REVIEW

Robotic Process Automation - A Systematic Mapping Study and Classification Framework

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ARTICLE HISTORY
Compiled October 8, 2021

ABSTRACT
Robotic Process Automation (RPA) deals with the automation of rule-based process tasks to increase process efficiency and to reduce process costs. Due to the utmost importance of business process automation in industry, RPA attracts increasing attention in the scientific field as well. This paper presents the state-of-the-art in the RPA field by means of a Systematic Mapping Study (SMS). In this SMS, 63 publications are identified, categorised, and analysed along well-defined research questions. From the SMS findings, additionally, a framework for systematically analysing, assessing, and comparing existing as well as upcoming RPA works is derived. The discovered thematic clusters suggest further investigations in order to develop a more elaborated structural research approach for RPA.

KEYWORDS
Systematic Mapping Study; Robotic Process Automation; RPA; Systematic Evaluation; RPA Classification Framework

1. Introduction

In our continuously changing world, it is indispensable that business processes are highly adaptive (Reichert and Weber 2012) and become more efficient and cost-effective (Lohrmann and Reichert 2016). As a consequence, companies demand for an increasing degree of business process automation to stay competitive in their markets. In this context, business process management (BPM) plays a crucial role in the digital lifecycle support of business processes involving multiple participants and software systems (Weber, Sadiq, and Reichert 2009). Currently, BPM is enhanced by the use of process mining and Robotic Process Automation (RPA). While the former gives companies objective and data-driven insights into the actual flow of their business processes (van der Aalst 2011), the latter describes software robots (bots for short) mimicking human interaction (Asatiani and Penttinen 2016). RPA constitutes a ‘highly promising approach’ (Cewe, Koch, and Mertens 2017) and more and more companies rely on this cutting edge technology (Asatiani and Penttinen 2016) to optimise, implement, and automate selected process tasks.

1.1. *Problem Statement*

RPA constitutes an emerging technology raising high expectations in industry (Auth and Bensberg 2019). For enterprises, however, it is still difficult to grasp the fundamental concepts of RPA, to understand the differences in comparison to other methods and technologies (e.g., BPM and process mining), and to estimate the effects the introduction of RPA will have on an enterprise and its staff. As preliminary work and preparation of this systematic mapping study (SMS), we conducted an exploratory case study in the automotive industry (Wewerka and Reichert 2021), whose results motivate the problem described above.

Due to the increasing scientific attention of RPA (see, for example, the RPA Forum established in conjunction with the BPM Conference Series[1]), the number of publications on RPA will further increase over time. RPA projects have an impact on organisation and management, IT enterprise architectures, business processes, and business process stakeholders (Auth and Bensberg 2019; Fernandez and Aman 2018; Ian, Dhayalan, and Andy 2016). Therefore, RPA publications can be attributed to different scientific areas, including e.g., management or computer science. As opposed to other SLRs in the field (e.g., (Ivančić, Vugec, and Vukšić 2019; Riedl and Beetz 2019)), this work considers publications from these different fields in order to provide a holistic overview of RPA publications, not just focusing on single aspects such as organisational or socio-technical ones. More precisely, we conducted an SMS to provide a structured overview of RPA research. The results of this study, in turn, have been used to systematically derive a classification framework for analysing, assessing, and comparing RPA works (Petersen, Vakkalanka, and Kuzniarz 2015). In particular, the framework shall help researchers to easily find relevant RPA publications.

1.2. *Contribution*

This paper provides an SMS on RPA as well as a classification framework derived from it. We aim to present the state-of-the-art on RPA by systematically analysing and assessing the most relevant publications in the field. In this context, we provide meanings attached to RPA, discuss differences to related technologies, introduce criteria for RPA-suitable process tasks, and give insights into RPA effects. Furthermore, we present case studies, give an overview of RPA methods, and discuss the combination of Artificial Intelligence (AI) methods with RPA. Taking the results of the SMS, we derive the ANCOPUR classification framework for systematically mapping, **an**alysing, and **co**mparing emerging **pu**blications on **R**PA, and link them to existing publications to assess their novelty and research contribution. The main contributions of our work to RPA research are as follows:

1. We provide a holistic overview of the state-of-the-art of RPA research that covers multiple perspectives, including organisation and management, IT enterprise architectures, business processes, and business process stakeholders.
2. We focus on seven thematic RPA clusters: RPA meanings, differences to related technologies, criteria for selecting process tasks, RPA use cases, RPA effects, methods for RPA projects, and RPA and AI.
3. We derive a classification framework to analyse, assess, and compare RPA research works.
4. We categorise methods for RPA projects along the software development life

[1] `https://bpm2021.diag.uniroma1.it/call-for-rpa-forum/`

cycle stages.

The remainder of this paper is structured as follows. First, backgrounds on RPA and related work are provided in Section 2. Section 3 introduces the research methodology we applied, followed by the obtained results in Section 4. Section 5 derives the ANCOPUR classification framework. Then, the results of this article are discussed in Section 6. We conclude with a summary and an outlook in Section 7.

2. Backgrounds

This section presents background information needed for understanding this work. First, Robotic Process Automation is explained and an example is given. Second, related work from the RPA field is summarised. To start, the differences between business process management, process mining, and RPA are clarified (cf. Figure 1). BPM deals with the modelling, implementation, execution, monitoring, and evolution of business processes (Reichert and Weber 2012). Process mining, in turn, may be considered as a sub-discipline of BPM that supports business process discovery (i.e., to discover business process models from event logs), conformance checking (i.e., to check to what degree a given event log and business process model conform with each other), and data-driven business process analysis (e.g., log-based verification of business process compliance) (Geyer-Klingeberg, Nakladal, and Baldauf 2018). Finally, RPA targets at the automation of process tasks and, thus, hands them over to a bot. All three disciplines can be induced by artificial intelligence.

Process mining can also help to discover process models from the interactions a process participant performs with software systems and, thus, seems to be appropriate for identifying process tasks being suitable for RPA (1). In addition, process mining can analyse RPA logs and, thus, monitor RPA bots (1). RPA supports BPM by enabling full automation of selected process tasks and contributes to improved business process performance (3). Process mining, in particular business process discovery techniques provide valuable input for BPM projects, e.g., the discovery of the actual as-is business process (2). Recently, process discovery has increasingly been used to derive RPA scripts for routine process tasks from user interface (UI) logs (1).

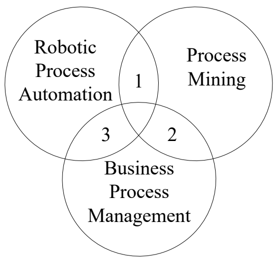

Figure 1. Relation between Process Mining, Business Process Management, and Robotic Process Automation.

2.1. *Robotic Process Automation*

The IEEE Standards Association defines RPA as follows (IEEE 2017): ‘A preconfigured software instance that uses business rules and predefined activity choreography to complete the autonomous execution of a combination of processes, activities, transactions, and tasks in one or more unrelated software systems to deliver a result or service with human exception management.'

For a better understanding we consider an example (Aguirre and Rodriguez 2017). Note that we distinguish between the notions of *business process* and *process task*. The former consists of a set of activities (i.e., process tasks) that are performed in coordination in an organisational and technical environment. These process tasks jointly realise a business goal (Weske 2007), and describe pieces of work to be performed within a certain time period (Mundbrod and Reichert 2017). RPA, in turn, automates one or several tasks of a business process. We illustrate this relation by an example: Figure 2 visualises the business process of a payment generation: the customer communicates with the call centre and requests a payment receipt. In the front office, the agent receives the request and creates the corresponding case in the Customer Relationship Management (CRM) database. A back office agent opens the case from the database, generates the payment receipt from the accounting system, and sends the receipt via email to the customer. Finally, the case is closed in the CRM database. These process tasks of the back office agent are rule-based, highly repetitive, and well-structured. Furthermore, two unrelated software systems, i.e., the CRM and the accounting systems are used. A correlation between these two systems can be established via the customer ID, which is copied and pasted from one system to the other. According to the aforementioned IEEE definition, RPA could be applied to deliver the same result.

