

# **Aligning business processes with regulatory requirements**

**a systematic literature review**

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## Document Control

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Draft	0.4	26 Apr 2024	From 9 to 21 selected articles
Draft	0.3	25 Mar 2024	None

# 1 Introduction

In the context of the DBA program at Vlerick Business School a literature review is one of two deliverables of year two. The research topic is “BPM for regulatory compliance”. The goal of this review is to get an overview of relevant literature and identify topics listed as possibilities for future research. The type of literature review is a systematic literature review (SLR). The SLR has been performed following the steps described in Kitchenham and Charters (2007).

Chapter 2 states the main research question, three subquestions and provides for a definition of the central concepts.

Chapter 3 is about the planning of the research. It describes the databases that were searched, the search terms used, the criteria for selecting articles and how the bibliographic data and the articles have been obtained.

Chapter 4 concerns the execution of the research. It describes the studies found, which studies have been selected, how the quality of the studies has been assessed, how the data was collected and a synthesis of the data.

Chapter 5 concerns the reporting of the research. It describes how the results of this study will be shared, limitations of the study and possibilities for further research suggesting possible improvements.

## 2 Research question(s)

The research question (RQ) and the three supporting sub-questions (SQ) that are addressed in this literature review are:

RQ: What are approaches for aligning business processes with regulatory requirements to achieve regulatory compliance by design?

SQ1: How can businesses identify relevant regulatory requirements?

SQ2: How can businesses analyze which business processes are affected by changes in regulatory requirements?

SQ3: How can businesses integrate compliance requirements into business process design?

The focus of this review is specifically the first question (RQ). The following is the research question repeated whereby the central terms and concepts in this review are boxed: What are approaches for aligning business processes with regulatory requirements to achieve regulatory compliance by design?

compliance by design

A definition of the three central concepts:

Business process management (BPM) is defined as all activities performed by businesses to discover, model, automate, analyze, measure, improve and optimize business processes (Liu, Müller, and Xu (2007)). A business process coordinates the behavior of people, systems, information and things to produce business outcomes in support of a business strategy. Processes can be structured and repeatable, or unstructured and variable.

Regulatory compliance is defined as ensuring that business processes, operations, and practices are in accordance with a prescribed and/or agreed set of norms. These compliance requirements may stem from legislature and regulatory bodies (e.g., Sarbanes-Oxley, Basel II, HIPAA), standards and codes of practice (e.g., SCOR, ISO9000), and also business partner contracts (Hashmi (2015)).

Compliance by design refers to approaches and methodologies where compliance requirements are integrated into business process models (Sadiq and Governatori (2010)) and enterprise applications from the very beginning. This concept emphasizes embedding compliance within the fabric of business practices (Lohmann (2013)) rather than treating it as a separate or after-the-fact activity.



## 3 Review plan

### 3.1 Resources to be searched

An initial set of databases was selected to perform the literature search on. Both commercial and open access databases have been selected. A description for these databases is included in table A.1.

1. Web of Science (WoS), Publisher: [Clarivate](#)
2. ScienceDirect (SD), Publisher: [Elsevier](#)
3. SSNR, Publisher: [Elsevier](#)
4. arXiv, Publisher: [cs](#)
5. dblp, Publisher: [dblp](#)
6. Zenodo, Publisher: [Zenodo](#)

As a test we performed some initial searches. The results of the initial searches were reviewed. SSNR and Zenodo yielded few results as compared to the other databases. The selection of databases was reduced to WoS, SD, SSNR, ArXiv and dblp.

### 3.2 Search terms used

The initial search terms have been formulated as follows:

1. (“business process management” or BPM) and “regulatory compliance”
2. (“business process management” or BPM) and “legal compliance”
3. (“business process management” or BPM) and “compliance”
4. “business process management” and (“regulation” or “regulatory”)
5. “business process \*engineering” and “compliance”
6. “business process \*engineering” and (“regulation” or “regulatory”)

Here too a test has been performed using the search terms. It was found that the combination of “business process management” with “regulatory compliance” or “legal compliance” yielded few results. Consequently, 1 and 2 were skipped. We searched for “business process management” and “compliance” which includes both “regulatory compliance” and “legal compliance”.

### 3.3 Study selection criteria

The quality of an article is assessed on the basis of the 4 criteria(QA1 through QA4). The criteria are equally weighted. An article is assigned 1 point for every QA criterium that is met. An article will thus get score of 0 through 4. Other metrics like author h-index and journal impact factor will not be considered in the selection process.

Table 3.1: Study selection criteria

criteria	code	descriptions
inclusion	IC1	the title, abstract and full text are in english
	IC2	the publication is dated between 2000 and 2024
exclusion	EC1	the reference is to a book(chapter)
	EC2	the article has been retracted
	EC3	the type of article is a conference paper or a preprint
	EC4	a search term has a different meaning
	EC5	the application relates to a specific sector
	EC6	the title, abstract and full text are not in english
quality	QA1	the article is a peer-reviewed journal article
	QA2	the article appeared in one of the legible <a href="#">journals</a>
	QA3	has a citation count higher than 5 per year since the year of publication
	QA4	the first and second author have combined more than 50 publications listed on google scholar

### 3.4 Data extraction strategy

The initial 6 data sources have been reduced to 4 (excluding Zenodo). For the remaining 5 data-sources queries will be formulated for each data source. The resulting records found will be listed in an excel file “slr\_logbook.xlsx”.

## 4 Review execution

### 4.1 Research identification

Initially 6 queries have been run against the 6 databases resulting in 84 hits as shown in table 4.1 in appendix D. After testing the initially formulated 6 queries have been reduced to 4 queries. The first two queries search for “business process management” or BPM in the title. The last two queries search for “business process engineering” or business process reengineering” in the title.

1. TI=(“business process management” or BPM) AND (AB=(compliance) OR KP=(compliance))
2. TI=(“business process management” or BPM) AND (AB=(“regulat\*”) OR KP=(“regulat\*”))
3. TI=(“business process \*engineering”) AND (AB=(compliance) OR KP=(compliance))
4. TI=(“business process \*engineering”) AND (AB=(regulat\*) OR KP=(regulat\*))

The initial list (table D.1) contains a total of 84 records. An additional 6 records were found from other sources (table D.2). The total is 90 records. This list includes preprints and conference papers. Filtering the journal articles results in a list of 25 records (table D.3).

In the case of Web of Science (WoS) the four queries have been taken together using the “OR” operator. This final query yields 42 results when using the the Vlerick WoS subscription<sup>1</sup>. The search strings have been adapted to suit the specific requirements of the databases.

### 4.2 Selection of studies

The initial searches were done on all database fields. The search was subsequently made more specific by searching titles and abstracts. Lastly we searched titles, abstracts and keywords.

Across the 6 databases 84 articles have been identified, and an additional 6 records have been added from different sources. The found records are listed in Appendix D: table D.1 and table D.2.

The process to get to the final 23 papers included in this literature study is visualized in the flowchart in figure C.1 in Appendix C.

The WoS search yielded 29 hits. Excluding 4 articles with BPM in the title where BPM has a different meaning than “Business Process Management”. For example where BPM is an abbreviation of “Biodiesel Particulate Matter”. Excluding 1 article as it is a double, also occurring in the dblp search.

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<sup>1</sup>Web of Science: Core Collection  
Subscription : Vlerick Business School  
Editions : A&HCI , ESCI , CPCI-SSH , CPCI-S , SCI-EXPANDED , SSCI  
Date range: 2014-2024

The SD search yielded 7 hits. On the basis of article type (1 book chapter and 1 short communication) we have excluded two articles. An additional article was excluded as the title referred to “Business Process Management Map”, which is a different concept.

The SSRN search yielded 2 results, both excluded as they are preprints.

The arXiv search yielded 0 records when looking for articles with “Business Process Management” or BPM in the title field. Two records were found on the basis of abstract and keyword matches. All the same these records have been subsequently excluded when the exclusion criteria have been applied.

The dblp search yielded 41 records, including 2 books and 35 conference papers. After exclusion 4 records remain, 3 journal articles and one PhD thesis. For the next step, the abstract scan, the thesis has been replaced by a journal article by the same author about the same topic.

The Zenodo search yielded 0 records when looking for articles with “Business Process Management” or BPM in the title field.

Six additional records have been included identified via different sources: 4 journal articles, 1 PhD thesis and 1 conference paper. Here too, for the next step in the process the thesis has been replaced by a journal article by the same author about the same topic.

In summary:

Table 4.1: Result set

Database	Found	Additional	Subtotal	Excluded	Result set
WoS	29		29	-19	10
SD	7		7	-7	0
SSRN	0	+2	2	-2	0
arXiv	0	+4	4	-4	0
dblp	42		42	-37	5
zenodo	0				0
additional	0	+6	6		6
total	78	+12	90	-69	21

The abstracts of the remaining 21 articles are listed in [Appendix G](#), table [D.3](#).

### 4.3 Study Quality Assessment

The first quality indicator is about the type of journal. Peer reviewed articles are deemed to be of better quality than, for example, conference papers. The second quality indicator is an indirect measure of both the quality of the journal and the relevance of the article to the Information Systems field. The third quality indicator is a proxy for the quality of the article. The fourth indicator is deemed to be representative for the quality of the scholars.

The outcome for QA1 through QA4 is either 1 or 0 (1 means yes, 0 means no).

