

## Overview of context awareness approaches in Business Process Management<sup>1</sup>

We performed a literature review to obtain the studies aligned with our goal, which is two-fold. First, we aimed to create an overview of the context awareness approaches in BPM and facilitate understanding of the topic. Second, we sought to find an appropriate BPM context model to take as a basis for our framework. For the literature review, we developed queries and executed them in the commonly preferred scientific databases (see Table 1).

Database	Search query	Result
Scopus	TITLE( ("process*" OR "bpm") AND ("approach*" OR "method*" OR "model*" OR "tool*" OR "framework*") AND ("context-aware*" OR "context aware*"))	97
IEEE	((("DOCUMENT TITLE": "*process*" OR "BPM") AND ("DOCUMENT TITLE": "approach" OR "method*" OR "framework" OR "tool*" OR "model*") AND ("DOCUMENT TITLE": "context-aware*" OR "context aware*"))	17
Web of Science	TI= (("process*" OR "BPM") AND ("approach*" OR "method*" OR "framework*" OR "tool*" OR "model*") AND ("context-aware*" OR "context aware*") )	18

Table 1. Databases, search queries, and the resulting number of studies in the primary search.

We streamlined our review to the studies explicitly devoted to creating context awareness approaches. Notably, we excluded the studies having a descriptive character, not proposing any BPM approach to deal with context awareness, and focusing on case studies, evaluation measures, or state-of-the-art comparisons. At the same time, we included studies suggesting frameworks, models, methods, and tools for context awareness, as these terms are closely related and often used as synonyms in the community (Denner, Röglinger, Schmiedel, Stelzl, & Wehking, 2018). When several works of the same author on the same topic were encountered, more comprehensive and impactful work was considered. The most relevant and exhaustive results were obtained using the Scopus database (see Table 1). After removing the duplicates and filtering out the irrelevant ones, a set of 18 papers was selected. With the help of a backward and forward search, we identified three additional studies, which made up 21 papers in the final set. Each paper was analyzed, emphasizing the requirements and shortcomings of the approaches (see Table 2 below).

Reference	Description	Requirements	Shortcomings
(Rosemann, Recker, & Flender, 2008)	Stratified framework differentiating four forms of context into concentric layers of an onion model: immediate, internal, external, environmental	<ul style="list-style-type: none"> <li>Specification of the contextual factors in the four layers</li> </ul>	<ul style="list-style-type: none"> <li>Taxonomy as an initial reference on research in process contextualization</li> <li>No specification of the extraction of the contextual factors</li> </ul>
(vom Brocke, Zelt, & Schmiedel, 2016)	Integrated framework of contextual factors related to four dimensions: goal, process, organization, environment	<ul style="list-style-type: none"> <li>Specification of the contextual factors in the four dimensions</li> </ul>	<ul style="list-style-type: none"> <li>Contextual factors requiring empirical investigation in BPM</li> <li>More research on validation and extension of contextual factors</li> </ul>
(vom Brocke et al., 2021)	Context-Aware BPM Method Assessment and Selection (CAMAS) Method helping to assess contexts for BPM methods application and select BPM methods for given contexts	<ul style="list-style-type: none"> <li>Set of BPM methods (method bases)</li> <li>Classification framework (Excel)</li> <li>Specification of contextual factors</li> </ul>	<ul style="list-style-type: none"> <li>Assumptions of the method</li> <li>Evaluation</li> <li>No specification of the contextual factors extraction</li> </ul>
(Anastassiou, Santoro, Recker, & Rosemann, 2016)	Method to identify the contextual elements of a process based on the analysis of a process model	<ul style="list-style-type: none"> <li>process model and process related information (input, output, resources, and activities)</li> <li>Context-related information</li> </ul>	<ul style="list-style-type: none"> <li>Lack of detailed information in process models</li> <li>Lack of formalization</li> <li>Focus on immediate/internal contextual elements based on the process model</li> </ul>
(Hoang & Jung, 2014)	Ontological framework for context-aware collaborative business process formulation	<ul style="list-style-type: none"> <li>Process execution data (event logs)</li> <li>Ontologies</li> </ul>	<ul style="list-style-type: none"> <li>Focus on primitive ontologies</li> <li>Context information is limited to process execution data and ontologies</li> </ul>