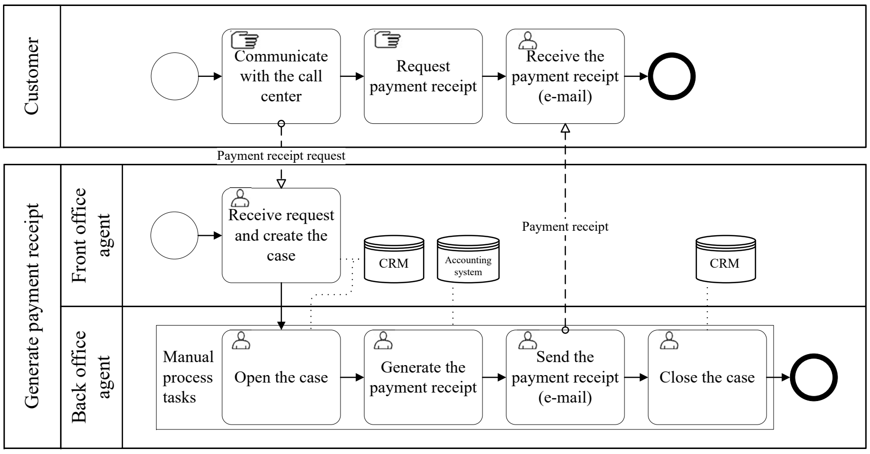

Figure 2. Business Process of Payment Generation without RPA based on (Aguirre and Rodriguez 2017)

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After applying RPA, the business process remains the same. The four process tasks that have been manually performed by the back office agent so far, are now replaced by one automated task implemented with RPA (cf. Figure 3). The bot accesses the CRM system, copies the customer ID, and pastes it to the accounting system. Then, the corresponding payment receipt is generated, and the bot sends it to the customer before closing the case.

2.2. *Related Work*

Systematic literature reviews (SLRs) and Systematic Mapping Studies (SMSs) exist in various areas. Especially, they are used to cluster research on emerging technologies, e.g., big data analytics (Khanra et al. 2020), Internet of Things (Ng et al.

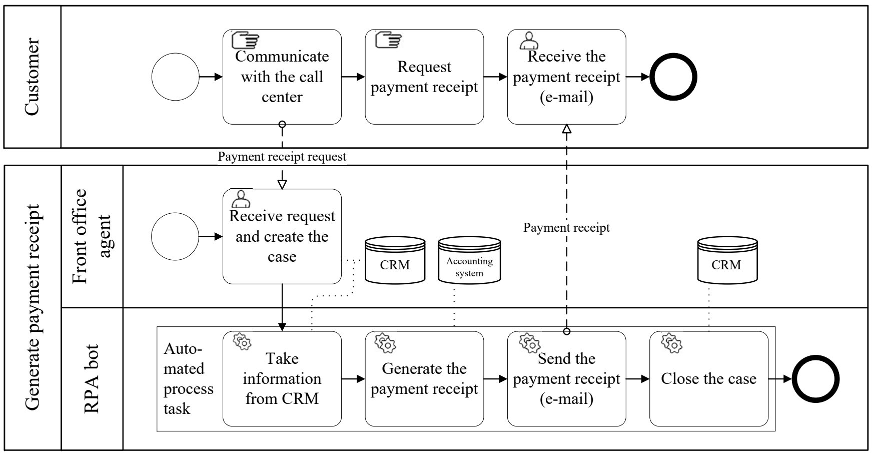

Figure 3. Business Process of Payment Generation with RPA for some process tasks based on (Aguirre and Rodriguez 2017).

2018), business process management software (Steinau et al. 2019), or process mining (El-Khawaga et al. 2020). This section gives a short overview of literature research approaches in the RPA area.

To the best of our knowledge, there is only one other SMS (Enriquez et al. 2020) analysing the current state-of-the-art of RPA. The main focus of this SMS, is to evaluate 14 commercial RPA tools concerning the coverage of 48 functions mapped to RPA life cycle phases. As major result, the operation phase is covered by over 80% of the RPA tools, whereas support for the analysis phase is below 15%. This shows the potential for process mining when applying it to UI event logs. Note that this SMS focuses on the technology perspective of RPA, while our SMS takes a holistic approach.

Furthermore, there exist SLRs dealing with RPA. Note that SMS and SLR differ in several aspects, e.g., an SMS addresses multiple and broader research questions and data analysis is descriptive summarising existing data, whereas an SLR uses more in-depth analysis techniques. Moreover, the main goal of an SMS is to provide an overview of the scope of the research area (Kitchenham and Charters 2007; Petersen, Vakkalanka, and Kuzniarz 2015). We are aware of the following SLRs on RPA:

- (Riedl and Beetz 2019): The main focus of this SLR is to derive selection criteria for assessing the RPA suitability of process tasks as well as to develop a corresponding evaluation method.
- (Ivančić, Vugec, and Vukšić 2019): This SLR aims to systematically investigate RPA experiences from business practices in Scopus and Web of Science.
- (Syed et al. 2020): RPA-related topics and challenges for future research are investigated. This SLR focuses on the description of RPA readiness and maturity, the potential of RPA, an effective RPA methodology, and RPA technologies. The results of the SLR are used to highlight key research challenges for future RPA research.

Finally, we discovered two works relying on a literature review and other methods to address research questions in the RPA area:

- (Gotthardt et al. 2019) examines the current state of RPA as well as fundamental challenges in accounting and auditing. For this purpose, a literature review, interview results, and case studies are presented to summarise key factors. In particular, (Gotthardt et al. 2019) follows a domain-specific approach by focusing on accounting and auditing, with a special emphasis on the role of AI.

- (Santos, Pereira, and Vasconcelos 2019) provides an approach for evaluating RPA development in enterprises. A conceptual model on the relationships between RPA topics, identified in a literature review, is presented. The model consists of three steps, i.e., definition of strategic goals, process task assessment, and tactical evaluation as well as factors for a successful RPA implementation. Influencing factors include benefits, disadvantages, selection criteria, future challenges, and future opportunities.

In summary, to the best of our knowledge, there are no other publication addressing the scope presented in Section 1.1.

3. Methodology

We conduct an SMS to provide an overview of RPA research from the perspectives of organisation and management, IT enterprise architectures, business processes, and business process stakeholders as well as to structure this research area (Kitchenham and Charters 2007; Petersen, Vakkalanka, and Kuzniarz 2015). Following the guidelines described by Petersen as well as the procedures suggested by (Khanra et al. 2020; Ng et al. 2018), we design a protocol (cf. Figure 4) that describes the formulation of research questions (cf. Section 3.1), the definition of rules for conducting the search (cf. Section 3.2), the selection of publications (cf. Section 3.3), the data extraction method (cf. Section 3.4), and the data analysis method (cf. Section 3.5).