QA1: the article is of the type peer-reviewed journal article

QA2: the journal is in the eligible journals list

QA3: the article has been referenced an average of 5 times per year since publication

QA4: author 1 and author 2 have together authored at least 50 articles

The detail of the calculation for QA3 en QA4 is shown in [appendix F](#).

```
from IPython.display import Markdown
from tabulate import tabulate
from lib.my_excel_lib import get_tables
from lib.my_custom_lib import xls2md

tables = get_tables('tables/slr_logbook.xlsx')

Markdown(tabulate(
    xls2md(tables['quality_assessment']),
    headers=['Seq', 'Source', 'QA1', 'QA2', 'QA3', 'QA4', 'Score'],
    missingval=".",
    maxcolwidths=[2, 8, 8, 8, 8, 8, 8],
    showindex=False,
    colalign=('left', 'left', 'center', 'center', 'right', 'right', 'center')))
```

Table 4.2: Quality assessment

Seq	Source	QA1	QA2	QA3	QA4	Score
1	WoS_02	1	0	0	0	1
2	WoS_03	1	0	0	1	2
3	WoS_04	1	0	1	1	3
4	WoS_05	1	0	0	1	2
5	WoS_06	1	1	0	1	3
6	WoS_10	1	0	1	1	3
7	WoS_14	1	0	1	1	3
8	WoS_15	1	0	1	1	3
9	WoS_16	1	0	0	1	2
10	WoS_17	1	0	0	0	1
11	dblp_01	1	0	0	1	2
12	dblp_03	1	0	1	1	3
13	dblp_08	1	0	0	0	1
14	dblp_13	1	0	0	1	2
15	dblp_28	0	0	0	0	0
16	other_01	1	0	1	0	2
17	other_02	1	0	0	1	2
18	other_03	1	0	1	1	3
19	other_04	1	0	1	1	3

Table 4.2: Quality assessment

Seq	Source	QA1	QA2	QA3	QA4	Score
20	other_05	0	0	0	1	1
21	other_06	1	0	1	1	3

For the final list we only consider the 9 articles where three or more conditions are met (see: [appendix E](#), table D.4).

#### 4.4 Data collection

The output of each query has either been a bib file or a ris file. All bib files have been converted to ris files. The mapping of bibliographic elements to the ris fields differs per data sources. A script has been written to get to a uniform ris-format.

The open access databases do not contain the full text articles if the articles are not open access. DBLP also doesn't contain abstracts. The absence of full text articles or abstracts is explained by constraints imposed by copyrights.

The excel file containing the article lists has been stored on zenodo for future reference ([zenodo 10795823](#)).

#### 4.5 Synthesis of extracted data

8-12 years ago: the two oldest papers in the dataset are Vanderfeesten, Reijers, and Van Der Aalst (2011) and Hadasch, Maedche, and Gregor (2016). The article of Irene Vanderfeesten is on the subject of her PhD thesis (Vanderfeesten, Reijers, and Van Der Aalst (2011)). It describes the concept of a Product Data Model which, in workflow systems, can be compared to a Bill of Material in manufacturing systems. The article doesn't mention future research but does mention collaboration with industrial partners to incorporate a PDM in a commercial tool. The Hadasch paper is a quantitative study about users' process compliance as a function of process explanations either in textual or diagram format (DE/DDE). Broadly stated, the paper concludes that the better explanations result in better compliance. Other than a recommendation that the findings of the paper be leveraged in future research, there is no specific guidance about future research.

4-8 years ago: the four papers published in the 2016-2019 timeslot are Van Der Aalst (2018), Hashmi and Governatori (2017), Hashmi et al. (2018) and van der Aa, Leopold, and Reijers (2017). The van der Aalst paper compares and contrasts spreadsheet technology with process mining technology. It mentions checking for compliance as the activity whereby a process as run in reality is compared to a normative model. The article mentions future process mining research should be about automatically improving processes by changing underlying process models. The first Hashmi paper compares six Compliance Modeling Frameworks (CMFs). There are two pointers to future research directions. 1) Studying the formal semantics of the norms modeling languages. 2) Studying the useability of the

norms modeling constructs in practice. The second Hashmi paper is a SLR where 79 papers were included in the study. The study provides a comprehensive overview of the attributes of compliance in BPM. There is a general direction for future research given: to improve modeling languages to take into account all compliance requirements. The article by van der Aa et al. is about the possible divergence of process descriptions and graphical process models. A quantitative analysis is performed on 53 real-life model-text pairs. One of the suggested future research directions is to also capture process information in other formats. Among the examples given of such other formats are rules and regulations.

0-4 years ago: the three most recent papers in the set are the papers and Kir and Erdogan (2021), Bernardo Junior and De Padua (2023) and Viriyasitavat et al. (2023). The Kir paper introduces *agileBPM*, a modeling methodology. The main differentiator is that next to control flow *agileBPM* also captures knowledge, rules and goals. A prototype of the system is compared to other similar systems (ADEPT, SmartPM, Planlets, Go4Flex). The paper doesn't mention future research. The Bernardo paper includes a SLR, interviews and expert consultations. Agile BPM is defined. Future research is suggested to be on practices necessary for empirical application of BPM in organizations. The Viriyasitavat article is a SLR on the use of blockchain technology for business process compliance. The paper argues that blockchain technologies can and are applied for business process compliance. Existing work has a focus on technical implementation of the functionalities of traditional BPM systems. However the use of blockchain technologies also allows for new functionalities. The further research section specifically mentions organizational and legal aspects.

Table 4.3: Relevance to research question

	Year	Article	Alignment Concepts	Future Research
1	2011	Vanderfeesten et al.	ProductData Model	N
2	2016	Hadasch et al.	(Diagram)Descriptive Explanations	N
3	2017	Van der Aa et al.	Consistency between representation	Y (specific)
4	2018	Van Der Aalst	Prescriptive Analytics	Y (general)
5	2018	Hashmi et al.	Compliance Modeling Frameworks	Y (specific)
6	2018	Hashmi et al.	Compliance Modeling Languages	Y (general)
7	2021	Kir et al.	Context Awareness / Norm adoption	N
8	2023	Viriyasitavat et al.	Blockchain	Y (general)
9	2023	Bernardo Junior et al.	-	Y (general)

All papers mention approaches for alignment of business processes with regulatory requirements except the Bernardo Junior paper about agile BPM.

From these 9 papers reviewed, 6 mention future research directions. Two papers mention specific future research topic, for example around “consistency between different process representations” and “the useability of norm modelling constructs”.

## 5 Review reporting

### 5.1 Dissemination strategy

A subsequent version of this review will be part of the PhD work. The aim is to get three by-products out of this review:

- A poster that explains this literature review process and its results to be presented on a research day.
- A version of the software script that is installable and useable by somebody else.
- An open access publication.

### 5.2 Limitations

The database searches resulted in a set of relevant articles for the subject of this review. Selecting a different set of databases would have resulted in a different set of relevant articles. The selection of databases was made from the databases available to us. We did not consider databases that require additional payment for access.

It is also noted that search results may differ among different databases. If the content of two databases is identical, the same query run against both databases can yield different results. The differences stem, among others, from different search fields, different query languages, different API's and different search engines. Examples of notable differences are:

- for WoS: the search results may differ depending on the subscription that is available to the user.
- for SD: the search results may differ as query's are interpreted based on language heuristics ([source](#)). Also, SD does not support wildcards.
- for dblp: the *CompleteSearch* engine autocompletes search terms, see Bast and Weber (2006).
- for arXiv: wildcards can not be used as the first character of a search term ([source](#)). For example “\*engineering” will trigger an error message.

To assess the quality of the 21 identified articles a set of 4 indicators has been considered. There are many other indicators which can be used to assess the quality of an article. Changing the number of indicators and/or changing the selection of parameters could alter which full text articles are selected for the review.



### 5.3 Future research

In follow-on research it may be interesting to include openAIRE (Open Access Infrastructure for Research in Europe) as a data source. Schumm et al. (2010), p. 11 reference research that has been performed under the 2008-2011 COMPAS research project funded by the EU and coordinated by the Technische Universität Wien. More information about the research output of these projects will be available via OpenAIRE. When OpenAIRE will be included as a data source we will also again include Zenodo. Zenodo was created as part of the OpenAIRE initiative.

For reproducibility a future version of this literature review shall have the protocol altered. For commercial databases one and the same query can yield different results if it is run with two different licenses. This has been found to be the case with Web of Science. For the query used in this review the Vlerick Business School license of WoS yielded 42 hits while the Amsterdam University of Applied Sciences license of WoS yielded 24 hits (to be included in appendix). It is assumed the average user does not have precise information of the licenses that Academic institutions hold. As such WoS is better not used in the early stages of the search. The protocol could instead dictate the use of open databases, such as OpenAlex, for the early stages of the search. Commercial databases would then be used in a later stage to get abstracts and full texts of selected articles that are not available from open databases.

For quality assessment we have now used a self-constructed indicator (QA4) that has as inputs the number of publications by the first and second author. If further research is conducted it can be considered to replace this indicator with the ubiquitous h-index (Poirrier, Moreno, and Huerta-Canepa (2021)). Also, the fact that only 1 article is from the eligible journals list seems to indicate that either the list needs to be revised. Alternatively a different indicator, such as the journal impact factor, can be a substitute quality indicator.

Finally, where it relates to compliance checks, in the literature there is a divide between “design time” and “run time”. As the RQ of this research refers to compliance by design, future research may have more of different search terms to also filter research about “design time” compliance checking.

