Technology-, Human-, and Data-Driven Developments in Business Process Management: A Literature Analysis

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Abstract. Approaches of business process management (BPM) are always changing, because underlying business strategies and technological implementation are constantly evolving. Likewise, methodical approaches, how business processes are planned, optimized, managed and controlled, come and go. This article collects and systematizes the trends discussed at major BPM conferences of the year 2019. The identified hot spots include e.g. process mining, predictive BPM, BPM trust, modeling, BPM platforms, team-driven BPM.

Keywords: Business process management · Trend analysis · Research discourses · BPM body of knowledge

1 Introduction

Even if business process management (BPM) as a discipline is not always mentioned, a classical process-oriented approach is often used in initiatives, research, or projects [1–4]. Currently, companies are trying to use digital transformation to change from product-/function-oriented designs to process-oriented approaches [5]. When this happens using intelligent data analysis or new technologies, the term "digital transformation" or simply "digitalization" is often used [2, 6, 7]. However, the underlying concepts result from and are enabled by the discipline of BPM [8], as has been shown in several studies for BPM [1, 4, 9]. Thus, many concepts used are not fundamentally new, but have already been used in previous BPM research. This transfer of ideas and approaches happens either *directly* (e.g. process mining has been known for decades as the analysis of process instance data, but is now content of numerous publication) or *indirectly* (holistic approaches such as smart home, smart cities, and smart grid are based on the control and data flows of workflow models or instances). However, many transfers conform to the core principle

© Springer Nature Switzerland AG 2020
M. Freitag et al. (Eds.): S-BPM ONE 2020, CCIS 1278, pp. 217–231, 2020.
https://doi.org/10.1007/978-3-030-64351-5_15

of BPM, namely the design of IT-supported or manual implementation and control of business processes [10].

As stated, there is a multitude of topics and challenges in the context of digitalization that are discussed either in the BPM discipline or are originally coming from the BPM discipline (e.g. Industry 4.0, Intelligent Business Models) [7, 11]. Possible reasons behind these developments have also been described. However, as these analyses were created two years in the past and with ever evolving business strategies, technological implementations, and research interest [4, 9], the authors of this paper saw the necessity for an update. This will be done analogous to [4, 9] with the following research questions:

(1) What catchwords is the scientific community using when discussing new concepts and methods?
(2) What are the current process management trends based on the catchword and which directions are they taking?

The concepts and terms in digitalization directly or indirectly relate to BPM and are subject to continuous change. This article is intended to help researchers and practitioners to gain an overview of current discussions. The analysis is also intended to renew and possibly expand one's own perspective on process management. The classification should help researchers to discover adjacent BPM discussions in related disciplines, avoid misunderstandings and uncertainties, and to discover relevant original research results in the different BPM communities.

Section 2 describes the applied methodology and Sect. 3 shows the classification of the individual topics and challenges (called catchwords). A discussion of the underlying developments as well as of the developments compared to the study before is presented in Sect. 4. A brief summary of the study can be found in Sect. 5.

2 Methodology

As mentioned above, this contribution serves as an update and extension to the results of [4, 9]. Therefore, the methods used will be applied again. Even if there are small adjustments, please refer to the core texts [4, 9] for a more detailed documentation of the procedure. As a major difference, the categories for the catchwords were not developed from scratch. Instead, after the topics were collected, they were classified into the dimensions known from the former study (human-driven, data-driven and case-driven). It turned out that it was also necessary to change one dimension.

The analysis with the goal of collecting relevant catchwords and assigning them to dimensions was carried out in a five-step qualitative content analysis. Specifically, the methodology followed the recommendations by [11–13] with the restriction that the classifications used are not conclusive or exclusive, but rather represent tendencies, i.e. dimensions. These dimensions thus stand for viewpoints, the respective papers take in order to investigate the catchword (e.g. more a human- or technology-driven view on topics).

For the *first step*, eight main BPM conferences (see Table 1) have been investigated[1], while WI (International Conference Wirtschaftsinformatik, engl. International Conference on Information Systems) and MKWI (Multikonferenz Wirtschaftsinformatik, engl. Multi Conference on Information Systems) being recorded once due to their merger. All analyzed conference proceedings have in common that (i) they have or have had a clear BPM focus, (ii) they are technically or business-oriented, (iii) they have a minimum of scientific quality (e.g. ranking), (iv) at least ten conference proceedings in the past are available, and (v) a sufficient degree of publicity is given. Note that, more and more upcoming conferences, which are originally organized by companies (e.g. software providers), were excluded because of possible bias in their topics.

