•			
14	[73]	Deontic BPMN		•		
15	[74]	Scenario-based process modeling (GRETA)		•		
16	[75]	Role-based process modeling	•			
17	[76]	Context-driven process modeling	•			
18	[77]	Aspect-oriented BPM (AO-BPM)		•		
19	[78]	Spreadsheet-based process modeling	•	•		
20	[60]	end-user approach to process modeling			•	
21	[79]	Hypertext Expl. for process models (OMT Explainer)				•
22	[8]	Text Generation for process models				•
23	[80]	Personalized process model visualization (Proviado)		•		
24	[81]	Integration of natural language artifacts				•
25	[82]	Personalized and verbalized PM descriptions (proView)		•		•
26	[40]	Storyboard Augmentation		•	•	
27	[83]	3D repr. of business process models (RELAX NG)		•		
28	[9]	3D representation of BP Models			•	
29	[38]	Tangible business process modeling	•			
30	[84]	Event-driven Proc. Chain abstraction		•		
31	[85]	cBPM in 3D virtual worlds (I)	•	•	•	
32	[11]	cBPM in 3D virtual worlds (II)	•	•	•	
33	[10]	Modeling in 3D virtual worlds	•	•	•	
34	[86]	3D-Navigator for BP Models		•		
35	[87]	BPMN layout patterns		•		
36	[88]	Interactive BPMN layout tool		•		
37	[41]	Token flow animation			•	
38	cited in [12]	cPM (ProcessWave)	•			
39	[37]	cPM (CoMoMod)	•			
40	[42]	cPM (COMA)	•			
41	cited in [43]	cPM (BONAPART Collaborative)	•			
42	cited in [43]	cPM (Signavio Process Editor)	•	•		
43	cited in [43]	cPM (Enterrise Architect)	•			
44	cited in [43]	cPM (CA ERwin Process Modeler)	•			
45	cited in [43]	cPM (iGrafx Process Modeler)	•			
46	cited in [43]	cPM (Business Modeler Advanced)	•			
47	cited in [43]	cPM (Microsoft Visio)	•			
48	cited in [43]	cPM (Adonis)	•	•		
49	cited in [43]	cPM (Savvion Process Manager)	•			
50	cited in [43]	cPM (Innovator for Business Analysts)	•			
51	cited in [11]	cPM (ARIS Business Architect)	•	•		
52	cited in [11]	cPM (SAP StreamWork)	•	•		
53	cited in [11]	cPM (IBM Blueworks Live)	•	•		
54	[44]	Language generation for process models				•
55	[45]	Virtual business role-play	•		•	
56	[46]	Layout features of process models	•	•		
57	[47]	BPMN refactoring		•		
58	[48]	Layout features of process models	•	•		
59	[49]	Optimizing spaghetti process models		•		
60	[50]	Business processes to touch	•	•		
61	[51]	User-friendly model Visualizations		•		
62	[52]	Task-specific visual cues		•		
63	[53]	Collaborative articulation of models	•			
64	[54]	Collaborative product and process model		•		
65	[55]	Visualizing declarative process models	•			
66	[56]	Dynamic visualization of process models		•	•	
67	[57]	Revealing hidden dependencies		•		
68	[58]	Process model refactoring		•		
69	[59]	Syntax highlighting in process models		•		
Σ			**35**	**41**	**9**	**5**

5 Discussion

According to the research question and based on the characteristics of cBPM presented in the research background, we discuss the concepts and their methods for supporting model understandability regarding their applicability in cBPM.

Modeling support and cBPM. Due to the increased number of stakeholders in cBPM [4], collaborating techniques for modeling are required. Therefore, modeling methods that integrate collaborative technology are promising (e.g. No. 32, 39). However, these methods support the modeling process that is mainly performed by modeling experts instead of domain experts. Thus, the increased semantic complexity perceived by domain experts is not overcome and can only be addressed by communication between domain experts and modeling experts.

The group of methods that provide new or extended modeling language strives to increase model understandability by focusing on reduced syntactic complexity of the modeling language (e.g. No. 13). However, new modeling languages require extensive implementation efforts as existing modeling practices need to be reorganized which is especially relevant in cBPM settings with many diverse stakeholders.