## A Databases Searched

Table A.1: Databases consulted

Platform	Type	Focus	Coverage	Access
Web of Science	Citation index	Wide range of disciplines (including hard sciences, social sciences, and the humanities)	Over 18,000 academic journals, books, patents, and other scholarly publications	Subscription-based
ScienceDirect	Academic literature platform	Science, technology, medicine, and social science	Over 3,500 peer-reviewed journals	Subscription-based and open access
SSRN	Preprints	Social sciences, economics, and business	Early-stage social science, economics, and business research papers	Open access
arXiv	Preprints	Hard sciences and quantitative sciences	Early-stage research papers in a wide range of disciplines	Open access
DBLP	Bibliography database	Computer science	Scholarly publications in computer science	Open access
Zenodo	Dataset repository	Data from various disciplines	Data from research projects, surveys, and other data collection efforts	Open access

Table A.2: Other resources - not consulted

Platform	Operator	Note
Scopus	<a href="#">Elsevier</a>	not available via Vlerick
OpenAlex <sup>1</sup>	<a href="#">OpenAlex</a>	
OpenAIRE	<a href="#">OpenAIRE</a>	Mentioned in connection with Zenodo and also EU Research Programs
CEUR Workshop Proceedings		

<sup>1</sup>For a description of OpenAlex see Priem, Piwowar, and Orr (2022).

## B List of eligible journals

The columns: level and impact factor (IF) are taken from the Vlerick Strategic Journal List (the List), effective as of January 2020. Empty means the journal is not on the List.

Table B.1: Basket of 11

Journal Title	Level	IF
MIS Quarterly ( <a href="#">MISQ</a> )	A*	7,268
Journal of Management Information Systems ( <a href="#">JMIS</a> )	A*	2,744
Information Systems Journal ( <a href="#">ISJ</a> )	A	4,267
Journal of the Association for Information Systems ( <a href="#">JAIS</a> )	A	2,839
Communications of the Association for Information Systems ( <a href="#">CAIS</a> )	A	?
Information Systems Research ( <a href="#">ISR</a> )	A*	2,301
Journal of Information Technology ( <a href="#">JIT</a> )	A	4,435
European Journal of Information Systems ( <a href="#">EJIS</a> )	A	2,819
Decision Support Systems ( <a href="#">DSS</a> )	A	2,819
Information & Management ( <a href="#">IAM</a> )	A	3,890
Information and Organization ( <a href="#">IAO</a> )		

Next to the basket of 11 there are other journals that are of interest. BISE is of interest because it is an european (IS) journal (as is EJIS). BPMJ and IJDG may be of interest given the subject matter their titles refer to.

Table B.2: Other journals of interest

Journal Title	Level	IF
Business Process Management Journal ( <a href="#">BPMJ</a> )		
Business & Information Systems Engineering ( <a href="#">BISE</a> )		
Journal of Disclosure and Governance ( <a href="#">IJDG</a> )		

## C Literature Selection

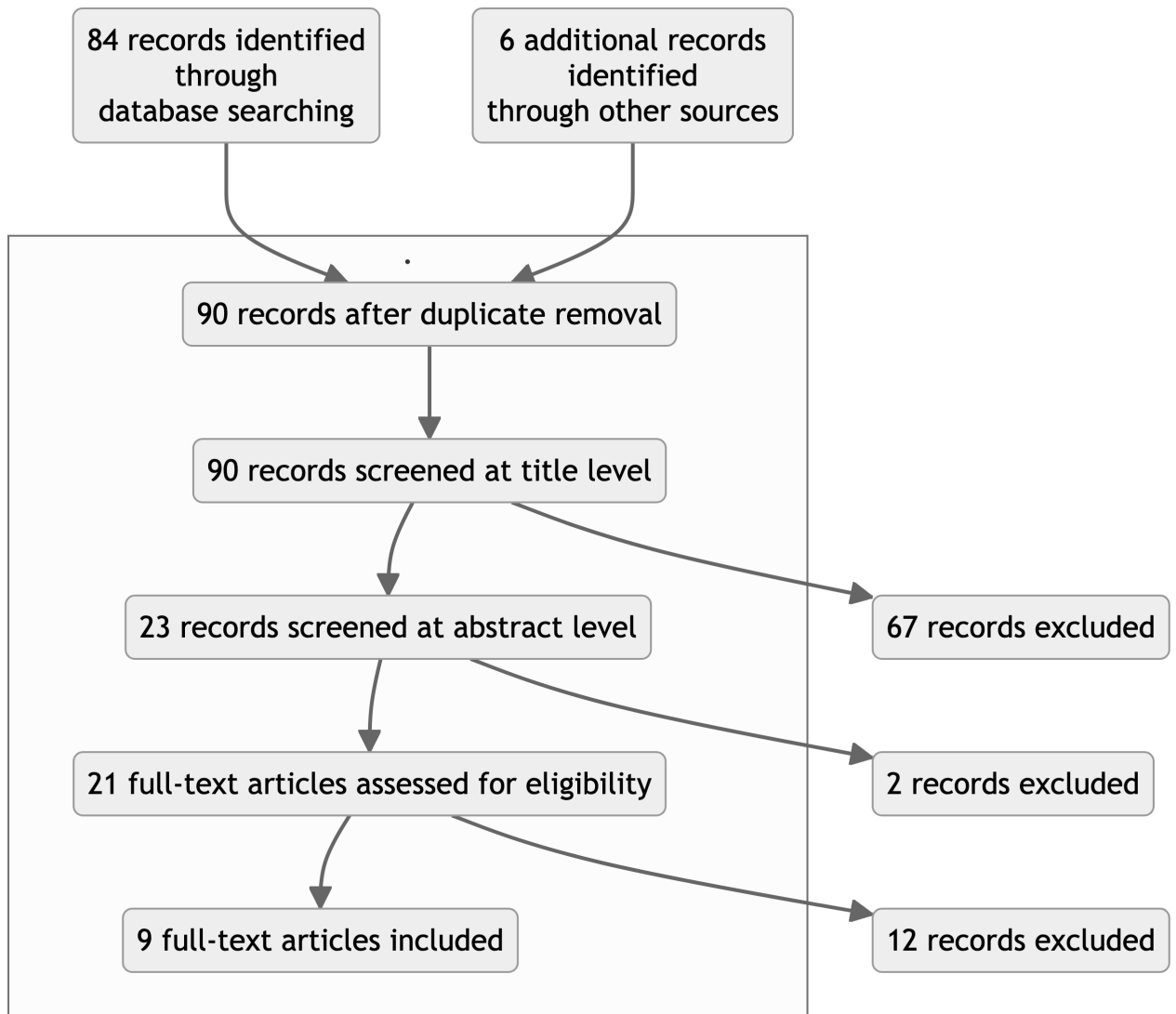


Figure C.1: Flowchart depicting literature selection.

## D Literature Identified

The tables below show records found. Seq (sequence) shows a table row number. Source shows the data source where the record was found. Type holds the type of publication (conference proceedings, journal article, preprint, etc.) Title is the title of the publication. EC (exclusion criterion) shows the reason a record is excluded. If a record is excluded for multiple reasons, only one reason is shown. QA (quality assessment) shows the QA-score the record obtained (0-4).

Table D.1: Identified through database searching

Seq	Source	Type	Title	EC
1	WoS_01	cpaper	Design Solutions for Business Process Reengineering of an Agricultural Enterprise	5
2	WoS_02	jour	Blockchain-as-a-Service for Business Process Management: Survey and Challenges	-
3	WoS_03	jour	Business Process Management - A Traditional Approach versus a Knowledge Based Approach	-
4	WoS_04	jour	Blockchain-based business process management (BPM) framework for service composition in industry 4.0	-
5	WoS_05	jour	Regulatory Instability, Business Process Management Technology, and BPM Skill Configurations	-
6	WoS_06	jour	The influence of directive explanations on users' business process compliance performance	-
7	WoS_07	cpaper	Business Process Management Driven by Data Governance	3
8	WoS_08	cpaper	An Open-Source Proactive Security Infrastructure For Business Process Management	3
9	WoS_09	cpaper	Cloud Based Privacy Preserving Collaborative Business Process Management	3
10	WoS_10	jour	A knowledge-intensive adaptive business process management framework	-
11	WoS_11	cpaper	Process model verifier for integrated medical healthcare systems using business process management system	5
12	WoS_12	cpaper	Agile Innovation Through Business Process Management: Realizing the Potential of Digital Transformation	3
13	WoS_13	cpaper	Managing Security Objects and -Processes Using an Extended BPM Approach and -System	3
14	WoS_14	jour	Toward agile Business Process Management: Description of concepts and a proposed definition	-
15	WoS_15	jour	Spreadsheets for business process management Using process mining to deal with "events" rather than "numbers"?	-
16	WoS_16	jour	BPM perspectives to support ICSs: Exploiting the integration of formal verifications into investment service provision processes	-
17	WoS_17	jour	Improved Compliance by BPM-Driven Workflow Automation	-
18	WoS_18	jour	Simulation of the Inventory Process in a Postharvest of Export Roses Under a Business Process Management approach	5
19	WoS_19	cpaper	Business Process Management Notation for a Costing Model Conception	5
20	WoS_20	cpaper	BPM analysis and security case study: dining rooms Cartagena military, Colombia	5
21	WoS_21	cpaper	The Value of Business Process Management to Understand Complex Asset Management Processes	5
22	WoS_22	cpaper	The Business Process Management Map - an Effective Means for Managing the Enterprise Value Chain	5