Table 1. Identified BPM papers in the conference proceedings

Catchword	**Conference**								
	BPM	**WI**	**INF**	**ECIS**	**SEAA**	**CBI**	**S-BPM**	**BIS**	**Sum**
Process Mining	11	2							13
Conformance checking	2					2	1		5
Context awareness	1	1		1		1		2	6
NLP	1	1	1	1					4
Predictive BPM	1	3		2				3	9
Management	3			2	1		1		7
Modelling	6	6	2	2	1	1	1	2	21
BPM trust	2			4					6
User-centric BPM	1	1		4				1	7
Internet of Things (IoT)	1			1		2	2		6
Platforms		3				1			4

Legend: BPM = International Conference on Business Process Management; WI = International Conference Wirtschaftsinformatik, engl. International Conference on Information Systems; INF = Informatik, engl. Informatics; SEAA = Euromicro Conference on Software Engineering and Advanced Applications; CBI = IEEE International Conference on Business Informatics; S-BPM = International Conference S-BPM ONE; BIS = International Conference on Business Information Systems; NLP = Natural language processing

In a *second step*, from the total of 752 papers (all contributions from the conferences) only those with a clear BPM focus were selected. For this purpose, generic BPM-relevant elements (e.g. control flow, process orientation, recurring patterns) were screened in title, abstract and keywords.

[1] This implies only the main scientific conference and the according publications. Workshops, industrial forums, or poster presentations have been excluded.

Thus, 88 contributions went into *step three*. In this step the catchwords were grouped into topics by researcher triangulation. This means each researcher identified catchwords and grouped them to topics separately and then the results have been discussed and merged.

In *steps four and five*, categories were formed for identified topics. The researcher triangulation used in the former study was repeated to adjust and form the first categories. However, different to the former study, a Delphi study was conducted additionally. In two Delphi rounds the assignment of individual catchwords to the categories was evaluated on a quantitative 3-point scale and deviations were discussed afterwards. The four participating experts were BPM researchers with a doctorate, a total of more than 45 years of experience and more than 150 publications on BPM topics. This change in the methodology was necessary because the dimensions are no longer disjunct compared to the ones used in publications [4, 9]. Single topics (e.g. BPM 2.0) could be clearly assigned to one category in the previous study (e.g. social-driven), whereas many catchwords of this updated study (e.g. IoT, platforms) can be assigned to several categories (e.g. technology and people). The classification therefore becomes dependent on the viewpoint of the contributions analyzed in a multidimensional spectrum (see also Fig. 1).

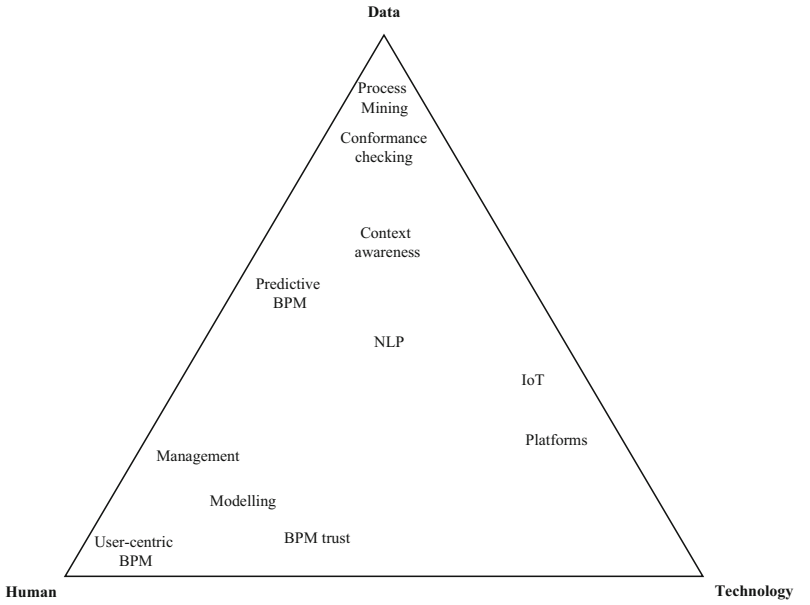

Fig. 1. Visual classification of the identified catchwords into the three identified dimensions

As a result, 11 single catchwords were grouped into three basic dimensions: data-driven, social-driven, and technology-driven BPM. Section 3 presents the identified trends and internal research discussions in greater detail. The originally existing category "case-driven" no longer appears in current discussions.