Another group of methods focuses on existing modeling languages that are used in specific ways (e.g. No. 6, 29). Such methods could lead to a closer integration of modeling experts and domain experts during the model creation. An advantage is less implementation effort since these languages may already be in use.

Process model transformation and cBPM. Methods that modify the model's physical structure to abstract from insignificant details reduce the complexity of process models. In this way, the diverse domain knowledge of the many participating stakeholders [5] is addressed as personalized model views contain only relevant process logic. Furthermore, these methods are relevant to preserve autonomy and privacy of collaborating organizations, which are of increased importance in cBPM [89]. They allow the omission of sensitive and confidential internal information (e.g. No. 3, 23).

Transforming the process model's presentation allows for tailoring the model elements to the specifics of stakeholders. However, the increased model complexity in cBPM [3] is not completely addressed as the number of activities and control flow relations is not reduced by changing its presentation. Especially, the aspect of privacy issues in cBPM settings is not targeted by those methods since they do not hide model elements. Therefore, these methods are only applicable in combination with structural transformations to ensure privacy (e.g. No. 6, 14, 25).

Process model visualization and cBPM. The visualization of process models overcomes difficulties in understanding modeling language elements, i.e. the syntax of language elements [10]. Consequently, visualizations allow focusing on model semantics rather than syntax. To handle the increased semantic complexity in cBPM [3], visualization methods can be used since they abstract from model syntax and thereby decrease complexity for domain experts with low modeling expertise. In contrast, process model transformation methods rely on the model syntax and are therefore less appropriate in cBPM.

Since processes are more complex in cBPM scenarios [3], more complex methods are required for increasing model understandability in general. Hence, within the group of methods for process model visualization, 3D virtual environments are superior to less comprehensive methods (e.g. No. 31, 33). However, confidentially of private activities remains an open issue in all methods that are subsumed under this concept.

Process model description and cBPM. The set of methods that create process model descriptions strives to increase model understandability by natural language representations of process models. The translation of process models to natural language reduces the relevance of understanding formal modeling syntax. In consequence, these methods are more effective than methods for process model transformation to increase model understandability in cBPM in general.

Apparently, generic methods are superior to methods that are dedicated to a specific modeling language. Many diverse stakeholders with different modeling conventions are involved in a cBPM scenario. Therefore, methods that can handle different modeling languages are recommended (e.g. No. 22, 25). Besides, privacy requirements are more easily met with manual instead of automatic methods.

6 Conclusion

The aim of this paper was to derive concepts for supporting model understandability in the context of BPM, present exemplary implementations of these concepts, and discuss their suitability in cBPM contexts. The identified concepts *process model transformation*, *process model visualization*, *process model description* and *modeling support* are promising to be useful for cBPM-specific issues, although to varying degrees. Process model transformation is useful for specifying views to hide confidential information, process model visualization and process model description are suitable to increase the model understandability for domain experts with low modeling experience and methods supporting the modeling itself provide valuable mechanisms for the collaborative development of business process models. In total, 41 implementations for model transformation were detected; nine methods deal with model visualization, five methods focus on model description and 35 implementations provide modeling support.

This paper contributes to research by providing an overview of methods for addressing model understandability that allows for the identification of academic voids and presenting four categories to classify such methods. Practitioners can use our results as guidance for the use in cBPM scenarios. In future research, our paper can be extended by a detailed comparison of the analyzed methods related to each concept. Additionally, the methods can be empirically validated regarding their applicability in cBPM contexts. Besides, it can be investigated whether factors that influence model understandability differ from traditional BPM to cBPM.