Table D.1: Identified through database searching

Seq	Source	Type	Title	EC
23	WoS_23	cpaper	Business Process Management Systems in Support of Corporate Governance: Applying Orlikowski's Theoretical Lens	3
24	WoS_24	cpaper	How do Machine Learning, Robotic Process Automation, and Blockchains Affect the Human Factor in Business Process Management?	3
25	WoS_24	jour	Multi-objective container scheduling and multi-path routing for elastic business process management in autonomic multi-tenant cloud	5
26	WoS_26	cpaper	Experiences from Selecting a BPM Notation for an Enterprise	3
27	WoS_27	jour	Compositional Analysis of Biodiesel Particulate Matter (BPM) from a Non-Road Diesel Generator	4
28	WoS_28	cpaper	BPM-CUL3 E3 ligase modulates thermotolerance by facilitating negative regulatory domain-mediated degradation of DREB2A in Arabidopsis	4
29	WoS_29	jour	The Pumilio RNA-binding protein APUM24 regulates seed maturation by fine-tuning the BPM-WRI1 module in Arabidopsis	4
30	dblp_01	jour	Business Process Modelling in Healthcare and Compliance Management: {A} Logical Framework	-
31	dblp_02	proc	Checking Compliance in Data-Driven Case Management	3
32	dblp_03	jour	Norms modeling constructs of business process compliance management frameworks: a conceptual evaluation	-
33	dblp_04	proc	Compliance Checking for Decision-Aware Process Models	3
34	dblp_05	proc	Checking Business Process Models for Compliance - Comparing Graph Matching and Temporal Logic	3
35	dblp_06	proc	Using Business Process Compliance Approaches for Compliance Management with Regard to Digitization: Evidence from a Systematic Literature Review	3
36	dblp_07	coll	Enabling Flexibility of Business Processes Using Compliance Rules: The Case of Mobiliar	3
37	dblp_08	jour	Comparative Analysis of Business Process Modelling Tools for Compliance Management Support	-
38	dblp_09	proc	Embracing Process Compliance and Flexibility Through Behavioral Consistency Checking in ACM - A Repair Service Management Case	3
39	dblp_10	coll	Managing Regulatory Compliance in Business Processes	X
40	dblp_11	proc	Online Compliance Monitoring of Service Landscapes	3
41	dblp_12	proc	Unterstützung von dynamischen Compliance Prozessen durch Business Process Management Plattformen	6
42	dblp_13	jour	Business process management enabled compliance-aware medical record sharing	-
43	dblp_14	proc	A Methodological Evaluation of Business Process Compliance Management Frameworks	3
44	dblp_15	proc	Supporting Domain Experts to Select and Configure Precise Compliance Rules	3
45	dblp_16	proc	Compliance Check in Semantic Business Process Management	3
46	dblp_17	proc	Business Process Regulatory Compliance Management Solution Frameworks: {A} Comparative Evaluation	3
47	dblp_18	proc	Towards Compliance of Cross-Organizational Processes and Their Changes - Research Challenges and State of Research	3
48	dblp_19	proc	EU Project BPM-GOSPEL - Applying Compliance Management Scenarios in Business Process Modelling for Trusted Business Coaching Programs	3
49	dblp_20	proc	Causes-based problems in business process compliance based management	3
50	dblp_21	proc	Making Compliance Measures Actionable: {A} New Compliance Analysis Approach	3
51	dblp_22	proc	Separating Compliance Management and Business Process Management	3
52	dblp_23	proc	Activity-Oriented Clustering Techniques in Large Process and Compliance Rule Repositories	3
53	dblp_24	proc	Towards an Integration of {GRC} and {BPM} - Requirements Changes for Compliance Management Caused by Externally Induced Complexity Drivers	3
54	dblp_25	proc	Compliance Oriented Process Management Using the Example of Clinical Trials	3
55	dblp_26	proc	Business Process and Regulations Compliance Management Technology	3
56	dblp_27	proc	A systematic review of goal-oriented requirements management frameworks for business process compliance	3
57	dblp_28	phdt	A compliance management framework for business process models	-
58	dblp_29	proc	Business Control Management - A Discipline to Ensure Regulatory Compliance of {SOA} Applications	3

Table D.1: Identified through database searching

Seq	Source	Type	Title	EC
59	dblp_30	proc	Business Process Compliance Tracking Using Key Performance Indicators	3
60	dblp_31	proc	Essential Aspects of Compliance Management with Focus on Business Process Automation	3
61	dblp_32	proc	Process Views to Support Compliance Management in Business Processes	3
62	dblp_33	proc	Visualization of Compliance Violation in Business Process Models	3
63	dblp_34	proc	Semantic Compliance Management in Business Process Management	3
64	dblp_35	proc	A Semantic Framework for Compliance Management in Business Process Management	3
65	dblp_36	proc	Aligning Risk Management and Compliance Considerations with Business Process Development	3
66	dblp_37	proc	Checking Compliance of Execution Traces to Business Rules	3
67	dblp_38	proc	Detecting Regulatory Compliance for Business Process Models through Semantic Annotations	3
68	dblp_39	proc	Service Contract Compliance Management in Business Process Management	3
69	dblp_40	proc	Policy-Based Semantic Compliance Checking for Business Process Management	3
70	dblp_41	proc	Compliance Aware Business Process Design	3
71	dblp_42	proc	Business Process and Business Rule Modeling Languages for Compliance Management: A Representational Analysis	3
72	SD_01	book	Chapter 4: Next-Generation Business Process Management (BPM)	1
73	SD_02	short	Business Process Reengineering of emergency management procedures: A case study	3
74	SD_03	cpaper	The Business Process Management Map – an Effective Means for Managing the Enterprise Value Chain	3
75	SD_04	cpaper	A knowledge-intensive adaptive business process management framework	3
76	SD_05	cpaper	From policy implementation to business process management: Principles for creating flexibility and agility	3
77	SD_06	cpaper	Improved Compliance by BPM-Driven Workflow Automation	3
78	SD_07	cpaper	Improving Telemedicine Processes Via BPM	5
79	SSRN_01	preprint	Efficient Vehicle Certification Management with Business Process Management	5
80	SSRN_02	preprint	Balancing Flexibility and Compliance in Response to Long-Tailed Business Process Changes	3
81	arXiv_01	preprint	Efficient Checking of Timed Order Compliance Rules over Graph-encoded Event Logs	3
82	arXiv_02	preprint	Predictive Compliance Monitoring in Process-Aware Information Systems: State of the Art, Functionalities, Research Directions	5
83	arXiv_03	preprint	Semi-automated checking for regulatory compliance in e-Health	5
84	arXiv_04	preprint	An Open-Source Integration of Process Mining Features into the Camunda Workflow Engine: Data Extraction and Challenges	3

Table D.2: Identified through other sources

Seq	Source	Type	Title	EC
1	other_01	jour	Evaluation of Compliance Rule Languages for Modelling Regulatory Compliance Requirements	-
2	other_02	jour	RegelSprak: a CNL for Executable Tax Rules Specification	-
3	other_03	jour	Are we done with business process compliance: state of the art and challenges ahead	-
4	other_04	jour	Comparing textual descriptions to process models – The automatic detection of inconsistencies.	-
5	other_05	cpaper	Supporting domain experts to select and configure precise compliance rules	-
6	other_06_b	jour	Product-Based Workflow Support	-



Table D.3: Records screened at abstract level

Seq	Source	Type	Title	QA
1	WoS_02	jour	Blockchain-as-a-Service for Business Process Management: Survey and Challenges	1
2	WoS_03	jour	Business Process Management - A Traditional Approach versus a Knowledge Based Approach	2
3	WoS_04	jour	Blockchain-based business process management (BPM) framework for service composition in industry 4.0	3
4	WoS_05	jour	Regulatory Instability, Business Process Management Technology, and BPM Skill Configurations	2
5	WoS_06	jour	The influence of directive explanations on users' business process compliance performance	3
6	WoS_10	jour	A knowledge-intensive adaptive business process management framework	3
7	WoS_14	jour	Toward agile Business Process Management: Description of concepts and a proposed definition	3
8	WoS_15	jour	Spreadsheets for business process management Using process mining to deal with "events" rather than "numbers"?	3
9	WoS_16	jour	BPM perspectives to support ICSs: Exploiting the integration of formal verifications into investment service provision processes	2
10	WoS_17	jour	Improved Compliance by BPM-Driven Workflow Automation	1
11	dblp_01	jour	Business Process Modelling in Healthcare and Compliance Management: A Logical Framework	2
12	dblp_03	jour	Norms modeling constructs of business process compliance management frameworks: a conceptual evaluation	3
13	dblp_08	jour	Comparative Analysis of Business Process Modelling Tools for Compliance Management Support	1
14	dblp_13	jour	Business process management enabled compliance-aware medical record sharing	2
15	dblp_28	phdt	A compliance management framework for business process models	0
16	other_01	jour	Evaluation of Compliance Rule Languages for Modelling Regulatory Compliance Requirements	2
17	other_02	jour	RegelSpraak: a CNL for Executable Tax Rules Specification	2
18	other_03	jour	Are we done with business process compliance: state of the art and challenges ahead	3
19	other_04	jour	Comparing textual descriptions to process models – The automatic detection of inconsistencies.	3
20	other_05	cpaper	Supporting domain experts to select and configure precise compliance rules	1
21	other_06	jour	Product-Based Workflow Support	3

Table D.4: Records included in the study

Seq	Source	Type	Title	QA	Year
1	other_06	jour	Product-Based Workflow Support	3	2011
2	WoS_06	jour	The influence of directive explanations on users' business process compliance performance	3	2016
3	other_04	jour	Comparing textual descriptions to process models – The automatic detection of inconsistencies.	3	2017
4	WoS_15	jour	Spreadsheets for business process management Using process mining to deal with "events" rather than "numbers"?	3	2018
5	dblp_03	jour	Norms modeling constructs of business process compliance management frameworks: a conceptual evaluation	3	2018
6	other_03	jour	Are we done with business process compliance: state of the art and challenges ahead	3	2018
7	WoS_04	jour	Blockchain-based business process management (BPM) framework for service composition in industry 4.0	3	2020
8	WoS_10	jour	A knowledge-intensive adaptive business process management framework	3	2021
9	WoS_14	jour	Toward agile Business Process Management: Description of concepts and a proposed definition	3	2023

## E Quality Criteria

### Indicator QA3

The table shows the inputs for calculating the QA3-score. The score is 1 if the outcome of the calculation is larger than or equal to 5, otherwise it is 0. The calculation is:  $\text{cited/year} = \text{number of citations} / (2024 - \text{Publication Year})$ .