3 Results

Based on the distribution of the classified catchwords (see methodology), the following solution space can be spanned. It shows to which general view the identified catchwords tend to be assigned to within the respective proceeding papers.

In the following, the current research discourses on the individual catchwords are presented. Since the catchwords mentioned here are oriented directly after the analyzed publications (see previous section), naturally the descriptions differ in granularity.

3.1 Process Mining

Process Mining was already a relevant topic in the previous study. In the publications on this catchword, static methods, technique, as well as supporting tools are discussed. Generally, it stands for approaches that aim to extract information from real process executions (mostly recorded in event logs of information systems like Enterprise Resource Planning). In this analysis, again it was a very prominent topic with 13 publications.

This is probably due to increasing overall importance of the data and the focus on the intelligent evaluation (machine learning). Process Mining is seen as a solution to many BPM challenges (e.g. cost optimization, identifying bottlenecks, uncovering anomalies, or creating transparency/compliance). Even a contribution on how mining can be used to communicate conflicting goals can be found in the analysis. It is interesting to note that the business implications often reflect classic BPM optimization rules (e.g. remove activities, reorder resources, accelerate process paths).

In general (especially through the conference 'BPM'), more and more case studies on use cases of mining are published. Prominent examples are classical optimizations in Smart Factory, real-time evaluation/assessment of processes as well as Robot Process Automation (RPA). But also new ideas like interactions or the measurement of events at the transition between humans and machines are topics in papers. A first meta-study on application scenarios is also available.

Separated from use cases, research is being conducted on methodology in the narrower sense and on improving the mining basis. In the field of methodology, approaches exist on how declarative instead of descriptive information can be obtained from data. Furthermore, alternative mathematical/statistical methods are reported on the central question, how the accuracy of mining can be improved. There are also many publications on this topic in the research of Machine Learning. The central topic in BPM is still the question of how a reasonable consideration of certainly good (e.g. correct) data can be combined with less good (e.g. vague, old, generic) data for better decisions. In the area of improving the data basis, approaches are generally published that not only use flat event logs, but also enrich them or supplement them with additional data. For example, some papers discuss the urgent need for additional data for conformance checking. The ideas here range from labelling to describing the context. Some papers also apply mining techniques to other entities from process models. This includes classical elements (e.g. functions, actions) and is often analogous or complementary (e.g. labels for affected attributes to enrich semantics). However, extended elements are also used as a data basis for mining (e.g., business rules or best practices within processes).

Currently, less discussed is the question of suitable tools. The only papers on actual software focuses on the meaningful visualization of complex data and interrelationships. If this analysis were to be repeated in the coming years, special process mining conferences would also have to be considered.

3.2 Conformance Checking

The discipline of conformance checking can partially be considered a sub-domain of process mining [14]. In its most simple definition, it basically is concerned with methods, algorithms, and tools that can check whether event logs or traces comply with model definitions in formal process models [14–16].

Debatable is the question whether conformance checking can or should be considered the same as compliance checking. The fundamental premise in both cases is the same: there is a pre-definition of what is-supposed-to-be (process models or laws/regulations) and recording of what-is during execution (in both cases process or event logs of workflow tools but also specifications that describe process that should adhere to given regulations) [17, 18]. With compliance checking the chance that the is-supposed-to-be definitions are available in a formal computational form is less likely than with pure conformance checking. Partially NLP may be required.

3.3 Context Awareness

A simple and direct interpretation of context awareness would be research or studies that are geared towards more extensively and holistically considering more/all aspects in the surrounding execution system when executing BPM activities.

Into this category fall developments, analysis, and meta models that allow to define certain contexts for e.g. electronic marketplaces such as [19] or research regarding business process improvement activities with consideration of differences in organizational size, culture, and resources [20]. This broader interpretation is also covered in a study by Song et al. that is geared *Towards a Comprehensive Understanding of the Context Concepts in Context-aware Business Processes* [21]. The same researcher team also has extensively worked on a specialized technical oriented aspect of this domain, where modeling languages are required to describe *Context-Aware Business Process Models* [22] which in turn allows the integration of Internet of Things (IoT) technologies for Context-aware BPM Using IoT-integrated context ontologies and IoT-enhanced decision models [23].