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References

1. Houy, C., Fettke, P., Loos, P., van der Aalst, W. M. P., Krogstie, J.: BPM-in-the-Large – Towards a Higher Level of Abstraction in Business Process Management. In: Janssen, M., Lamersdorf, W., Pries-Heje, J., and Rosemann, M. (eds.) E-Government, E-Services and Global Processes. pp. 233–244. Springer Berlin Heidelberg (2010).
2. van der Aalst, W. M. P.: Business Process Management : A Comprehensive Survey. ISRN Softw. Eng. 2013, 1–37 (2013).
3. Adam, O., Hofer, A., Zang, S.: A collaboration framework for cross-enterprise business process management. In: Preproceedings of the First International Conference on Interoperability of Enterprise Software and Applications INTEROP-ESA. pp. 499–510 (2005).
4. Niehaves, B., Plattfaut, R.: Collaborative business process management: status quo and quo vadis. Bus. Process Manag. J. 17, 384–402 (2011).
5. Aleem, S., Lazarova-Molnar, S., Mohamed, N.: Collaborative Business Process Modeling Approaches: A Review. In: Proc. of the 2012 IEEE 21st International workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises. pp. 274–279 (2012).
6. Chen, Q., Hsu, M.: Inter-enterprise collaborative business process management. In: Proceedings of the 17th International Conference on Data Engineering. pp. 253–260. Published by the IEEE Computer Society (2001).
7. Reijers, H. A., Mendling, J.: A Study Into the Factors That Influence the Understandability of Business Process Models. IEEE Trans. Syst. Man Cybern. Part A. 41, 449–462 (2011).
8. Leopold, H., Mendling, J., Polyvyanyy, A.: Generating Natural Language Texts from Business Process Models. In: Ralyte, J., Franch, X., Brinkkemper, S., and Wrycza, S. (eds.) Advanced Information Systems Engineering. pp. 64–79. Springer Berlin Heidelberg (2012).
9. Guo, H., Brown, R., Rasmussen, R.: Virtual worlds as a model-view approach to the communication of business processes models. CEUR Workshop Proc. 855, 66–73 (2012).
10. Brown, R. A.: Conceptual Modelling in 3D Virtual Worlds for Process Communication. In: Procedings of the 7th Asia-Pacific Conference on Conceptual Modelling (APCCM 2010). pp. 25 – 32. , Brisbane (2010).
11. Poppe, E., Brown, R., Recker, J., Johnson, D.: Improving Remote Collaborative Process Modelling using Embodiment in 3D Virtual Environments. In: 9th Asia-Pacific Conference on Conceptual Modelling. pp. 51–60 (2013).
12. Recker, J., Mendling, J., Hahn, C.: How collaborative technology supports cognitive processes in collaborative process modeling: A capabilities-gains-outcome model. Inf. Syst. 38, 1031–1045 (2013).
13. Recker, J., Reijers, H. A., van de Wouw, S. G.: Process model comprehension: The effects of cognitive abilities, learning style, and strategy. Commun. Assoc. Inf. Syst. 34, 199–222 (2014).
14. Houy, C., Fettke, P., Loos, P.: Understanding understandability of conceptual models - What are we actually talking about? In: Atzeni, P., Cheung, D., and Ram, S. (eds.) Conceptual Modeling. pp. 64–77. Springer Berlin Heidelberg (2012).
15. Houy, C., Fettke, P., Loos, P.: on the Theoretical Foundations of Research Into the Understandability of Business Process Models. In: Proceedings of the 22nd European Conference on Information Systems. pp. 1–26 (2014).
16. Mendling, J., Strembeck, M.: Influence Factors of Understanding Business Process Models. In: Abramowicz, W. and Fensel, D. (eds.) Business Information Systems. pp. 142–153. Springer Berlin Heidelberg (2008).
17. Mendling, J., Reijers, H. A., Cardoso, J.: What Makes Process Models Understandable? In: Alonso, G., Dadam, P., and Rosemann, M. (eds.) Business Process Management. pp. 48–63. Springer Berlin Heidelberg (2007).