### Indicator QA4

The table shows the inputs for calculating the QA4-score. The score is 1 if the outcome of the calculation is larger than or equal to 100, otherwise it is 0. The columns 'First Author' and 'Second Author' hold the number of articles by these authors on google Scholar.

Table E.1: Calculation of the QA3-score and QA4-score

Seq	Id	Citations	Year	Cited/Year	QA3-Score	First Author	Second Author	Total Articles	QA4-Score
1	WoS_02	4	2022	2	0	92	0	92	0
2	WoS_03	5	2015	0.6	0	145	0	145	1
3	WoS_04	333	2020	83.3	1	92	374	466	1
4	WoS_05	10	2019	2	0	0	134	134	1
5	WoS_06	12	2016	1.5	0	0	557	557	1
6	WoS_10	78	2021	26	1	9	99	108	1
7	WoS_14	5	2023	5	1	51	83	134	1
8	WoS_15	38	2018	6.3	1	1881	-	1881	1
9	WoS_16	8	2020	2	0	0	322	322	1
10	WoS_17	5	2014	0.5	0	0	0	0	0
11	dblp_01	4	2022	2	0	35	122	157	1
12	dblp_03	32	2018	5.3	1	46	416	462	1
13	dblp_08	8	2017	1.1	0	0	22	22	0
14	dblp_13	8	2013	0.7	0	14	93	107	1
15	dblp_28	36	2010	2.6	0	90	0	90	0
16	other_01	5	2023	5	1	0	46	46	0
17	other_02	10	2021	3.3	0	0	192	192	1
18	other_03	149	2018	24.8	1	46	416	462	1
19	other_04	70	2017	10	1	95	151	246	1
20	other_05	23	2013	2.1	0	11	189	200	1
21	other_06	110	2011	8.5	1	121	514	635	1

Meaning of the column names:

- Citations : the number of citations on google scholar
- Year : Year of Publication
- First author : the number of publications by the first author on google scholar
- Second author : the number of publications by the second author on google scholar

## F Selected Abstracts

Toward Agile Business Process Management: Description of Concepts and a Proposed Definition (Bernardo Junior and De Padua (2023))

Business Process Management (BPM) needs to be adjusted quickly and flexibly to cope with the dynamics of the business environment, so the demand for the incorporation of agility has reached BPM. To contribute to the theoretical consolidation of Agile BPM, it is necessary to develop a conceptualization for the term, that is, to describe the essential attributes for its understanding. Communicating the meaning of the concept in reduced words occurs through the definition, so the main objective of this study is to develop a scientific definition for Agile BPM. This study was performed in three phases. First, a systematic literature review was conducted to investigate how the scientific literature has addressed Agile BPM. Next, a deductive analysis was performed to conceptualize Agile BPM. In the third phase, a consultation with experts was conducted to refine the conceptual view and critique a tentative definition, preceded by judges' analysis to consolidate the definition. As a result, the concept of Agile BPM was elaborated, and based on the reduction of this conceptualization, a scientific definition was presented which describes that Agile BPM is "the promotion of BPM in which practitioners stimulate change quickly and flexibly in order to meet organizational demands with compliance and provide a better customer experience". There is a pioneering spirit in the present study regarding the deliberate conceptualization of Agile BPM, which provides the basis for discussion of the topic, and helps scientific dissemination through a definition, contributing to the development of a theory of Agile BPM.

**Keywords:** Agility, bpm governance, Business And Economics–Management, Business process management, challenges, Communication, critical success factors, Customer satisfaction, implementation capabilities, intuition, knowledge systems, Literature reviews, operations strategy, organization, Systematic review

Business Process Reengineering of Emergency Management Procedures: A Case Study (Bevilacqua, Ciarapica, and Paciarotti (2012))

The production and storage of dangerous substances in an industrial establishment creates risks for man, environment and properties in the surrounding area. Safety regulations require the establishment of a preventive information campaign regarding industrial risks and self-defence measures to adopt in an emergency situation. In the case of a major accident, people must be promptly made aware of the appropriate self-defence actions and behaviours to adopt. This strategic activity can reduce the panic effect, make citizens more cooperative and guarantee the effectiveness of any emergency plan. In this paper, the information chain is studied as an industrial process modelled by the IDEF0 language. Through this method, each link in the chain has been deeply analysed. For each function of the process, the inputs, outputs and necessary controls and resources have been identified. Starting from a clear view of the current state, the process of re-engineering has been implemented to minimise or eliminate downtime, deficiencies and illnesses and, thus, consequent time losses. The main contribution of the IDEF0 application in emergency management is to provide a clear view of the whole system, a communication system between emergency actors, a rich information source and a structured base for the re-engineering process.

**Keywords:** Emergency management, IDEF0, Information supply, Information system, Public, Risk information, Safety management

RegelSpraak: A CNL for Executable Tax Rules Specification (Corsius et al. (2021))

RegelSpraak is a CNL developed at the Dutch Tax Administration (DTA) over the last decade. Keeping up with frequently changing tax rules poses a formidable challenge to the DTA IT department. RegelSpraak is a central asset in ongoing efforts of the DTA to attune their tax IT systems to automatic execution of tax law. RegelSpraak now is part of the operational process of rule specification and execution. In this practice-oriented paper, we present the history of RegelSpraak, its properties and the context of its use, emphasizing its double functionality as a language readable by non-technical tax experts but also directly interpretable in a software generating setup.

Keywords: CNL

Supporting Domain Experts to Select and Configure Precise Compliance Rules (Ramezani, Fahland, and van der Aalst (2013))

Compliance specifications concisely describe selected aspects of what a business operation should adhere to. To enable automated techniques for compliance checking, it is important that these requirements are specified correctly and precisely, describing exactly the behavior intended. Although there are rigorous mathematical formalisms for representing compliance rules, these are often perceived to be difficult to use for business users. Regardless of notation, however, there are often subtle but important details in compliance requirements that need to be considered. The main challenge in compliance checking is to bridge the gap between informal description and a precise specification of all requirements. In this paper, we present an approach which aims to facilitate creating and understanding formal compliance requirements by providing configurable templates that capture these details as options for commonly-required compliance requirements. These options are configured interactively with end-users, using question trees and natural language. The approach is implemented in the Process Mining Toolkit ProM.

Keywords: auditing, compliance checking, compliance specification, configurable compliance rules, question tree

Comparative Analysis of Business Process Modelling Tools for Compliance Management Support (Koncevics et al. (2017))

The paper presents results of the comparative analysis of business process modelling tools for supporting automated compliance management in organisations. By **compliance** in the paper we mean compliance to legislation, **regulations** of municipalities, external regulatory requirements and also internal organisational policies. The goal of the research is (1) to identify main attributes of business process modelling tools relevant in compliance management, and (2) to use the identified attributes for analysis of the tools to better understand the scope of their capability to support compliance management. The attributes of the tools have been derived from the related research. The analysis of the tools has been performed by installing each tool and evaluating it against a set of the identified attributes. The obtained results are useful in choosing the tools for compliance management in general and for open source solutions to develop new compliance management tools in particular.

Keywords: Business process compliance, compliance management, compliance management tools, open source business process modelling tools

A Compliance Management Framework for Business Process Models (Awad (2010))

Companies develop process models to explicitly describe their business operations. In the same time, business operations, business processes, must adhere to various types of compliance requirements. **Regulations**, e.g., Sarbanes Oxley Act of 2002, internal policies, best practices are just

a few sources of compliance requirements. In some cases, non-adherence to compliance requirements makes the organization subject to legal punishment. In other cases, non-adherence to compliance leads to loss of competitive advantage and thus loss of market share. Unlike the classical domain-independent behavioral correctness of business processes, compliance requirements are domain-specific. Moreover, compliance requirements change over time. New requirements might appear due to change in laws and adoption of new policies. Compliance requirements are offered or enforced by different entities that have different objectives behind these requirements. Finally, compliance requirements might affect different aspects of business processes, e.g., control flow and data flow. As a result, it is infeasible to hard-code compliance checks in tools. Rather, a repeatable process of modeling compliance rules and checking them against business processes automatically is needed. This thesis provides a formal approach to support process design-time compliance checking. Using visual patterns, it is possible to model compliance requirements concerning control flow, data flow and conditional flow rules. Each pattern is mapped into a temporal logic formula. The thesis addresses the problem of consistency checking among various compliance requirements, as they might stem from divergent sources. Also, the thesis contributes to automatically check compliance requirements against process models using model checking. We show that extra domain knowledge, other than expressed in compliance rules, is needed to reach correct decisions. In case of violations, we are able to provide a useful feedback to the user. The feedback is in the form of parts of the process model whose execution causes the violation. In some cases, our approach is capable of providing automated remedy of the violation.