3.1. *Formulation of the Research Questions*

Our general goal is to analyse the body of relevant publications in the RPA field. Therefore, we opt for multidisciplinarity and investigate RPA from different perspectives. In a first step, we want to understand the technology perspective of RPA and how it differs from related technologies, like intelligent automation (Bruno, Johnson, and Hesley 2017; Schmitz, Stummer, and Michael 2019; Suri et al. 2018) or BPM (Cewe, Koch, and Mertens 2017). Additionally, the exploratory case study performed in preparation to our SMS identified the challenge to explain RPA to end users (Wewerka and Reichert 2021). This results in our first research question: **RQ 1: What meanings are attached to RPA in literature and what are the differences between RPA and related technologies?** Secondly, managers want to understand what can be automated. Hence, criteria for assessing whether or not given process tasks are suited for RPA are investigated. One major challenge in RPA projects is therefore to identify the business process tasks suited for automation (Wewerka and Reichert 2021). Furthermore, from a technology perspective we are interested in the tools available for implementing RPA. This leads to our second research question: **RQ 2: Which process tasks can be automated with RPA and which tools are used for automation?** For newly emerging technologies, like RPA, the question arises whether it is worthwhile to adopt it. Therefore, from both an organisational and an economic perspective, we want to systematically understand RPA effects on humans and their daily worklife as well as on the enterprises implementing RPA projects. This results in our third research question: **RQ 3: What are RPA effects?** In a fourth step, we in-

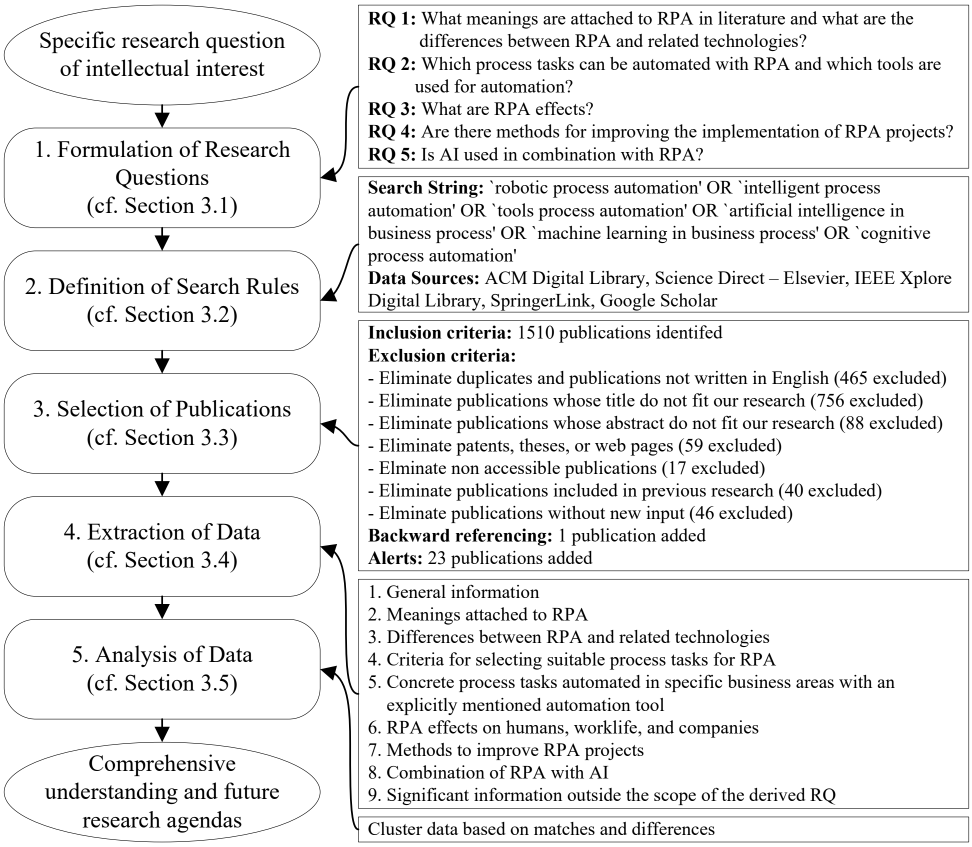

Figure 4. Protocol for Systematic Mapping Study (inspired by (Khanra et al. 2020)).

vestigate how far research has taken up on RPA. Note that all aforementioned aspects only work with methodological support. Particularly, we are interested in methods that aim to foster RPA implementation. The exploratory case study revealed that one particular challenge is to provide software development guidelines for RPA projects (Wewerka and Reichert 2021). This leads to our fourth research question: **RQ 4: Are there methods for improving the implementation of RPA projects?** Finally, the growing importance of AI in many areas of automation raises the question to what degree AI plays a role in connection with business process automation. The fifth research question addresses the topic of combining AI with RPA: **RQ 5: Is AI used in combination with RPA?**

3.2. *Definition of Search Rules*

Search String. We elaborate the search string iteratively based on our expert knowledge of the topic, the pre-specified research questions, and pilot searches. The search string is refined to retrieve a maximum number of publications to meet the goal of the SMS, i.e., to broadly cover the research area RPA from the aforementioned perspectives (organisation and management, IT enterprise architectures, business processes, and business process stakeholders) (Kitchenham and Charters 2007). The final search string for the SMS is as follows:

'robotic process automation' OR 'intelligent process automation' OR

'tools process automation' OR 'artificial intelligence in business process' OR 'machine learning in business process' OR 'cognitive process automation'.

Note that the acronym 'RPA' is not included, as the search then would yield around 31.000 results. RPA not only serves as acronym for Robotic Process Automation, but also for *Recombinase Polymerase Amplification* in the field of DNA chemistry and others. Though we omit RPA in the search string, all relevant publications are still included in the results.

Data Sources. We apply the search string to different data sources to discover relevant publications. Five electronic libraries are identified as relevant for conducting the SMS as they cover scientific publications in Computer Science, Management, and IT enterprise architecture:

ACM Digital Library, Science Direct - Elsevier, IEEE Xplore Digital Library, SpringerLink, and Google Scholar.

Additionally, we consider literature cited by the retrieved publications by performing a *backward reference search* (Jalali and Wohlin 2012). Finally, Google Scholar alerts are analysed during both the SMS procedure and the writing process to get notified about newly emerging publications on the topic.

Inclusion and Exclusion Criteria. To identify relevant publications, we define the following inclusion and exclusion criteria.

Inclusion Criteria:

1.) The publication deals with the topic of RPA and contributes answers to at least one of the aforementioned research questions.
2.) The title and the abstract seem to contribute to our research questions and contain terms such as robotic/intelligent/cognitive process automation, virtual assistant, process intelligence, business process model automation, intelligent business process management, or software bot.

Exclusion Criteria:

1.) The publication is not written in English.
2.) The title and abstract do not seem to contribute to our research questions and contain terms such as business process management, business intelligence, analytics, multi-agent system, big data, or process mining.
3.) The publication is a patent, master thesis, or web page.
4.) The publication is not electronically accessible without payment.
5.) All relevant aspects of the publication are included in another publication.
6.) The publication only compares existing research and has no new input.

A publication is included if the inclusion criteria are met, but is then excluded if any of the exclusion criteria is fulfilled.

3.3. *Selection of Publications*

The search string is applied to the identified data sources, which yields 1510 results (Inclusion Criterion 1). To select relevant publications, the metadata is loaded into Microsoft Excel. It includes title, author, year, abstract, and keywords. In a first step, duplicates and publications not written in English (Exclusion Criterion 1) are excluded resulting in 1045 publications afterwards. Then, publications whose title does not indicate any contribution to one of the research questions are excluded, leaving 289 publications (Inclusion Criterion 2, Exclusion Criterion 2). Following this, the abstracts of the remaining publications are scanned leading to 201 publications (Inclusion Criterion 2, Exclusion Criterion 2). We then exclude publications corresponding to patents, theses, or web pages, resulting in 142 relevant publications (Exclusion Criterion 3). Thereof, 125 are accessible without payment (Exclusion Criterion 4) and 85 are not included in another publication (Exclusion Criterion 5). Finally, 39 publications provide new input to the research questions and are included in the final publication list (Exclusion Criterion 6). Through backward referencing one additional publication is identified and included.

The initial search was performed on 6 June 2019. Since then (until June 2020) the alerts from Google Scholar have revealed 1206 new publications. 23 of them meeting the inclusion criteria and not fulfilling any of the exclusion criteria. Thus, they are added to our final publication list, which comprises 63 relevant publications in total.

3.4. *Data Extraction Method*

To each of the 63 relevant publications, a data extraction method is applied in order to answer the research questions derived in Section 3.1. We extract the following information:

1.) General information, i.e., title, author, publication year, publication venue, number of citations, and publication type,
2.) Meanings attached to RPA (RQ 1),
3.) Differences between RPA and related technologies, e.g., intelligent automation, BPM, etc. (RQ 1),
4.) Criteria for selecting suitable process tasks for RPA (RQ 2),
5.) Concrete process tasks automated in specific business areas with an explicitly mentioned automation tool (RQ 2),
6.) RPA effects on humans, worklife, and enterprises (RQ 3),
7.) Methods to improve RPA projects (RQ 4),
8.) Combination of RPA with AI (RQ 5), and
9.) Significant information outside the scope of the derived research questions.