18. Mendling, J., Strembeck, M., Recker, J.: Factors of process model comprehension-Findings from a series of experiments. Decis. Support Syst. 53, 195–206 (2012).
19. Figl, K., Mendling, J., Strembeck, M., Recker, J.: On the cognitive effectiveness of routing symbols in process modeling languages. In: Abramowicz, W. and Tolksdorf, R. (eds.) Business Information Systems. pp. 230–241. Springer Berlin Heidelberg (2010).
20. Liu, C., Li, Q., Zhao, X.: Challenges and opportunities in collaborative business process management: Overview of recent advances and introduction to the special issue. Inf. Syst. Front. 11, 201–209 (2009).
21. Mendling, J., Recker, J. C., Wolf, J.: Collaboration Features in Current BPM Tools. EMISA Forum. 32, 48–65 (2012).
22. Moody, D.: Cognitive Load Effects on End User Understanding of Conceptual Models: An Experimental Analysis. In: Benczur, A., Demetrovics, J., and Gottlob, G. (eds.) Advances in Databases and Information Systems. pp. 129–143. Springer Berlin Heidelberg (2004).
23. Scheer, A.-W., Nüttgens, M.: ARIS Architecture and Reference Models for Business Process Management. In: van der Aalst, W., Desel, J., and Oberweis, A. (eds.) Business Process Management. pp. 366–379. Springer Berlin Heidelberg (2000).
24. Moody, D. L.: Theoretical and practical issues in evaluating the quality of conceptual models: current state and future directions. Data Knowl. Eng. 55, 243–276 (2005).
25. Moreno-Montes de Oca, I., Snoeck, M., Reijers, H. A., Rodríguez-Morffi, A.: A systematic literature review of studies on business process modeling quality. Inf. Softw. Technol. 58, 187–205 (2015).
26. Wand, Y., Weber, R.: Research Commentary: Information Systems and Conceptual Modeling—A Research Agenda. Inf. Syst. Res. 13, 363–376 (2002).
27. Lindland, O. I., Sindre, G., Solvberg, A.: Understanding quality in conceptual modeling. IEEE Softw. 11, 42–49 (1994).
28. Nelson, H. J., Poels, G., Genero, M., Piattini, M.: A conceptual modeling quality framework. Softw. Qual. J. 20, 201–228 (2012).
29. Krogstie, J., Sindre, G., Jørgensen, H.: Process models representing knowledge for action: a revised quality framework. Eur. J. Inf. Syst. 15, 91–102 (2006).
30. Patig, S.: A practical guide to testing the understandability of notations. Conf. Res. Pract. Inf. Technol. Ser. 79, 49–58 (2008).
31. Moody, D. L., Sindre, G., Brasethvik, T., Sølvberg, A.: Evaluating the Quality of Process Models: Empirical Testing of a Quality Framework. In: Spaccapietra, S., March, S. T., and Kambayashi, Y. (eds.) Conceptual Modeling - ER 2002. pp. 380–396. Springer Berlin Heidelberg (2003).
32. Krogstie, J., Lindland, O. I., Sindre, G.: Defining quality aspects for conceptual models. In: Proceedings of the IFIP international working conference on Information system concepts: Towards a consolidation of views. pp. 216–231 (1995).
33. Webster, J., Watson, R. T.: Analyzing the Past to Prepare for the Future: Writing a Literature Review. MIS Q. 26, xiii – xxiii (2002).
34. vom Brocke, J., Simons, A., Niehaves, B., Riemer, K., Plattfaut, R., Cleven, A.: Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process. In: ECIS 2009 Proceedings. pp. 2206–2217 (2009).
35. Cooper, H. M.: Organizing knowledge synthesis: a taxonomy of literature reviews. Knowl. Soc. 1, 104–126 (1988).
36. Netto, J. M., Franca, J. B. S., Baiao, F. A., Santoro, F. M.: A notation for Knowledge-Intensive Processes. In: Proceedings of the 2013 IEEE 17th International Conference on Computer Supported Cooperative Work in Design, CSCWD 2013. pp. 190–195 (2013).