Keywords: No keywords available

Business Process Compliance Management: An Integrated Proactive Approach (Elgammal et al. (2014))

Today's enterprises demand a high degree of compliance of business processes to meet regulations, such as Sarbanes-Oxley and Basel I-III. To ensure continuous guaranteed compliance, compliance management should be considered during all phases of the business process lifecycle; from the analysis and design to deployment, monitoring and evaluation. This paper introduces an integrated business process compliance management framework that incorporates design-time verification and runtime monitoring approaches. The nutshell of the approach is the Compliance Request Language (CRL), which is a high-level pattern-based language for the abstract specification of compliance requirements. From CRL expressions, formal compliance rules can be automatically generated, thereby eliminating the need for business and compliance experts to learn and use complex low-level formal languages. Formalized compliance rules enable automated approaches to be used for the static verification and dynamic monitoring of business processes. An integrated prototypical tool-suite is developed as a proof-of-concept to help validating the applicability of the approaches, and validated by experiment with two real-life case studies.

Keywords: No keywords available

The Influence of Directive Explanations on Users' Business Process Compliance Performance (Hadasch, Maedche, and Gregor (2016))

Purpose – In organizations, individual user's compliance with business processes is important from a regulatory and efficiency point of view. The restriction of users' choices by implementing a restrictive information system is a typical approach in many organizations. However, restrictions and mandated compliance may affect employees' performance negatively. Especially when users need a certain degree of flexibility in completing their work activity. The purpose of this paper is to introduce the concept of directive explanations (DEs). DEs provide context-dependent feedback to users, but do not force users to comply.

Keywords: No keywords available

Norms Modeling Constructs of Business Process Compliance Management Frameworks: A Conceptual Evaluation (Hashmi and Governatori (2017))

The effectiveness of a compliance management framework (CMF) can be guaranteed only if the framework is based on sound conceptual and formal foundations. In particular, the formal language used in the CMF is able to expressively represent the specifications of normative requirements (hereafter, norms) that impose constraints on various activities of a business process. However, if the language used lacks expressiveness and the modelling constructs proposed in the CMF are not able to properly represent different types of norms, it can significantly impede the reliability of the compliance results produced by the CMF. This paper investigates whether existing CMFs are able to provide reasoning and modeling support for various types of normative requirements by evaluating the conceptual foundations of the modeling constructs that existing CMFs use to represent a specific type of norm. The evaluation results portray somewhat a bleak picture of the state-of-the-affairs when it comes to represent norms as none of the existing CMFs is able to provide a comprehensive reasoning and modeling support. Also, it points to the shortcomings of the CMFs and emphasises exigent need of new modeling languages with sound theoretical and formal foundations for representing legal norms.

Keywords: Business Processes, Compliance, Compliance Management Frameworks, Modelling Constructs, Modelling Languages, Norms

Are We Done with Business Process Compliance: State of the Art and Challenges Ahead (Hashmi et al. (2018))

Literature on business process compliance (BPC) has predominantly focused on the alignment of the regulatory rules with the design, verification and validation of business processes. Previously surveys on BPC have been conducted with specific context in mind; however, the literature on BPC management research is largely sparse and does not accumulate a detailed understanding on existing literature and related issues faced by the domain. This survey provides a holistic view of the literature on existing BPC management approaches, and categories them based on different compliance management strategies in the context of formulated research questions. A systematic literature approach is used where search terms pertaining keywords were used to identify literature related to the research questions from scholarly databases. From initially 183 papers, we selected 79 papers related to the themes of this survey published between 2000–2015. The survey results reveal that mostly compliance management approaches center around three distinct categories namely: design-time (28%), run-time (32%) and auditing (10%). Also, organisational and internal control based compliance management frameworks (21%) and hybrid approaches make (9%) of the surveyed approaches. Furthermore, open research challenges and gaps are identified and discussed with respect to the compliance problem.

Keywords: Business process compliance, Business processes, Compliance Management Frameworks, Normative requirements, Norms compliance

Improved Compliance by BPM-Driven Workflow Automation (Holzmüller-Laue et al. (2014))

Using methods and technologies of business process management (BPM) for the laboratory automation has important benefits (i.e., the agility of high-level automation processes, rapid interdisciplinary prototyping and implementation of laboratory tasks and procedures, and efficient real-time process documentation). A principal goal of the model-driven development is the improved transparency of processes and the alignment of process diagrams and technical code. First experiences of using the business process model and notation (BPMN) show that easy-to-read graphical process models can achieve and provide standardization of laboratory workflows. The model-based development allows one to change processes quickly and an easy adaption to changing requirements. The process models are able to host work procedures and their scheduling in compliance with predefined guidelines and policies. Finally, the process-controlled documentation of complex workflow results

addresses modern laboratory needs of quality assurance. BPMN 2.0 as an automation language to control every kind of activity or subprocess is directed to complete workflows in end-to-end relationships. BPMN is applicable as a system-independent and cross-disciplinary graphical language to document all methods in laboratories (i.e., screening procedures or analytical processes). That means, with the BPM standard, a communication method of sharing process knowledge of laboratories is also available.

Keywords: BPMN, end-to-end workflow, laboratory automation, model-based application development, systems integration

A Knowledge-Intensive Adaptive Business Process Management Framework (Kir and Erdogan (2021))

Business process management has been the driving force of optimization and operational efficiency for companies until now, but the digitalization era we have been experiencing requires businesses to be agile and responsive as well. In order to be a part of this digital transformation, delivering new levels of automation-fueled agility through digitalization of BPM itself is required. However, the automation of BPM cannot be achieved by solely focusing on process space and classical planning techniques. It requires a holistic approach that also captures the social aspects of the business environment, such as corporate strategies, organization policies, negotiations, and cooperation. For this purpose, we combine BPM, knowledge-intensive systems and intelligent agent technologies, and yield one consolidated intelligent business process management framework, namely agileBPM, that governs the entire BPM life-cycle. Accordingly, agileBPM proposes a modeling methodology to semantically capture the business interests, enterprise environment and process space in accordance with the agent-oriented software engineering paradigm. The proposed agent-based process execution environment provides cognitive capabilities (such as goal-driven planning, norm compliance, knowledge-driven actions, and dynamic cooperation) on top of the developed business models to support knowledge workers' multi-criteria decision making tasks. The context awareness and exception handling capabilities of the proposed approach have been presented with experimental studies. Through comparative evaluations, it is shown that agileBPM is the most comprehensive knowledge-intensive process management solution.

Keywords: Agent-based business process management, Agile business process management, Business process management, Knowledge-intensive processes, Process adaptation, Process modeling and execution

Compliance Monitoring in Business Processes: Functionalities, Application, and Tool-Support (Ly et al. (2015))

In recent years, monitoring the compliance of business processes with relevant regulations, constraints, and rules during runtime has evolved as major concern in literature and practice. Monitoring not only refers to continuously observing possible compliance violations, but also includes the ability to provide fine-grained feedback and to predict possible compliance violations in the future. The body of literature on business process compliance is large and approaches specifically addressing process monitoring are hard to identify. Moreover, proper means for the systematic comparison of these approaches are missing. Hence, it is unclear which approaches are suitable for particular scenarios. The goal of this paper is to define a framework for Compliance Monitoring Functionalities (CMF) that enables the systematic comparison of existing and new approaches for monitoring compliance rules over business processes during runtime. To define the scope of the framework, at first, related areas are identified and discussed. The CMFs are harvested based on a systematic literature review and five selected case studies. The appropriateness of the selection of CMFs is demonstrated in two ways: (a) a systematic comparison with pattern-based compliance approaches and (b) a classification of existing compliance monitoring approaches using the CMFs. Moreover, the application of the CMFs is showcased using three existing tools that are applied to two realistic

data sets. Overall, the CMF framework provides powerful means to position existing and future compliance monitoring approaches.

Keywords: Business process compliance, Compliance monitoring, Operational support

Blockchains for Business Process Management-Challenges and Opportunities (Mendling et al. (2018))

Blockchain technology promises a sizable potential for executing inter-organizational business processes without requiring a central party serving as a single point of trust (and failure). This paper analyzes its impact on business process management (BPM). We structure the discussion using two BPM frameworks, namely the six BPM core capabilities and the BPM lifecycle. This paper provides research directions for investigating the application of blockchain technology to BPM.

Keywords: Top100

BPM Perspectives to Support ICSs: Exploiting the Integration of Formal Verifications into Investment Service Provision Processes (Raucci et al. (2020))

**Purpose** This paper investigates the criteria for a selective integration, in the multidisciplinary business process management (BPM) areas, between information technologies tools and the company's internal control systems (ICSs) aimed at directing organizational behaviours. Adopting a process-based perspective, the authors propose a formal methodology to increase ICSs aims, related to the segregation of duties (SoDs) models, efficiently and effectively. **Design/methodology/approach** The authors examine the applicability of formal verifications to validate a banking process of providing investment services, which is mapped through the workflow management system. To mitigate the state explosion problem of formal methods, the authors propose an efficient methodology that has been proved on the SoDs models in the bank ICSs, as a case study. **Findings** The authors' investigations suggest that in the BPM domain, the banking ICSs aims can benefit from the aforesaid methodologies, originating from the formal methods area, to increase the reliability and correctness in the design, modelling and implementation of the SoDs models. **Originality/value** The proposed methodology is quite general and can be efficiently applied to large-scale systems in different business contexts or areas of the BPM. Its application to the bank's SoD prevents or detects significant weaknesses, operational risks, excessive risk appetite and other undesirable behaviours in the investment services provision processes. This guarantees that the investment ordered/offered is "suitable and appropriate" with the client's risk profile, especially non-professional, required by the MiFID II Directive.