3.4 NLP

Natural Language Processing (NLP) is a research and/or technology domain concerned with the computational analysis of natural human languages. As such, it is also a sub domain of artificial intelligence research. The goal is to allow computer systems to handle or be part of human information exchange. This encompasses text as well as spoken languages and includes aspects ranging from classical spell checking, thesauruses, to optical character recognitions (OCR), text-to-speech, voice recognition, but also more

complex interaction systems that try to emulate human behavior on language level. In the context of BPM most research such as [17] is concerned with applying NLP technologies to their respective domain and in order to derive or generate formalized process models from natural language descriptions (usually in the English language). Other examples try to use chat-bots for service-desk customer interactions [24] or try to identify ambiguous, redundant, and missing roles in textual descriptions of workflow systems [25].

In all investigated cases, only textual descriptions were concerned and as far as discernable, other aspects of NLP such as voice recognition have not been applied to BPM concerns.

3.5 Predictive BPM

Same as Process Mining, Predictive BPM was already a catchword in the previous analysis and stands for data analytics approaches that aim to predict any kind of future behavior. The current research shows the classical use cases in digitalization (Predictive Maintenance, see the previous paper) is being continued. However, in the past, prediction systems with simple process data derived too imprecise predictions. The ongoing developments are to be seen in three areas: (i) In addition to structured data of processes, context information is increasingly used, which is nevertheless complicated to capture (see also Context Awareness). Therefore, mostly only specialized use-cases (e.g. document analysis) are being researched. (ii) Algorithms are also further developed (e.g. support vector machine/machine learning). Here two current trends can be seen. On the one hand, attempts are made to use patterns and to extend taxonomies in order to transfer predictions into known knowledge/open new fields of knowledge. On the other hand, other researchers show interest in individual and specific analysis methods, which use individual forecasts without patterns. (iii) Monitoring of processes was originally the goal of predictive BPM - but it is being expanded in ongoing research. Although there are still approaches that focus on classic KPI-based predictions with standard sets, many researchers are trying to explore individualized measures. These mostly originate from performance management and are currently only partially linked to concrete application scenarios (research from the energy industry and production planning was found).

3.6 Management

The topic management has already surfaced in [4, 9]. This is not surprising as is a basic theme and an inherent part of BPM. We identified seven paper belonging to this catchword. Simply speaking they cover research focusing on the improvement of Business Process Management approaches.

One research stream is to align Business Process Management with other management areas in an organisation in order to achieve a successful implementation and adoption of business processes. More specifically, one approach is for example suggesting aligning BPM with practices related to Human Resource Management (BPM - Understanding the Alignment of Employee Appraisals and Rewards with Business Processes) [26].

Another trend identified is to adopt software engineering approaches such as agile approaches for BPM. Here, the focus is on the transfer of agile models from software

engineering to BPM (e.g. Synthesis of Design Parameters for the Transfer of Agility from Software Engineering to Process Management). On a more specific level the application of agile methods and personas to S-BPM is analysed in [27].

Other approaches are focusing on best practices and reference processes for different domains (e.g. research management processes and patient pathways). Lastly, one paper has quite a different focus. However, it is worth mentioning as it provides a BPM skills taxonomy drawn from an analysis of job ads to enable a better understanding of BPM Skill configurations and shifting business demands [28]. The work shows how the digitalisation has influenced the business demands and as such is important for the BPM curricula.

To summarize, in the management topic, we identified a trend to combine classical BPM approaches with human-centric approaches to enhance process implementation and adoption.

3.7 Modelling

Modelling of processes is a fundamental and traditional aspect of any concern in Business Process Management. As such, 'catchword' is not even a fitting term. Rather, BPM research concerned with modeling per se is very diversified and ties into many other domains, usually as a foundation to build further aspect on.

Examples range from proposals for specialized modeling languages and language extensions such as Annotated Textual Description of a Process (ADTP) for the field of Context Awareness [17, 29].

Papers may be concerned with declarative process descriptions and the according reasoning formalisms [30] or with the parameterized verification of Data-Aware BPMN [31].

Other possible topics that fall under the catchword modeling are e.g., more general consideration and overview studies review problems and challenges when using multiple conceptual models [32]. Some others try to give and overview and find themes and paths for future research regarding the learning of conceptual modeling [33]. Moreover, they derive a method-wise approach for selecting the most suitable business process modelling notation [34].

Just to name a few and provide an idea of the broadness of what could be implied with general topic of modeling.

3.8 BPM Trust

This topic is covering research focusing on techniques enhancing trust and transparency issues in BPM to enable secure and efficient processes. Half of the identified research papers investigate blockchain and its potential to realize (interorganizational) business processes and improve trust (e.g., [35, 36]).