Tables 1 and 2 give an overview of the 63 relevant publications indicating the reference, ID, title, type of publication, and research questions the publication refers to. In the following, the ID is used to refer to the corresponding publication. The publication type, in turn, distinguishes between *Method*, *Case Study*, *Review*, and *Research Paper*. A publication is classified as *Method* if it reports on the development and testing of a new RPA method, as *Case Study* if it focuses on a practical use case, as *Review* if it provides a synthesis of acquainted knowledge, and as *Research* otherwise.

3.5. *Data Analysis Method*

After having extracted relevant data from all selected publications, we cluster the obtained data. For each research question, we scan relevant information and build groups based on matches and differences.

Concerning RQ 1, we study all meanings attached to RPA by the publications, identify different aspects, e.g., ‘software-based solution’, ‘mimics human behaviour’ or ‘rule-based nature’, and label the publications according to the aspects they cover.

Table 1. Final list of the 63 relevant publications indicating reference, ID, and answers to the research questions.

Ref	ID	Title	Type	RQ1	RQ2	RQ3	RQ4	RQ5
(Aguirre and Rodriguez 2017)	P01	Automation of a Business Process Using Robotic Process Automation (RPA): A Case Study	Case Study	x	x	x		
(Asatiani and Penttinen 2016)	P02	Turning robotic process automation into commercial success - Case OpusCapita	Research	x	x	x		
(Asquith and Horsman 2019)	P03	Let the robots do it! - Taking a look at Robotic Process Automation and its potential application in digital forensics	Case Study	x	x	x		
(Auth and Bensberg 2019)	P04	Impact of Robotic Process Automation on Enterprise Architectures	Research			x		
(Bosco et al. 2019)	P05	Discovering Automatable Routines From User Interaction Logs	Method				x	
(Bruno, Johnson, and Hesley 2017)	P06	Robotic disruption and the new revenue cycle	Research	x	x	x		
(Cewe, Koch, and Mertens 2017)	P07	Minimal Effort Requirements Engineering for Robotic Process Automation with Test Driven Development and Screen Recording	Method	x			x	
(Chacón-Montero, Jiménez-Ramírez, and Enríquez 2019)	P08	Towards a Method for Automated Testing in Robotic Process Automation Projects	Method				x	
(Chalmers 2018)	P09	Machine Learning with Certainty: A Requirement For Intelligent Process Automation	Research					x
(Cohen, Rozario, and Zhang 2019)	P10	Exploring the Use of Robotic Process Automation (RPA) in Substantive Audit Procedures	Case Study	x	x	x		
(Eikebrokk and Olsen 2019)	P11	Robotic Process Automation for Knowledge Workers - Will It Lead To Empowerment or Lay-Offs?	Research			x		
(Eikebrokk and Olsen 2020)	P12	Robotic Process Automation and Consequences for Knowledge Workers; a Mixed-Method Study	Research			x		
(Fernandez and Aman 2018)	P13	Impacts of Robotic Process Automation on Global Accounting Services	Research			x		
(Fung 2014)	P14	Criteria, Use Cases and Effects of Information Technology Process Automation (ITPA)	Research	x	x	x		
(Gao et al. 2019)	P15	Automated robotic process automation: A self-learning approach	Method				x	
(Geyer-Klingeberg, Nakladal, and Baldauf 2018)	P16	Process Mining and Robotic Process Automation: A Perfect Match	Method				x	
(Hallikainen, Bekkhus, and Pan 2018)	P17	How OpusCapita Used Internal RPA Capabilities to Offer Services to Clients	Case Study		x	x		
(Hindel, Cabrera, and Stierle 2020)	P18	Robotic Process Automation: Hype or Hope?	Research			x		
(Houy, Hamberg, and Fettke 2019)	P19	Robotic Process Automation in Public Administrations	Research	x		x		x
(Huang and Vasarhelyi 2019)	P20	Applying robotic process automation (RPA) in auditing: A framework	Method				x	
(Hwang et al. 2020)	P21	MIORPA: Middleware System for open-source robotic process automation	Method				x	
(Ian, Dhayalan, and Andy 2016)	P22	The future of professional work: Will you be replaced or will you be sitting next to a robot?	Method				x	
(Issac, Muni, and Desai 2018)	P23	Delineated Analysis of Robotic Process Automation Tools	Review		x			
(Jiménez-Ramírez et al. 2020)	P24	Automated testing in robotic process automation projects	Method				x	
(Jiménez-Ramírez et al. 2019)	P25	A Method to Improve the Early Stages of the Robotic Process Automation Lifecycle	Method			x	x	
(Kin et al. 2018)	P26	Cognitive Automation Robots (CAR)	Research					x
(Koch et al. 2020)	P27	'Mirror, Mirror, on the wall': Robotic Process Automation in the Public Sector using a Digital Twin	Method				x	
(Kokina and Blanchette 2019)	P28	Early evidence of digital labor in accounting: Innovation with Robotic Process Automation	Research		x	x		
(Lacity and Willcocks 2017)	P29	A New Approach to Automating Services	Research	x		x		
(Lacity, Willcocks, and Craig 2015a)	P30	Robotic process automation at Xchanging	Case Study		x	x		
(Lacity, Willcocks, and Craig 2015b)	P31	Robotic Process Automation: Mature Capabilities in the Energy Sector	Case Study		x	x		
(Lacity, Willcocks, and Craig 2016)	P32	Robotizing Global Financial Shared Services at Royal DSM	Case Study		x	x		
(Lacity, Willcocks, and Craig 2017)	P33	Service Automation: Cognitive Virtual Agents at SEB Bank	Research	x		x		x
(Leno et al. 2020a)	P34	Automated Discovery of Data Transformations for Robotic Process Automation	Method				x	

Table 2. Final list of the 63 relevant publications indicating reference, ID, and answers to the research questions - Continuation.