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(Bucchiarone, Marconi, Pistore, & Sirbu, 2011)	Framework supporting context-aware evolution of processes based on process instance execution and adaptation history, identifies recurring adaptation needs	<ul style="list-style-type: none"> <li>• Process execution data (event logs)</li> </ul>	<ul style="list-style-type: none"> <li>• Context information is limited to process execution data</li> <li>• Lack of specific solutions for the identified adaptation needs</li> </ul>
(De Maio, Fenza, Loia, Orciuoli, & Herrera-Viedma, 2016; Enrique, De Maio, Fenza, Loia, & Orciuoli, 2016)	Framework, model for context-aware heterogeneous group decision making in processes	<ul style="list-style-type: none"> <li>• Data regarding decision making (decision makers, opinions, weights, records of past decision making)</li> <li>• Contexts modelled with Semantic Web languages and vocabularies like OWL2 and SKOS</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on decision makers and opinion weights</li> <li>• Limitations regarding weights learning</li> <li>• Context information is limited to Semantic Web languages and vocabularies like OWL2 and SKOS</li> </ul>
(Wang, Shi, Li, & Liu, 2016)	Framework for context-aware semantic complex event processing	<ul style="list-style-type: none"> <li>• Event log</li> <li>• Event ontologies</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on event log data</li> <li>• Context information is limited to ontologies</li> </ul>
(Hompes, Buijs, & van der Aalst, 2016)	Framework to analyze key process performance indicators by considering the process context	<ul style="list-style-type: none"> <li>• Event log</li> <li>• Descriptive context labels assigned to process entities by applying context functions</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on event log data</li> <li>• Careful interpretation of the results of the automated analysis technique</li> </ul>
(Ploesser, Recker, & Rosemann, 2010)	Conceptual model of context-awareness comprising process elements, goals, and context elements	<ul style="list-style-type: none"> <li>• KPIs</li> <li>• Expert interviews</li> </ul>	<ul style="list-style-type: none"> <li>• Limitations of the expert interviews</li> </ul>
(Boukadi, Chaabane, & Vincent, 2009)	Framework for context-aware process modeling considering functional, non-functional, and environmental contexts	<ul style="list-style-type: none"> <li>• Roles, business rules, goals</li> <li>• process model</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on modeling</li> <li>• Abundant non-functional and environmental contextual factors</li> <li>• No specification of the extraction of the contextual factors</li> </ul>
(Saidani & Nurcan, 2009)	Context model for process modeling including information on who, what, where, when, why, how	<ul style="list-style-type: none"> <li>• Roles, business rules, goals</li> <li>• Process model</li> <li>• Context information</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on modeling</li> <li>• No specification of the contextual factors extraction</li> </ul>
(Rekik, Boukadi, & Ben-Abdallah, 2017)	Framework to integrate context awareness in process outsourcing to the cloud, includes process (KPI, workload), temporal, resource (cost, risk, performance) contexts	<ul style="list-style-type: none"> <li>• Process execution data (event logs)</li> <li>• Context information</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on the specific problem</li> <li>• No specification of the contextual information extraction</li> </ul>
(Mounira & Mahmoud, 2010)	Context-aware process mining framework for process flexibility	<ul style="list-style-type: none"> <li>• Event log</li> <li>• Process mining and context awareness components</li> <li>• Contextual variables</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on process mining and technical perspective</li> </ul>
(Said, Chaabane, Andonoff, & Bouaziz, 2014)	BPMN metamodel for modeling process variability of considering the contextual dimension	<ul style="list-style-type: none"> <li>• Context parameters including goal, resources, data, behavioral</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on process modeling</li> </ul>
(Song, Vanthienen, Cui, Wang, & Huang, 2019b)	Context-aware business process management ecosystem including context-aware process models, context models, decision models and context-aware process execution	<ul style="list-style-type: none"> <li>• Process execution data (event logs)</li> <li>• Process models</li> <li>• Decision rules</li> <li>• Context ontology</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on methodology</li> <li>• Focus on the Internet of Things</li> <li>• Complex requirements</li> <li>• Context interpretation</li> </ul>
(Cartelli, Di Modica, & Tomarchio, 2015)	Cost-centric model for context-aware (resources, environment) simulations of processes	<ul style="list-style-type: none"> <li>• Process execution data (event logs)</li> <li>• Process models</li> <li>• Context models</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on simulations and costs</li> <li>• No specification of the contextual information extraction</li> </ul>
(Song, Vanthienen, Cui, Wang, & Huang, 2019a)	DMN-based method for context-aware process modeling	<ul style="list-style-type: none"> <li>• Context-dependent decisions</li> <li>• Process and decision models</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on methodology</li> <li>• Focus on decision modeling</li> </ul>
(Liptchinsky, Khazankin, Truong, & Dustdar, 2012)	Approach and a graphical notation to model context-aware collaboration processes	<ul style="list-style-type: none"> <li>• Process context information, including related actors and artifacts</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on modeling of collaboration processes</li> <li>• Absence of explicit communication entities (events or messages)</li> </ul>
(Hidri, M'tir, Ben Saoud, & Ghedira-Guegan, 2019)	Metamodel for context-aware adaptive business process as a service in a collaborative cloud environment	<ul style="list-style-type: none"> <li>• Service, provider, customer, BPaaS, environment context information</li> </ul>	<ul style="list-style-type: none"> <li>• Conceptual formalisation</li> <li>• No specification of the contextual information extraction</li> </ul>

Table 2. Overview of BPM context awareness approaches.

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