Other research focuses on a more general approach and not a specific technique. For example, the paper Trust-Aware Process Design (Trust-Aware Process Design) introduces a conceptualization of trust for BPM and [37] provides examples on how to design useful transparency.

3.9 User-Centric

Research under that topic is focusing on how to support users in evolving their capabilities to improve employee alignment and process performance. Overall, we identified 13 papers belonging to this category showing the high importance of this category in current BPM research. The largest part of the research (6 papers in 2019) is concerned with user acceptance of organizational routines and new technologies. User acceptance and resistance can express itself in multiple forms including workarounds, and lack of cooperation as well as physical sabotage. User acceptance has a high impact on process performance. Interestingly, most of the current research is concentrating on workarounds and their dual nature. It investigates if a workaround is to be accepted or not accepted (e.g. [38]).

Another focus in this category is teaching, more specifically, in how to teach BPM using game-based approaches. This is due to its potential to enhance learning. Finally, there is another trend emerging in this category, this is the individualisation of processes. This research area is adding a micro perspective to the BPM body of knowledge for example by developing design patterns for Business Process individualisation (e.g. [39]). This is a trend that might become even bigger as BPM methods in general are focusing on process standardization and economies of scale, while the emerging digitalization enables process individualization and this in turn might enhance process performance [39].

3.10 Internet of Things (IoT)

The Internet of Things (IoT) describes a network of interacting devices (Things) connected via the Internet. The 'things' are for example sensors, actuators, or hardware/software combinations in embedded systems, etc. They generate and exchange data and are integral parts of technical as well as business processes. IoT technology supports the horizontal and vertical integration of such processes, in particular the transformation of the traditional automation pyramid (from bottom: Shop Floor, Manufacturing Execution Systems, Enterprise Resource Planning Systems, Supply Chain & Customer Relationship Management) into a networked environment across arbitrary enterprise architecture layers. IoT concepts and solutions involve Cyber-Physical Systems and also humans. They are not limited to industrial use-cases, but also occur in many other domains like health care or smart home. The increasing importance is reflected by the number of six papers we could assign to IoT in relation with BPM in the 2019 issues of the screened conferences. Like in previous publications, an emphasis is still on modelling. Topics reach from IoT-based business process layer, over IoT systems' architecture layer to IoT framework layer [40–42]. The high degree of integration in IoT settings mainly based on data and information flow causes vulnerability with respect to availability. To tackle this [43] suggest communication design and blockchain-based data sharing facilities in order avoid a single point of failure, while [44] present a modelling approach that depicts dependencies in IoT networks and allows to analyze threat propagation. An interesting path is followed by [45], who show how IoT technology in smart homes can be used for habit mining.

3.11 Platforms

Platforms are a cornerstone of digitalization. They match demand and supply of products, services, information etc. and support transactions between buyer and seller. Thus, platforms facilitate digital business models and enable ICT-based execution of business processes. For that reason, we consider platforms as a BPM-related topic and identified them as a relevant catchword in the publications under review, even if processes were not mentioned explicitly. [46] conceptualize a marketplace for production capacities, particularly for additive manufacturing, but also transferable to other use cases. Successfully kicking off an Industrial Internet of Things platform ecosystem is subject of the work of [19]. They conducted a case study that revealed conflicting horizontal and vertical aspects of a platform strategy. Helping SMEs to articulate needs and configure appropriate cyber-physical systems is the objective of [47]. The authors present a methodology for a respective matching platform. More general, not focusing on B2B platforms in industrial scenarios, [48] researched the combinability of strategic approaches of network economics in order to tackle the critical mass problem of two-sided marketplaces.

4 Discussion

In this discussion, a comprehensive summary and brief interpretation of the current BPM topics is provided. In addition, significant developments and changes to the study conducted 2017 will be highlighted.

In the previous study, the developments were classified into three clearly distinguishable categories (human-, data-, and case-driven). First, it should be noted that in the current proceedings no studies could be found which include the classic idea of case management for processes. At the same time, the constitutive characteristic of this research field, namely that the design and execution phases merge into one another, is found in some papers. Nevertheless, these new approaches (e.g. parts of conformance checking, process mining, predictive BPM) focus more on the data dimension. In the ideas of adaptive or emergent case management of the old study, the basic idea was to support knowledge workers with rough templates. These were then adapted manually for actual instances. With current data-driven developments, the focus is more on making digital data (and sometimes complex connections, e.g. with context data and varying data quality) available at short notice. This makes live monitoring or even automated adjustment of instances by machines possible. Nevertheless, in comparison to classical case management, where many applications and case studies have been reported, the current BPM papers mostly only show theoretical research results.