Ref	ID	Title	Type	RQ1	RQ2	RQ3	RQ4	RQ5
(Leno et al. 2018)	P35	Multi-Perspective process model discovery for robotic process automation	Method			x	x	
(Leno et al. 2020b)	P36	Robotic Process Mining: Vision and Challenges	Method				x	
(Leno et al. 2019)	P37	Action Logger: Enabling Process Mining for Robotic Process Automation	Method				x	
(Leopold, van Der Aa, and Reijers 2018)	P38	Identifying candidate tasks for robotic process automation in textual process descriptions	Method				x	
(Leshob, Bourgouin, and Renard 2018)	P39	Towards a Process Analysis Approach to Adopt Robotic Process Automation	Method				x	
(Lewicki, Tochowicz, and van Genuchten 2019)	P40	Are Robots Taking Our Jobs? A RoboPlatform at a Bank	Case Study	x	x			x
(Masood and Hashmi 2019)	P41	Cognitive Robotics Process Automation: Automate This!	Research			x		x
(Moffitt, Rozario, and Vasarhelyi 2018)	P42	Robotic Process Automation for Auditing	Research			x		
(Mohanty and Vyas 2018)	P43	Intelligent Process Automation = RPA + AI	Research	x		x		x
(Osmundsen, Iden, and Bygstad 2019)	P44	Organizing Robotic Process Automation: Balancing Loose and Tight Coupling	Method	x			x	
(Patel et al. 2019)	P45	Customized Automated Email Response Bot using Machine Learning and Robotic Process Automation	Research	x				x
(Penttinen, Kasslin, and Asatiani 2018)	P46	How to Choose Between Robotic Process Automation and Back-End System Automation?	Research	x	x	x		
(Radke, Dang, and Tan 2020)	P47	Using Robotic Process Automation (RPA) to enhance Item Master Data Maintenance Process	Case Study		x	x		
(Riedl and Beetz 2019)	P48	Robotic Process Automation: Developing a Multi-Criteria Evaluation Model for the Selection of Automatable Business Processes	Method				x	
(Rutschi and Dibbern 2020)	P49	Towards a framework of implementing software robots: Transforming Human-executed Routines into Machines	Method				x	
(Schmitz, Dietze, and Czarnecki 2019)	P50	Enabling digital transformation through robotic process automation at Deutsche Telekom	Case Study		x	x		
(Schmitz, Stummer, and Michael 2019)	P51	Smart Automation as Enabler of Digitalization? A Review of RPA/AI Potential and Barriers to Its Realization	Review	x	x	x		
(Séguin and Benkalaï 2020)	P52	Robotic Process Automation (RPA) Using an Integer Linear Programming Formulation	Method				x	
(Stople et al. 2017)	P53	Lightweight IT and the IT Function: experiences from robotic process automation in a Norwegian bank	Case Study	x	x			
(Suri et al. 2018)	P54	Automation of Knowledge-Based Shared Services and Centers of Expertise	Research	x		x		
(Suri, Elia, and van Hillegersberg 2017)	P55	Software Bots - The next frontier for shared services and functional excellence	Research			x		
(van der Aalst, Bichler, and Heinzl 2018)	P56	Robotic Process Automation	Research	x				x
(Wanner et al. 2020)	P57	Process selection in RPA projects - Towards a quantifiable method of decision making	Method				x	
(Willcocks and Lacity 2015)	P58	Robotic Process Automation: The Next Transformation Lever for Shared Services	Case Study	x	x	x		
(Willcocks and Lacity 2016)	P59	Robotic Process Automation at Telefónica O2	Case Study	x	x	x		
(Willcocks, Lacity, and Craig 2015)	P60	The IT Function and Robotic Process Automation	Research	x				
(William and William 2019)	P61	Improving Corporate Secretary Productivity Using Robotic Process Automation	Case Study		x	x		
(Wróblewska et al. 2018)	P62	Robotic Process Automation of Unstructured Data with Machine Learning	Research		x	x		x
(Yatskiv et al. 2019)	P63	Improved Method of Software Automation Testing Based on the Robotic Process Automation Technology	Case Study		x			

The same procedure is applied to bundle differences to other technologies (RQ 1), criteria for selecting process tasks (RQ 2), and RPA effects (RQ 3).

Depending on the publication type, different data analysis methods are applied. Concerning case studies, we investigate the business area, the concerned process task, and the used automation tool. Then, we cluster these case studies (RQ 2). Method papers are co-related with the stage of the RPA project they aim to improve, in order to identify common points (RQ 4). Finally, research papers answering RQ 5 are treated separately to cluster approaches that combine RPA with AI.

The data analysis method aims to facilitate the derivation of a classification framework from our SMS results (Petersen et al. 2008).

4. Results

We analyse the 63 publications discovered with the SMS to answer the research questions (cf. Section 3.1). The answers are structured along the research questions and the seven discovered thematic clusters (i.e., RPA meanings, differences to related technologies, criteria for selecting process tasks, RPA use cases, RPA effects, methods for RPA projects, and RPA and AI). Table 3 gives an overview on which section covers which research question.

Table 3. Overview of Result Section.

Section	Content	Page
4.1	RPA meanings	12
	Differences to related technologies	13
4.2	Criteria for selecting process tasks	15
	RPA use cases	16
4.3	RPA effects	17
4.4	Methods for RPA projects	19
4.5	RPA and AI	23

We have noticed a growing interest in RPA in the scientific literature. Figure 5 shows the distribution of the publications included in this SMS over the recent years; it started with one to seven publications in the years 2014 to 2017. In 2018, 15 relevant publications appeared and in 2019, 21 works were published. In 2020 (until June), 11 publications could be identified.

Concerning the publication venue, there is no clear majority. RPA is important in a variety of areas covered by different conferences and journals. Regarding authorship, two researchers are dominating: M. Lacity and L. Willcocks are both co-authors of eight publications each.

4.1. *RQ 1: What meanings are attached to RPA in literature and what are the differences between RPA and related technologies?*

In Section 2 we provided the IEEE definition for RPA. The meanings attached to RPA in literature are revealed in this section. Further, we discuss differences to related technologies. It is important to profoundly understand RPA in order to avoid confusion with similar technologies. A clear positioning of the RPA technology between robotic desktop automation, intelligent automation, and BPM is, therefore, desirable. Remember that RPA aims to automate selected process tasks of business processes.

RPA Meanings. A first definition of RPA in literature can be found in P60: 'RPA

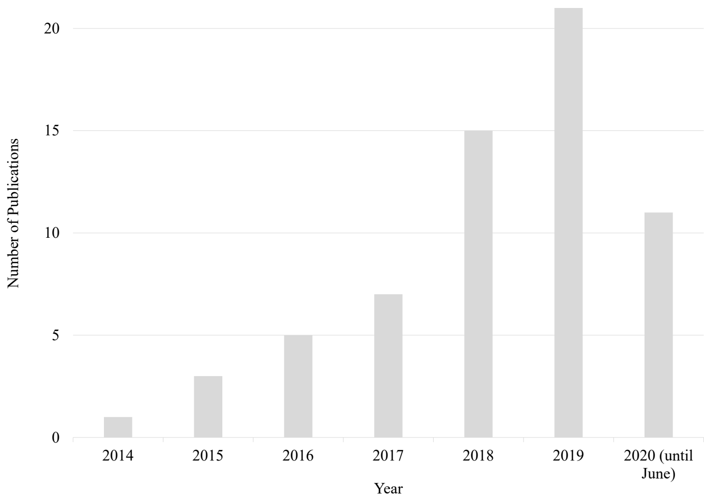

Figure 5. Distribution of Publications over Years.

is a software-based solution [...] [and] refers to configuring the software "robot" to do the work previously done by people.' This definition addresses two aspects. First, RPA corresponds to a **software-based solution** (cf. P33, P51, P58, P59). Second, it **mimics human behaviour** (cf. P43, P45, P51, P53, P59). Most publications pick up these meanings expanding them by two other characteristics (i.e., task automation and non-invasiveness). Instead of 'software-based solution', terms like 'software robot' (P40, P43) or 'virtual assistant' (P02) are used as well. Mimicking human behaviour is also expressed by phrases like 'enters data, just as a human would' (P40), 'mimics human actions' (P06), or 'operates [...] in the way a human would do' (P56).

Characteristics of the routines (i.e., process tasks) automated by software robots are included in the definitions. These characteristics cover the **rule-based nature** of the routines (P01, P10, P29, P45), the inclusion of **structured data** (P01, P10, P29, P53), and the emphasis on **routine tasks** (P01, P03, P06, P10, P51). Furthermore, some publications emphasise the **non-invasiveness** of RPA, meaning that RPA does not change the involved software systems (P06, P46, P51), but automation is realised on top of them. Figure 6 summarises the RPA meanings we discovered in the SMS. Note that these meanings also help to position RPA in relation to other approaches and technologies (see below).

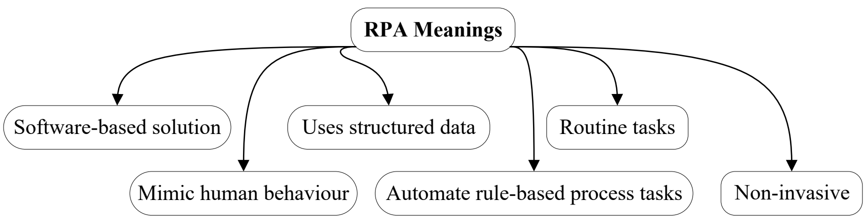

Figure 6. Meanings attached to RPA in literature.

Differences between RPA and Related Technologies. In the following, we analyse the differences between RPA and *Robotic Desktop Automation (RDA)*, *Intelligent/Cognitive RPA*, and *Business Process Management (BPM)*. These terms are mentioned the most frequently in the results of the SMS.