37. Dollmann, T., Houy, C., Fettke, P., Loos, P.: Collaborative business process modeling with CoMoMod: A toolkit for model integration in distributed cooperation environments. In: Proceedings of the 20th IEEE International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises, WETICE 2011. pp. 217–222 (2011).
38. Grosskopf, A., Edelman, J., Weske, M.: Tangible business process modeling - Methodology and experiment design. In: Rinderle-Ma, S., Sadiq, S., and Leymann, F. (eds.) Business Process Management Workshops. pp. 489–500. Springer Berlin Heidelberg (2010).
39. Schumm, D., Leymann, F., Streule, A.: Process Viewing Patterns. In: Proceedings - IEEE International Enterprise Distributed Object Computing Workshop, EDOC. pp. 89–98 (2010).
40. Kathleen, N., Ross, B., Kriglstein, S.: Storyboard Augmentation of Process Model Grammars for Stakeholder Communication. In: IVAPP 2014: Proceedings of the 5th International Conference on Information Visualization Theory and Applications. pp. 114–121. , Lisbon (2014).
41. Allweyer, T., Schweitzer, S.: A Tool for Animating BPMN Token Flow. In: Mendling, J. and Weidlich, M. (eds.) Business Process Model and Notation. pp. 98–106. Springer Berlin Heidelberg (2012).
42. Rittgen, P.: Collaborative Business Process Modeling – Tool Support for Solving Typical Problems. In: International Conference on Information Resources Management (CONF-IRM). pp. 1–11 (2010).
43. Riemer, K., Holler, J., Indulska, M.: Collaborative process modelling-tool analysis and design implications. In: ECIS 2011 Proceedings (2011).
44. Ackermann, L., Schönig, S., Zeising, M., Jablonski, S.: Natural Language Generation for Declarative Process Models. In: Barjis, J., Pergl, R., and Babkin, E. (eds.) Enterprise and Organizational Modeling and Simulation. pp. 3–19. Springer International Publishing (2015).
45. Harman, J., Brown, R., Johnson, D., Rinderle-ma, S., Kannengiesser, U.: Virtual Business Role-Play : Leveraging Familiar Environments to Prime Stakeholder Memory During Process Elicitation. 1, 166–180.
46. Bernstein, V., Soffer, P.: How Does It Look? Exploring Meaningful Layout Features of Process Models. In: Persson, A. and Stirna, J. (eds.) Advanced Information Systems Engineering Workshops. pp. 81–86. Springer International Publishing (2015).
47. Khlif, W., Ben-Abdallah, H.: Integrating semantics and structural information for BPMN model refactoring. In: Computer and Information Science (ICIS) (2015).
48. Berstein, V., Soffer, P.: Identifying and Quantifying Visual Layout Features of Business Process Models. In: Gaaloul, K., Schmidt, R., Nurcan, S., Guerreiro, S., and Ma, Q. (eds.) Enterprise, Business-Process and Information Systems Modeling. pp. 200–2013. Springer International Publishing (2015).
49. Chinces, D., Salomie, I.: Optimizing spaghetti process models. In: International Conference on Control Systems and Science. pp. 506–511 (2015).
50. Kannengiesser, U., Oppl, S.: Business Processes to Touch : Engaging Domain Experts in Process Modelling.
51. Hipp, M., Strauss, A., Michelberger, B., Mutschler, B.: Enabling a User-Friendly Visualization of Business Process Models. In: International Conference on Business Process Management. pp. 1–12. Springer International Publishing.
52. Petrusel, R., Mendling, J., Reijers, H.A.: Task-specific visual cues for improving process model understanding. Inf. Softw. Technol. 79, 63–78 (2016).
53. Oppl, S.: Articulation of work process models for organizational alignment and informed information system design. Inf. Manag. 53, 591–608 (2016).
54. Geryville, H. M., Bouras, A., Ouzrout, Y., Sapidis, N. S.: Collaborative Product and Process Model : Multiple Viewpoints Approach. In: Technology Management Conference (ICE) (2006).