Keywords: Banking Processes, Business Process Management, Formal Methods, Internal Control Systems, Investment Services, Segregation of Duties

Comparing Textual Descriptions to Process Models – The Automatic Detection of Inconsistencies (van der Aa, Leopold, and Reijers (2017))

Many organizations maintain textual process descriptions alongside graphical process models. The purpose is to make process information accessible to various stakeholders, including those who are not familiar with reading and interpreting the complex execution logic of process models. Despite this merit, there is a clear risk that model and text become misaligned when changes are not applied to both descriptions consistently. For organizations with hundreds of different processes, the effort required to identify and clear up such conflicts is considerable. To support organizations in keeping their process descriptions consistent, we present an approach to automatically identify inconsistencies between a process model and a corresponding textual description. Our approach detects cases where the two process representations describe activities in different orders and detect process model



activities not contained in the textual description. A quantitative evaluation with 53 real-life model-text pairs demonstrates that our approach accurately identifies inconsistencies between model and text.

Keywords: Business process management, Business process modeling, Compliance checking, Inconsistency detection, Matching, Natural language processing

Spreadsheets for Business Process Management: Using Process Mining to Deal with Events ' ' Rather than Numbers' ' (Van Der Aalst (2018))

Purpose – Process mining provides a generic collection of techniques to turn event data into valuable insights, improvement ideas, predictions, and recommendations. This paper uses spreadsheets as a metaphor to introduce process mining as an essential tool for data scientists and business analysts. The purpose of this paper is to illustrate that process mining can do with events what spreadsheets can do with numbers.

Keywords: No keywords available

Product-Based Workflow Support (Vanderfeesten, Reijers, and Van Der Aalst (2011))

Despite the industrial need for the improvement of information-intensive business processes, few scientifically grounded approaches exist to support such initiatives. In this paper, we propose a new approach that builds on concepts that are part of a product-oriented view on process optimization. Essentially, this approach allows end users to flexibly decide on the best possible way to create an informational product within the limits that are imposed by regulations and logical dependencies. We argue that this provides various benefits in comparison to earlier work. To support the end user in making sensible decisions, we describe two alternative approaches to provide her with recommendations to this end. We formalize these alternatives and discuss their relative strengths and weaknesses. The feasibility of the overall approach, which we refer to as Product-Based Workflow Support, is demonstrated by a workflow system realized using ProM and DECLARE.

Keywords: Business Process Modelling, Product Data Model, Workflow Management

Blockchain-as-a-Service for Business Process Management: Survey and Challenges (Viriyasitavat et al. (2023))

Blockchain technology (BCT) has brought a paradigm shift to Business Process Management (BPM). BCT provides a trusted decentralized infrastructure to secure data and process executions using distributed ledgers and smart contract to manage complex business processes. Numerous efforts have been made to exploit BCT in supporting dynamic and trusted collaborations of business processes. This paper aims to understand recent BCT development for its BPM applications and identify the limitations and challenges for further development via a systematic literature review (SLR). It is found that numerous works have reported using BCT as technical solutions to fulfill some traditional BPM functions. This paper is distinguished from existing works, especially several relevant surveys in the sense that (1) the impact of using BCT in BPM is thoroughly explored to identify new constraints and challenges explicitly brought by blockchains; (2) the requirements for Business Process Compliance (BPC) are firstly analyzed in detail. Note that BPC is to assure the adherence of business processes to pre-defined policies, standards, specifications, regulations, and laws when business processes are executed. To fill the gaps of BCT applications in these two aspects, Blockchain-as-aService (BCaaS) is adopted in business process architecture, and the trends of BCT developments are identified accordingly.

Keywords: No keywords available

Blockchain-Based Business Process Management (BPM) Framework for Service Composition in Industry 4.0 (Viriyasitavat (2020))

Business process management (BPM) aims to optimize business processes to achieve better system performance such as higher profit, quicker response, and better services. BPM systems in Industry 4.0 are required to digitize and automate business process workflows and support the transparent interoperations of service vendors. The critical bottleneck to advance BPM systems is the evaluation, verification, and transformation of trustworthiness and digitized assets. Most of BPM systems rely heavily on domain experts or third parties to deal with trustworthiness. In this paper, an automated BPM solution is investigated to select and compose services in open business environment, Blockchain technology (BCT) is explored and proposed to transfer and verify the trustiness of businesses and partners, and a BPM framework is developed to illustrate how BCT can be integrated to support prompt, reliable, and cost-effective evaluation and transferring of Quality of Services in the workflow composition and management.

**Keywords:** Block-chain technology (BCT), Business process management (BPM), Industry 4.0, Internet of Things (IoT), Quality of Service (QoS), Service selection and composition, Smart contracts, Trustworthiness

Recognizing and Splitting Conditional Sentences for Automation of Business Processes Management (Vo et al. (2021))

Business Process Management (BPM) is the discipline which is responsible for management of discovering, analyzing, redesigning, monitoring, and controlling business processes. One of the most crucial tasks of BPM is discovering and modelling business processes from text documents. In this paper, we present our system that resolves an end-to-end problem consisting of 1) recognizing conditional sentences from technical documents, 2) finding boundaries to extract conditional and resultant clauses from each conditional sentence, and 3) categorizing resultant clause as Action or Consequence which later helps to generate new steps in our business process model automatically. We created a new dataset and three models solve this problem. Our best model achieved very promising results of 83.82, 87.84, and 85.75 for Precision, Recall, and F1, respectively, for extracting Condition, Action, and Consequence clauses using Exact Match metric.

**Keywords:** Computer Science - Computation and Language

Evaluation of Compliance Rule Languages for Modelling Regulatory Compliance Requirements (Zasada et al. (2023))

Compliance in business processes has become a fundamental requirement given the constant rise in regulatory requirements and competitive pressures that have emerged in recent decades. While in other areas of business process modelling and execution, considerable progress towards automation has been made (e.g., process discovery, executable process models), the interpretation and implementation of compliance requirements is still a highly complex task requiring human effort and time. To increase the level of “mechanization” when implementing regulations in business processes, compliance research seeks to formalize compliance requirements. Formal representations of compliance requirements should, then, be leveraged to design correct process models and, ideally, would also serve for the automated detection of violations. To formally specify compliance requirements, however, multiple process perspectives, such as control flow, data, time and resources, have to be considered. This leads to the challenge of representing such complex constraints which affect different process perspectives. To this end, current approaches in business process compliance make use of a varied set of languages. However, every approach has been devised based on different assumptions and motivating scenarios. In addition, these languages and their presentation usually abstract from real-world requirements which often would imply introducing a substantial amount of domain knowledge and interpretation, thus hampering the evaluation of their expressiveness. This is a serious problem, since comparisons of different formal languages based on real-world compliance requirements are lacking, meaning that users of such languages are not able to make informed decisions about which language to choose. To close this gap and to establish a uniform evaluation basis,

we introduce a running example for evaluating the expressiveness and complexity of compliance rule languages. For language selection, we conducted a literature review. Next, we briefly introduce and demonstrate the languages' grammars and vocabularies based on the representation of a number of legal requirements. In doing so, we pay attention to semantic subtleties which we evaluate by adopting a normative classification framework which differentiates between different deontic assignments. Finally, on top of that, we apply Halstead's well-known metrics for calculating the relevant characteristics of the different languages in our comparison, such as the volume, difficulty and effort for each language. With this, we are finally able to better understand the lexical complexity of the languages in relation to their expressiveness. In sum, we provide a systematic comparison of different compliance rule languages based on real-world compliance requirements which may inform future users and developers of these languages. Finally, we advocate for a more user-aware development of compliance languages which should consider a trade off between expressiveness, complexity and usability.

Keywords: business processes, compliance rules modelling, conceptual modelling, expressiveness, language complexity, regulatory compliance

*Number of selected bibtex entries 22.*

## G Journals

Table G.1: Journals

#	Journal	Publisher	ISSN
1	Applied Computer Systems	De Gruyter Poland Sp. z o.o.	2255-8691
2	Artificial Intelligence and Law	Springer-Verlag	0924-8463
5	Government Information Quarterly	Elsevier	0740-624X
8	Information Systems	Elsevier	0306-4379
9	Knowledge and Information Systems	Springer-Verlag	0219-1377
10	Knowledge and Process Management	Wiley (John Wiley & Sons)	1092-4604
11	SLAS Technology	Elsevier	2472-6303
12	Safety Science	Elsevier	0925-7535
13	Software	Elsevier	2352-7110

The publisher and the ISSN number have been looked up at [crossref](#) using the journal name in the bibtex file.