As major difference between RDA and RPA, **RDA does not have its own iden-**

tity and, therefore, acts via the IT infrastructure of its users with the same roles and access control rights, whereas RPA is working autonomously in the background on a central server structure (P40). Furthermore, **RDA is attended**, whereas RPA is unattended (P40). *Attended automation* allows the user to monitor the bot as well as to pause, interrupt or stop it at any time. Furthermore, data can be provided during execution. Contrary, *unattended automation* does not take data during execution. Once triggered, the unattended bot runs without human involvement. Additionally, scripting and screen scraping are locally deployed from the user's desktop and can be seen as RDA, differing from RPA that meets IT requirements such as security, scalability, auditability, and changeability (P58). In P51, stand-alone automation includes macros, office program automation, and mouse/keyboard emulation. Table 4 summarises the differences between RPA and RDA.

Table 4. Differences between RPA and RDA.

Criterion	RPA	RDA	Ref
What?	virtual user working on central server	personal assistant on user's desktop	P40
How?	unattended	attended	P40

Many publications further distinguish between intelligent and cognitive automation. *Intelligent or enhanced RPA*, also denoted as self-learning RPA, uses data to learn how a user interacts with the system and mimics these interactions including human judgement (P06, P19, P51). Machine learning and process mining techniques (van der Aalst 2011) are used to build knowledge of the routines to be automated (P51, P54). As major advantage, no time-consuming interviews and workshops become necessary; instead the behaviour of the routine to be automated can be discovered from event logs. Section 4.4 presents methods for improving RPA projects, including a framework for combining process mining and RPA (P36). Finally, *cognitive RPA* relies on advanced machine learning and natural language processing to augment human intelligence and to learn how to optimise task performance (P06, P43, P54). The main differences between rule-based automation and intelligent automation are summarised in Table 5.

Table 5. Differences between RPA and intelligent automation.

Criterion	RPA	Intelligent Automation	Ref
Degree of standardisation	high	low	P58
Data	structured	unstructured	P51, P54
Decisions	rule-based	knowledge/experience-based	P06, P19, P51
Outcome	deterministic	probabilistic	P01, P54
Exceptions	demand human intervention	trigger machine learning	P43, P54

Many publications emphasise the differences between RPA and BPM. Understanding these difference is fundamental for appropriately applying RPA and BPM methods in an enterprise context. Figure 7 illustrates these differences. The x-axis indicates the number of process task variants (i.e., the complexity of the process task), whereas the y-axis displays the case frequency of all process task variants of the business process. The tasks on the left are suited best for BPM, the ones in the middle are candidate tasks for RPA, and the ones on the right can be solely performed by humans (cf. Figure 7) (P56, P60). As can be seen, RPA and BPM complement each other. Enterprises need to combine the two approaches in the right way to achieve the best automation results (P60).

Table 6 summarises the main differences between RPA and BPM.

To understand the difference between lightweight and heavyweight IT (Table 6,

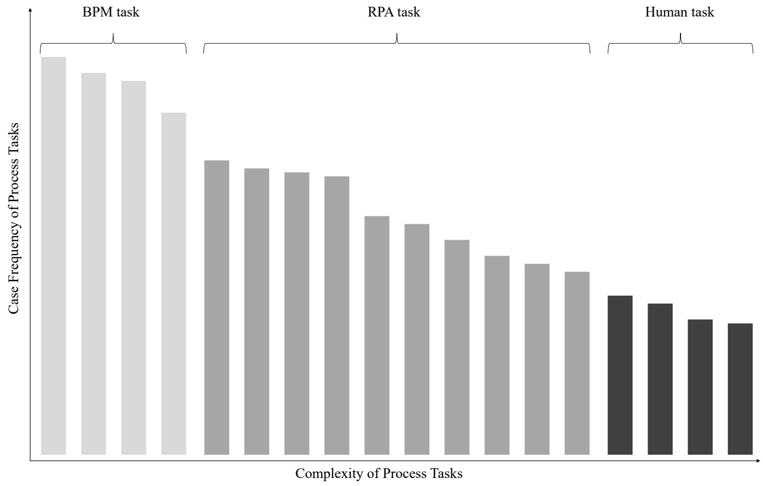

Figure 7. Comparison of tasks suitable for BPM, for RPA, and tasks only Humans can do.

Table 6. Differences between RPA and BPM.

Criterion	RPA	BPM	Ref
Goal	automation of selected process tasks by software bots	automation of business processes or parts involving the interactions at running time	P07
General idea	change 'where' work is done	change 'how' work is done	P07, P44, P53
Invasiveness	non-invasive, lightweight IT sitting on top of existing business applications	heavyweight IT interacting with business logic and creating new business applications	P01, P07, P46, P60
Problems	privacy, security issues	high complexity, expensive	P44, P46, P53

row 3), we summarise characteristics of suitable tasks for both types of automation. *Lightweight IT* automates tasks involving multiple systems and having a high volume. The systems are characterised by a stable UI. *Heavyweight IT*, in turn, automates tasks running in one system, having a very high volume, and relying on a stable back-end system architecture (P07).

P56 emphasises another differentiation: RPA versus *Straight Through Processing (STP)*. STP refers to business processes that can be performed without any human involvement, and, thus, is quite similar to RPA. However, STP has not been widely adopted in practice as it could only handle few business processes (cf. left side of Figure 7). RPA is an approach, which uses existing information systems without changing them, and virtual users interacting with these systems. If the information systems evolve, the RPA implementation can be adapted as well.

4.2. *RQ 2: Which process tasks can be automated with RPA and which tools are used for automation?*

For a successful uptake of RPA initiatives, it is crucial to identify those process tasks suited for an RPA automation. Discovering corresponding tasks is a challenge on its own and fosters the automation of business processes or parts of them. This section provides criteria for selecting process tasks and presents use cases to which RPA has been successfully applied.

Criteria for selecting process tasks. The most frequently mentioned criterion in literature is **repetitiveness**, i.e., the process task to be automated by bots shall have a high volume of transactions or a large number of process task executions (P06, P10, P14, P28, P31, P50, P58, P59, P62, P63). Regarding the predictability of the process task volumes, P06 states that process tasks with unpredictable peaks are suited for RPA implementations. By contrast, P31 emphasises that the volumes should be predictable.

Another criterion concerns the **rule-based** character of the process task, i.e., the process task to be automated shall be standardised, run in a stable environment, and only require little exception handling (P02, P06, P14, P28, P31, P46, P62, P63).

The next criterion is to check whether the process task requires **high manual efforts** and, thus, is prone to errors (P06, P14, P28, P51). Furthermore, digitisation gaps in business processes might fulfil this criterion as they indicate the need for human work. P51 even states that 'any activity that a person performs with mouse and keyboard can be carried out by a software robot.'

The **complexity** of the process task itself or, as a result, the complexity of its implementation, constitutes another selection criterion. All publications agree that the lower its complexity, the better a process task is suited for RPA (P17, P50, P58, P59). Moreover, the **duration of process task execution** can serve as a criterion, i.e., process tasks to be automated shall have a high expenditure of time (P14, P17).

Additionally, the following criteria are mentioned by a few publications: The inputs and outputs are digital and structured (P10, P28, P46), the process task only requires a limited number of human interactions, the process task accesses multiple applications, the effects of a business failure are high (P14, P28), and the transaction has a significant influence on the business (P14, P63). P06 proposes choosing process tasks for RPA automation that do not constitute a priority for the IT department. Figure 8 displays the six most relevant criteria for selecting process tasks. Note that in related studies, other numbers of criteria are stated, e.g., 13 in (Santos, Pereira, and Vasconcelos 2019). However, based on our empirical results the six criteria visualised are the most relevant ones.