55. Hanser, M., Ciccio, C. Di, Mendling, J.: A Novel Framework for Visualizing Declarative Process Models. In: ZEUS Workshop. pp. 27–28 (2016).
56. Emens, R., Vanderfeesten, I., Reijers, H. A.: The Dynamic Visualization of Business Process Models: A Prototype and Evaluation. In: Proceedings of the 4th International Workshop on Theory and Application of Visualizations and Human-centric Aspects in Processes (2015).
57. De Smedt, J., De Weerdt, J., Serral, E., Vanthienen, J.: Improving Understandability of Declarative Process Models by Revealing Hidden. In: CAiSE. pp. 83–98 (2016).
58. Weber, B., Reichert, M., Mendling, J., Reijers, H. A.: Refactoring large process model repositories. Comput. Ind. 62, 467–486 (2011).
59. Reijers, H. A., Freytag, T., Mendling, J., Eckleder, A.: Syntax highlighting in business process models. Decis. Support Syst. 51, 339–349 (2011).
60. Antunes, P., Simões, D., Carriço, L., Pino, J. A.: An end-user approach to business process modeling. J. Netw. Comput. Appl. 36, 1466–1479 (2013).
61. Kuester, J., Voelzer, H., Favre, C., Branco, M., Czarnecki, K.: Supporting Different Process Views through a Shared ProcessModel. In: Van Grop, P., Ritter, T., and Rose, L. M. (eds.) Modelling Foundations and Applications. pp. 20–36. Springer Berlin Heidelberg (2013).
62. Mafazi, S., Mayer, W., Grossmann, G., Stumptner, M.: A Knowledge-based Approach to the Configuration of Business Process Model Abstractions. In: 1st International Workshop on Knowledge-intensive Business Processes. pp. 60–74 (2012).
63. Polyvyanyy, A., Smirnov, S., Weske, M.: Process model abstraction: A slider approach. In: Proceedings - 12th IEEE International Enterprise Distributed Object Computing Conference, EDOC 2008. pp. 325–331 (2008).
64. Meyer, A., Weske, M.: Data Support in Process Model Abstraction. In: Conceptual Modeling. pp. 292–306. Springer Berlin Heidelberg (2012).
65. Fernández-Ropero, M., Pérez-Castillo, R., Piattini, M.: Graph-Based Business Process Model Refactoring. Simpda. 16–30 (2013).
66. Kolb, J., Reichert, M., Weber, B.: Using Concurrent Task Trees for Stakeholder-centered Modeling and Visualization of Business Processes. In: Oppl, S. and Fleischmann, A. (eds.) S-BPM ONE - Education and Industrial Developments. pp. 237–251. Springer Berlin Heidelberg (2012).
67. Smirnov, S., Reijers, H. A., Weske, M.: A Semantic Approach for Business Process Model Abstraction. In: Mouratidis, H. and Rolland, C. (eds.) Advanced Information Systems Engineering. pp. 497–511. Springer Berlin Heidelberg (2011).
68. Thom, L. H., de Oliveira, J. P. M., Gassen, J. B., Abel, M.: Towards an Ontological Process Modeling Approach. In: ONTOBRAS-MOST. pp. 242–247 (2012).
69. Fleischmann, A., Metasonic AG, Kannengiesser, U., Schmidt, W., Stary, C.: Subject-Oriented Modeling and Execution of Multi-agent Business Processes. Proc. - 2013 IEEE/WIC/ACM Int. Conf. Intell. Agent Technol. IAT 2013. 2, 138–145 (2013).
70. Charfi, A., Müller, H., Mezini, M.: Aspect-Oriented Business Process Modeling with AO4BPMN Modelling Foundations and Applications. In: Kühne, T., Selic, B., Gervais, M.-P., and Terrier, F. (eds.) Modelling Foundations and Applications. pp. 48–61. Springer Berlin Heidelberg (2010).
71. Heitkötter, H.: A Framework for Creating Domain-specific Process Modeling Languages. In: Proceedings of the 7th International Conference on Software Paradigm Trends (ICSOFT). pp. 127–136 (2012).
72. Schnabel, F., Gorronogoitia, Y., Radzimski, M., Lecue, F., Mehandjiev, N., Ripa, G., Abels, S., Blood, S., Mos, A., Junghans, M., Agarwal, S., Vogel, J.: Empowering business users to model and execute business processes. In: zur Muehlen, M. and Su, J. (eds.) Business Process Management Workshops. pp. 433–448. Springer Berlin Heidelberg (2011).