Topics that can be seen primarily to data-driven innovation have hardly changed in their naming. Process Mining was then and is now an important topic. Why exactly this form of Business Intelligence (partly also Business Analytics) has established itself in the BPM area or why it is not considered e.g. a sub-domain of machine learning, or business analytics ideas is an open question. Maybe it is because the starting point for these techniques is event tracking - an information that has always been important for automation in BPM for years. However, as with the other topics, simple ideas of data source usage or data analysis are no longer to be found in the publications. The main

driver of many publications is the absorption of complexity, for example by complicated predictions or big data, and the consideration of many data and/or sources (e.g. in Predictive BPM). It is therefore not surprising that data or intelligence topics dominate the various conferences themes. It is also noticeable, when looking at the authors of the publications, that researchers who have previously investigated formal or generally analytical topics now increasingly explicitly see data as the source of their research ideas. The Automated Knowledge Discovery to be found in the old study must now be viewed in a more fine-grained way, because many publications deal with partial aspects of this overarching topic such as the context, changed model entities (e.g. events plus actions) or even the people and machines involved in a process.

This leads to questions of technology as it is described as a new dimension in this paper. The use of technology has always been a driver for innovation in the information systems discipline, which naturally includes BPM. Technology-driven process innovation can happen through simple IT support of manual work, automation or even the digitalization of the market offer. No single topic identified in the study is – unlike the dimensions data and humans – purely seen in this dimension. Concepts related to the catchwords base on new technology in processes in order to use data potential (e.g. IoT) or to support people in their projects (e.g. modelling). Even if all proceedings contain pure technology topics (e.g. blockchain), only those described in the triangle (see Fig. 1) have a clear BPM reference. This shows that technology continues to be an enabler for processes and less the direct starting point for process innovation. Even though the question of whether technologies or business strategies are the drivers of innovation, this study comes to the conclusion that BPM communities tend to use technologies (e.g., connectivity in IoT, interfaces in platforms) to organize core BPM aspects (e.g., data and control flow).

A particularly interesting change has taken place in the dimension of human-driven topics. In the 2017 study, the topics mentioned in this area (e.g. Social BPM, BPM 2.0, Design Thinking) roughly all had the common goal of involving people in the design of processes, because their knowledge can be important for increasing effectiveness and efficiency. The topics analyzed 2017 not only had clearly different names than those in this new study, but also focused more on technical and operational issues (e.g. use of Web 2.0 tools, how workshops with process participants are to be organized, what quality assurance is required for ideas from teams). These user-focused concrete questions are still included (user-centric BPM), but the other topics go beyond this short-term view. They place people in a more individual and value-based context (e.g. trust, process individualization). The research topics are correspondingly a bit vaguer, but also often more challenging in study design. If one adds questions of culture as well as of trust, it becomes clear that the topics assigned to the human perspective tend to strive for greater values.

A scientific community such as S-BPM needs to measure its impact not only by core ideas (e.g. the further development of the modelling, the application of the concept in business practice). It has also do adapt or answer current scientific discourses from the parent BPM discipline. This paper can contribute to this, because for some of the concepts S-BPM is quite capable of providing suitable applications, theories or even descriptions.

5 Summary

This article followed in the research design of [4, 9] to give an overview of current research in the field of BPM. All eleven topics – referred to as catchwords – identified from academic conferences, were identified and their state of the art was summarized. All topics can be categorized as human-, technology- and/or data-driven.

Even though process management research is perhaps one of the oldest in the discipline of information systems, this study shows that many new developments and advancements are happening. Research at the scientific conferences tries to provide answers to classical questions of BPM with innovative ideas. The importance and drivers of people in processes was and is still a central question, as well as which technologies can support processes. A changed mindset (e.g. sustainability and sense making for people instead of operative integration of participants) and new technical possibilities (e.g. interoperability and computing power) find their ways into BPM. What they all have in common is that they attempt to promote incremental or radical process innovations using different ways and viewpoints. At the same time, due to a certain breadth of the digitization discussion, there are also papers that try to provide an overview (e.g. through taxonomies) on new trends. In general, data-based questions and solutions for processes are on the rise – a trend that BPM probably has in common with many other digital topics (e.g. Digital Health, Smart Energy).

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