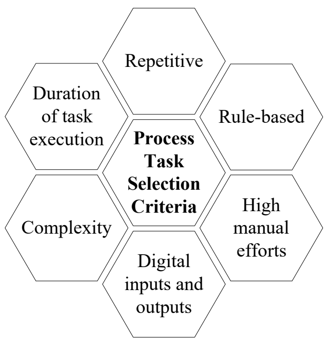

Figure 8. Criteria for selecting process tasks.

Use Cases. Table 7 summarises the 15 case studies, indicating in which *business area* RPA was applied, which *process task* was automated, and which *tool* was used for creating the respective software robot.

The most referred business areas are **Business Process Outsourcing (BPO)** (P01, P17, P30), **Shared Services** (P32, P58), **Telecommunication** (P50, P59), and **Banking** (P40, P53). One case study was conducted in each of the following areas: Digital Forensics (P03), Auditing (P10), Energy Supply (P31), Manufacturing (P47), Corporate Service Provider (P61), and Software Testing (P63).

The most frequently automated process tasks in these case studies are **swivel-**

Table 7. Business Area, Process Task, and Automation Tool for concrete Use Cases.

Ref	Business Area	Process Task	Automation Tool
P01	BPO	Generate payment receipt	-
P03	Digital Forensic	Search for keywords within Autopsy forensic software and import evidence files, process them and carry out image extraction in Griffeye forensic software	UiPath
P10	Auditing	Collect data; copy it to template; filter, prepare, transfer it to database, and perform audit tests for loan testing	-
P17	BPO	Update employee payment details and create new employment relationships	UiPath
P30	BPO	Create and validate Premium Advice Notes	Blue Prism
P31	Energy Supply	Resolve infeasible customer meter readings	-
P32	Shared Services	Generate financial close	Redwood
P40	Banking	Copy details of personal loan or current account from mainframe application to Excel	Roboplatform
P47	Manufacturing	Master data management	-
P50	Telecommunication	Bundle support tools for field service technician	Bluepond
P53	Banking	Manage information interaction between bank and governmental institution	Blue Prism
P58	Shared Services	Copy data from Excel to HRM System	Blue Prism
P59	Telecommunication	Carry out SIM swaps and apply pre-calculated credit to account	Blue Prism
P61	Corporate Service Provider	Generation of documents for annual compliance process and handle ad-hoc inquiries of customer	-
P63	Software Testing	Schedule and control software testing by executing test scripts and validating the UI	Workfusion

chair processes, i.e., 'processes where humans take inputs from one set of systems (for example email), process those inputs using rules, and then enter the outputs into systems of record (for example Enterprise Resource Planning (ERP) systems)' (P60).

For ten case studies, the used automation tool was mentioned in the respective publication: **Blue Prism** was used in four case studies (P30, P53, P58, P59), **UiPath** (P03, P17) in two case studies, and Redwood (P32), Bluepond (P50), Workfusion (P63), and Roboplatform (P40) in one case study each. Roboplatform is a proprietary tool that was built by the enterprise itself. P23 compares different automation tools, namely UiPath, Automation Anywhere, and Blue Prism based on criteria like openness of the platform, future scope, and performance. Their recommendation is to use UiPath as it 'triumphs all' (P23).

4.3. *RQ 3: What are RPA effects?*

To decide whether it is worthwhile to adopt RPA, the effects of RPA projects need to be understood. It is, therefore, crucial to know which RPA effects are reported in literature, and to exploit this knowledge as benchmark for assessing RPA projects. Therefore, we merge effects presented in different publications to a holistic view. The answer to RQ 3 is divided into two aspects: the first one deals with the RPA effects on humans and their worklife, whereas the second aspect deals with positive, controversially discussed, and negative effects on the company. Figure 9 gives an overview of the identified RPA effects.

As a positive effect of RPA on employees, the latter are **relieved from non-value adding tasks** and, consequently, become more satisfied (P12, P17, P25, P33, P47, P51, P55, P58). Furthermore, new tasks and jobs for employees are proposed. One area concerns the development, testing, and monitoring of software robots (P02, P28, P32). Most publications mention that humans should **focus on cognitively more**

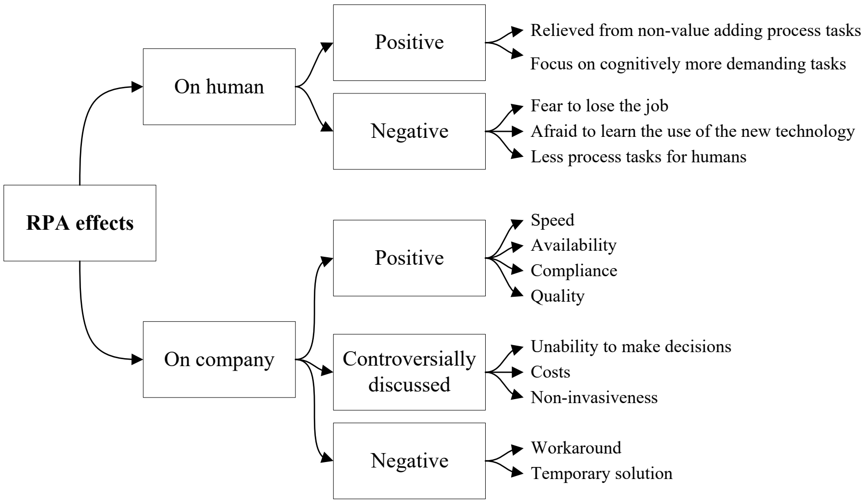

Figure 9. Effects of RPA introduction.

demanding tasks (P13, P17, P32, P41), including tasks that require judgement, interpretation, and assessment of results (P03, P10, P29, P54, P58). Furthermore, unstructured tasks (P29, P32, P54), creative tasks (P32), and tasks demanding for empathy and social interactions (P29, P58) are best suited for humans, e.g., to build relationships with the customer (P54).

According to (P02, P13, P17, P18, P30, P55), employees are **afraid of losing their job**, i.e., they consider the bots as their job competitors (P02, P18) and are **afraid of learning the use of the new technology** (P13, P14). Hence, acceptance problems might arise (P18). P29 and P54 propose combined human bot teams, where each team member performs the task he or she can do best. In P30, myths about RPA are demythologised, e.g., 'RPA is only used to replace humans with technology'. In turn, P30 is refuted by the fact that more work can be done with the same number of people and humans are not replaced by technology. According to P61, however, staff reduction is one effect of RPA implementations.

According to (P14, P32, P54), **less tasks will be left** for humans after introducing RPA, especially regarding low-level tasks not requiring any specific qualification. P11 and P12 emphasise that even knowledge workers are affected by lay-off due to RPA. On one hand, this has an impact on jobs in low-cost countries (P32). P30 proposes to automate offshore process tasks and keep them offshore, whereas P03 stresses that humans are needed to trigger the bot. On the other, organisational structures change. Nowadays, most companies are structured like a pyramid, having many less-skilled workers and fewer highly skilled workers (cf. Figure 10a). P32 predicts the change from that pyramid structure to a diamond structure meaning that employees at the bottom of the pyramid will be replaced by bots (cf. Figure 10b). P42 predicts that the pyramid structure will be replaced by a pillar structure regarding the human workforce (cf. Figure 10c). Bots will fill up the structure such that the overall organisation structure remains a pyramid.

The positive RPA effects on any company, excluding human aspects, can be clustered in four categories:

- **Speed:** Automated process tasks run faster and task duration becomes shorter (P01, P12, P14, P18, P28, P29, P35, P47, P50, P54, P55, P58, P61).

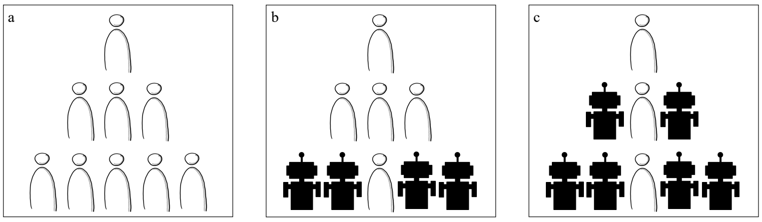

Figure 10. Organisational Structure in a Company - Human Workforce is a a: Pyramid b: Diamond c: Pillar.