73. Natschläger, C.: Deontic BPMN. In: Hameurlain, A., Liddle, S. W., Schewe, K.-D., and Zhou, X. (eds.) Database and Expert Systems Applications. pp. 264–278. Springer Berlin Heidelberg (2011).
74. Fahland, D., Weidlich, M.: Scenario-based process modeling with GRETA. In: Proceedings of the Business Process Management 2010. pp. 52–57 (2010).
75. Caetano, A., Zacarias, M., Silva, A. R., Tribolet, J.: A Role-Based Framework for Business Process Modeling. In: Proceedings of the 38th Hawaii International Conference on Systems Sciences (HICSS'05). pp. 1–7 (2005).
76. Born, M., Kirchner, J., Müller, J. P.: Context-driven business process modelling. In: Joint Proceedings of the 4th International Workshop on Technologies for Context-Aware Business Process Management, TCoB 2009. AT4WS 2009. AER 2009. MDMD 2009. In Conjunction with ICEIS 2009. pp. 17–26 (2009).
77. Cappelli, C., Santoro, F. M., Cesar Sampaio Do Prado Leite, J., Batista, T., Luisa Medeiros, A., Romeiro, C. S.: Reflections on the modularity of business process models: The case for introducing the aspect-oriented paradigm. Bus. Process Manag. J. 16, 662–687 (2010).
78. Krumnow, S., Decker, G.: A Concept for Spreadsheet-Based Process Modeling. In: Mendling, J., Weidlich, M., and Weske, M. (eds.) Business Process Modeling Notation. pp. 63–77. Springer Berlin Heidelberg (2010).
79. Dyke, N. W. Van: Generating Hypertext Explanations for Visual Languages. In: Proceedings of the Ninth ACM Conference on Hypertext and Hypermedia: Links, Objects, Time and Space - Structure in Hypermedia Systems. pp. 301–302 (1998).
80. Reichert, M.: Visualizing Large Business Process Models: Challenges, Techniques, Applications. In: La Rosa, M. and Soffer, P. (eds.) Business Process Management Workshops. pp. 725–736. Springer Berlin Heidelberg (2013).
81. Bittmann, S., Metzger, D., Fellmann, M., Thomas, O.: Additional Information in Business Processes: A Pattern-Based Integration of Natural Language Artefacts. In: Modellierung. pp. 137–152 (2014).
82. Kolb, J., Leopold, H., Mendling, J., Reichert, M.: Creating and Updating Personalized and Verbalized Business Process Descriptions. In: Grabis, J., Kirikova, M., Zdravkovic, J., and Stirna, J. (eds.) The Practice of Enterprise Modeling. pp. 191–205. Springer Berlin Heidelberg (2013).
83. Betz, S., Eichhorn, D., Hickl, S., Klink, S., Koschmider, A., Li, Y., Oberweis, A., Trunko, R.: 3D Representation of Business Process Models. MobIS. 73–87 (2008).
84. Polyvyanyy, A., Smirnov, S., Weske, M.: Reducing complexity of large EPCs. In: Modellierung betrieblicher Informationssysteme: Modellierung zwischen SOA und Compliance Management. pp. 195–207 (2008).
85. Brown, R., Recker, J., West, S.: Using virtual worlds for collaborative business process modeling. Bus. Process Manag. J. 17, 546–564 (2011).
86. Effinger, P.: A 3D-Navigator for Business Process Models. In: La Rosa, M. and Soffer, P. (eds.) Business Process Management Workshops. pp. 737–743. Springer Berlin Heidelberg (2013).
87. Effinger, P.: Layout Patterns with BPMN Semantics. In: Dijkman, R., Hofstetter, J., and Koehler, J. (eds.) Business Process Model and Notation. pp. 130–135. Springer Berlin Heidelberg (2011).
88. Effinger, P., Siebenhaller, M., Kaufmann, M.: An Interactive Layout Tool for BPMN. In: IEEE Conference on Commerce and Enterprise Computing. pp. 399–406 (2009).
89. Shen, M., Liu, D.-R.: Coordinating Interorganizational Workflows Based on Process-Views. In: Mayr, H. C., Lazansky, J., Quirchmayr, G., and Vogel, P. (eds.) Database and Expert Systems Applications. pp. 274–283. Springer Berlin Heidelberg (2001).