Table G.2: Authors

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Yiwei Gong	Marijn Janssen
Silke Holzmüller-Laue	Bernd Göde, Heidi Fleischer, Kerstin Thurow
Huseyin Kir	Nadia Erdogan
Domenico Raucci	Antonella Santone, Francesco Mercaldo, Tomasz Dyczkowski
Ronaldo Bernardo Junior	Silvia Ines Dallavalle de Padua
Han van der Aa	Henrik Leopold, Hajo A. Reijers
Mustafa Hashmi	Guido Governatori, Ho-Pun Lam, Moe Thandar Wynn
M. Bevilacqua	F.E. Ciarapica, C. Paciarotti
Mustafa Hashmi	Guido Governatori
Rolands Koncevičs	Ludmila Peņicina, Andrejs Gaidukovs, Māris Dargis and Rita Burbo, Ainārs Auziņš
Niels Lohmann	
Shazia Sadiq	Guido Governatori
David Schumm	Oktay Turetken, Natallia Kokash, Amal Elgammal and Frank Leymann, Willem-Jan van den Heuvel
Andrea Zasada	Mustafa Hashmi, Michael Fellmann, David Knuplesch
Elham Ramezani	Dirk Fahland, Wil van der Aalst
Irene Vanderfeesten	Hajo A. Reijers, Wil van der Aalst

Table G.3: Keywords

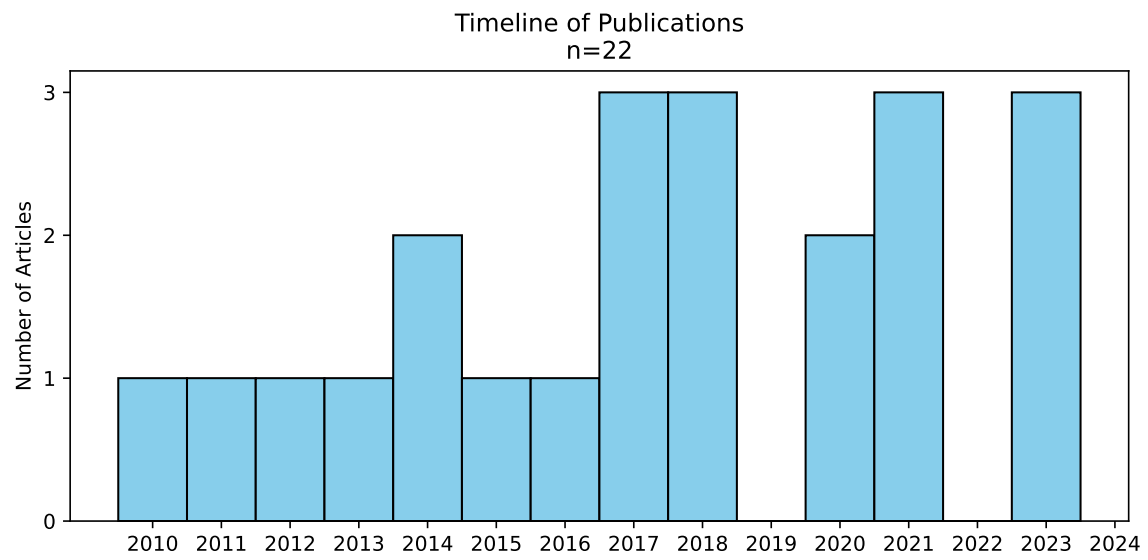
Citation Key	Keywords
gong2012policy	Flexibility, Agility, Business process management, Business services, Service orientation, Policy-making, Compliance
holzmüller_laue	laboratory automation, end-to-end workflow, systems integration, model-based application development, BPMN
kir2021knowledg	business process management, knowledge-intensive processes, Process modelling and execution, Process adaption, Agent-based business process management, Agile business process management
raucci2020bpm	Business Process Management, Internal Control Systems, Segregation of Duties, Formal Methods, Banking Processes, Investment Services
BernardoJuniorU	critical success factors, operations strategy, bpm governance, knowledge systems, implementation capabilities, organization, challenges, intuition
aa2017comparing	Business process management, Inconsistency detection, Compliance checking, Business process modeling, Natural language processing, Matching
hashmi2018are	Business processes, Business process compliance, Norms compliance, Normative requirements, Compliance Management Frameworks
bevilacqua2012b	Emergency management, IDEF0, Information system, Information supply, Risk information, Public, Safety management
hashmi2017norms	Norms, Compliance, Business Processes, Modelling Constructs, Modelling Languages, Compliance Management Frameworks
koncevičs2017co	Business process compliance, compliance management, compliance management tools, open source business process modelling tools
lohmann2013comp	Artifact-centric business processes, Process synthesis, Compliance management, Compliance by design
sadiq2010managi	Business Process, Control Objective, Linear Temporal Logic, Business Process Management, Semantic Annotation
schumm2010busin	Compliance, Business Process Management, Process Fragment, Formal Modeling, Proces Verification
zasada2023evalu	conceptual modelling, compliance rules modelling, regulatory compliance, business process expressiveness, language complexity
ramezani2014sup	compliance specification, compliance checking, configurabe compliance rules, auditing, question tree
vanderfeesten20	Business process modeling, Workflow management, Product Data Model

The keywords have been added to the bibtex file after consulting the publishers website and/or the web of science service.

## H Authors

Table H.1: Authors

First Author	Other Authors
Bernardo Junior, Ronaldo Bevilacqua, M. Corsius, Mischa	De Padua, Silvia Ines Dallavalle Ciarapica, F.E., Paciarotti, C. Hoppenbrouwers, Stijn, Lokin, Mariette, Baars, Elian, {Sangers-Van Cappellen}, Gertrude, Wilmont, Ilona
Ramezani, Elham Koncetics, Rolands	Fahland, Dirk, {van der Aalst}, Wil M. P. Penicina, Ludmila, Gaidukovs, Andrejs, Dargis, Maris, Burbo, Rita, Auzins, Ainars
Awad, Ahmed Mahmoud Hany Aly Elgammal, A	Sebahi, S, Turetken, O, Hacid, {MS}, Papazoglou, {MP}, {van den Heuvel}, { WJ}
Hadasch, Frank Hashmi, Mustafa Hashmi, Mustafa {Holzm{”u}ller-Laue}, Silke Kir, Huseyin Ly, Linh Thao	Maedche, Alexander, Gregor, Shirley Governatori, Guido Governatori, Guido, Lam, Ho-Pun, Wynn, Moe Thandar G{”o}de, Bernd, Fleischer, Heidi, Thurow, Kerstin Erdogan, Nadia Maggi, Fabrizio Maria, Montali, Marco, {Rinderle- Ma}, Stefanie, Van Der Aalst, Wil MP
Mendling, Jan	Weber, Ingo, Aalst, Wil Van Der, Brocke, Jan Vom, Cabanillas, Cristina, Daniel, Florian, Debois, S{ø}ren, Ciccio, Claudio Di, Dumas, Marlon, Dustdar, Schahram
Raucci, Domenico	Santone, Antonella, Mercaldo, Francesco, Dyczkowski, Tomasz
{van der Aa}, Han Van Der Aalst, Wil Vanderfeesten, Irene Viriyasitavat, Wattana Viriyasitavat, Wattana Vo, Ngoc Phuoc An	Leopold, Henrik, Reijers, Hajo A.  Reijers, Hajo A., Van Der Aalst, Wil M.P. Da Xu, Li, Dhiman, Gaurav, Bi, Zhuming
Zasada, Andrea	Manotas, Irene, Popescu, Octavian, Cerniauskas, Algimantas, Sheinin, Vadim Hashmi, Mustafa, Fellmann, Michael, Knuplesch, David



# I Keywords

Table I.1: Keywords

Citation Key	Keywords
Bernardo Junior and De Padua (2023)	Agility, bpm governance, Business And Economics–Management, Business process management, challenges, Communication, critical success factors, Customer satisfaction, implementation capabilities, intuition, knowledge systems, Literature reviews, operations strategy, organization, Systematic review
Bevilacqua, Ciarapica, and Paciarotti (2012)	Emergency management, IDEF0, Information supply, Information system, Public, Risk information, Safety management
Corsius et al. (2021)	CNL
Ramezani, Fahland, and van der Aalst (2013)	auditing, compliance checking, compliance specification, configurable compliance rules, question tree
Koncevics et al. (2017)	Business process compliance, compliance management, compliance management tools, open source business process modelling tools
Awad (2010)	No keywords
Elgammal et al. (2014)	No keywords
Hadasch, Maedche, and Gregor (2016)	No keywords
Hashmi and Governatori (2017)	Business Processes, Compliance, Compliance Management Frameworks, Modelling Constructs, Modelling Languages, Norms
Hashmi et al. (2018)	Business process compliance, Business processes, Compliance Management Frameworks, Normative requirements, Norms compliance
Holzmüller-Laue et al. (2014)	BPMN, end-to-end workflow, laboratory automation, model-based application development, systems integration
Kir and Erdogan (2021)	Agent-based business process management, Agile business process management, Business process management, Knowledge-intensive processes, Process adaptation, Process modeling and execution
Ly et al. (2015)	Business process compliance, Compliance monitoring, Operational support
Mendling et al. (2018)	Top100
Raucci et al. (2020)	Banking Processes, Business Process Management, Formal Methods, Internal Control Systems, Investment Services, Segregation of Duties



Table I.1: Keywords

Citation Key	Keywords
van der Aa, Leopold, and Reijers (2017)	Business process management, Business process modeling, Compliance checking, Inconsistency detection, Matching, Natural language processing
Van Der Aalst (2018)	No keywords
Vanderfeesten, Reijers, and Van Der Aalst (2011)	Business Process Modelling, Product Data Model, Workflow Management
Viriyasitavat et al. (2023)	No keywords
Viriyasitavat (2020)	Block-chain technology (BCT), Business process management (BPM), Industry 4.0, Internet of Things (IoT), Quality of Service (QoS), Service selection and composition, Smart contracts, Trustworthiness
Vo et al. (2021)	Computer Science - Computation and Language
Zasada et al. (2023)	business processes, compliance rules modelling, conceptual modelling, expressiveness, language complexity, regulatory compliance

The keywords have been added to the bibtex file after consulting the publishers website and/or the web of science service.

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