- **Availability:** Most RPA bots are available 24/7, and instant access is granted. Moreover, RPA is highly scalable to meet a varying intensity of demands (P01, P06, P14, P29, P33, P43, P50, P51, P59, P62).
- **Compliance:** Process tasks executed by a bot are highly transparent and documented in detail. As a consequence, compliance increases (P29, P32, P33, P35, P43, P51, P59).
- **Quality:** RPA eliminates human errors, improves both accuracy and data quality, and leads to higher customer satisfaction (P06, P12-P14, P28, P35, P43, P47, P50, P51, P54, P55, P58, P59, P62).

Certain effects of RPA projects are controversially discussed in literature. P43 and P46 criticise that RPA is **unable to make decisions**, P50 argues that it provides full transparency of all decisions. The latter means that if the bot fails, an employee still can perform the task manually. Section 4.5 discusses how AI is used to expand the limits of RPA, including decision making. The **costs** of RPA constitute another point of discussion: in P14 and P55, budget constraints are seen as a particular challenge for every RPA project, whereas many publications highlight the cheapness, cost reduction, and high return on investment coming with RPA (P03, P06, P13, P18, P31-P33, P35, P46, P47, P50, P54, P59). P18 differs between implementation and maintenance: The former is characterised by low costs, whereas the latter can be costly and tedious. The **non-invasiveness** of RPA is perceived differently: P03 and P46 criticise that RPA presumes an existing infrastructure and depends on the stability, availability, and performance of the systems. On the other, P54 considers the non-invasiveness of RPA as a benefit. P04 starts a discussion on possible RPA effects on enterprise architectures and argues that RPA might become invasive, i.e., RPA enables new workflows, requiring a modelling functionality in RPA systems, which contradicts the basic RPA idea. P46 emphasises that RPA is unable to adapt to a changing environment, whereas P02 and P62 notice that RPA implementations are easily modifiable and flexible.

Negative effects or limitations of RPA are seldomly reported. Only P19 characterises RPA solutions as **workarounds**, and P02 and P18 point out that they constitute a **temporary solution**. According to P03, there are software platforms, e.g., special forensic software, not compatible with current RPA solutions. Furthermore, P18 criticises that know-how and skills are required, and RPA solutions are not robust in respect to evolving user interfaces. P28 adds that RPA implementations require greater IT involvement than initially thought.

4.4. *RQ 4: Are there methods for improving the implementation of RPA projects?*

To analyse the publications that introduce methods for RPA projects, we oriented ourselves on the software development life cycle (SDLC) (Royce 1987). We assigned the methods to the corresponding stage in the life cycle for the sake of better illustration (cf. Figure 11). On one hand, RPA developers asking for support in RPA projects, can choose an adequate method according to their needs. On the other, researchers get an overview of existing methods upon which they can build their future work. To the best of our knowledge, there is no such holistic overview yet. In the following, the respective methods are described shortly for each development stage.

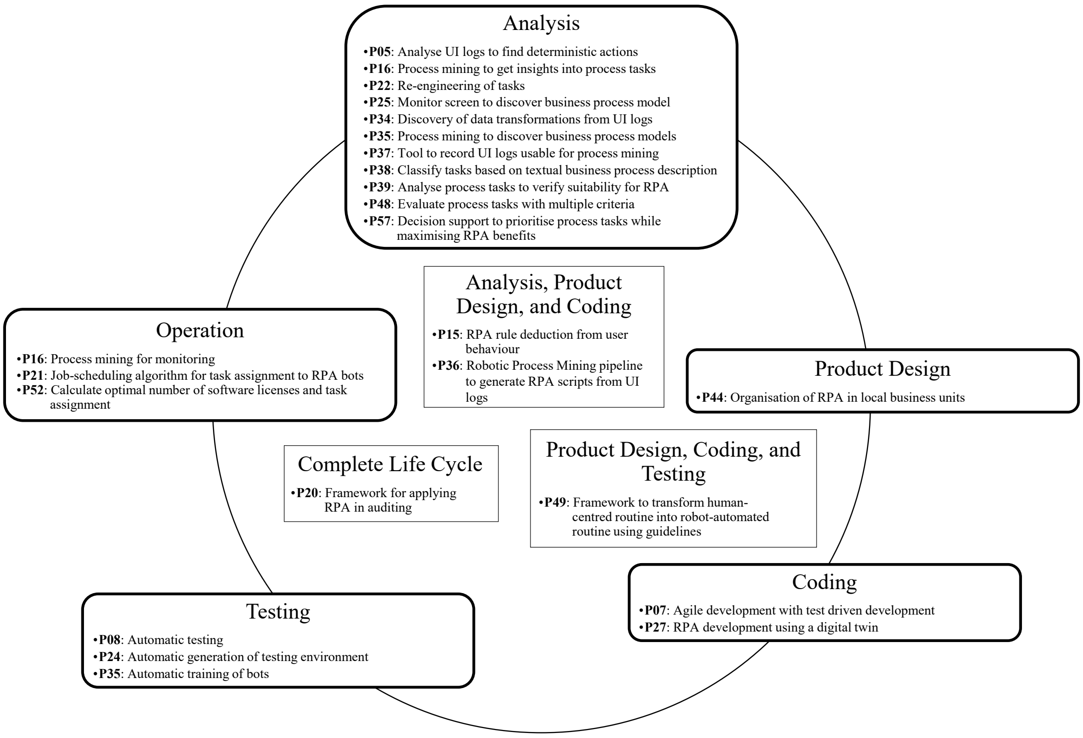

Figure 11. SDLC annotated with Publications providing Methods for RPA Projects.

Analysis Stage. The approaches to improve the Analysis Stage can be clustered into three areas: **business process insights**, **business process standardisation**, and **process task selection**.

P16 uses process mining to get insights into the business process, e.g., its automation rate. In P38, textual business process descriptions are used to classify the tasks into the categories *Manual Task*, *User Task*, and *Automated Task*. The goal is to automatically detect process tasks suited for RPA. To achieve this goal, P38 uses feature computation for prediction and a Support Vector Machine for classifying the business process descriptions based on the features.

The aim of P35 is to develop a new process mining technique that can deal with RPA and automatically discover business process models. The approach is to discover constraints within an event log, extract corresponding feature vectors, and label constraint violations. P35 uses clustering methods to identify correlations between activation and target payloads. In a subsequent publication of the same authors, i.e. P37, a tool ('Action Logger') is developed that records UI logs, which can directly serve as input to process mining tools. The UI logs contain all information relevant for RPA implementation. Finally, P34, again contributed by the same authors, develops an idea how to discover data transformations from UI logs.

In P16, process mining is used to standardise existing business processes. Another standardisation technique is proposed by P22, which emphasises the importance of not automating the as-is business process, but to optimise it before automation. Thus, the authors propose a framework for business process re-engineering.

The most difficult task in the analysis stage is to select the process tasks to be automated by a bot. Different approaches are proposed: P16 sticks to process mining for prioritising process tasks. P25 also uses process mining to discover process tasks, with a method focusing on creating event logs from screen monitoring data. P05 analyses UI logs to discover deterministic actions. As basic idea, 'a routine is automatable if its first action is always triggered when a condition is met [...] and the value of each parameter of each action can be computed from the values of parameters of previous actions' (P05).

P39 develops a four-step method to analyse a process task based on its characteristics (cf. Section 4.2): first, to be eligible for RPA, the process task has to be mature and standardised (Step 1). Step 2 assesses the RPA potential of the process task based on human interaction with the information systems and its rule-based nature. Step 3 evaluates the RPA relevance according to the volume of transactions and the degree of process task complexity. Finally, based on Steps 2 and 3, the process task is classified. P39 recommends selecting process tasks with high relevance and high potential. P48 follows a similar approach and develops a multi-criteria process task evaluation model, which assesses the technical feasibility and business potential criteria to find suitable process tasks for RPA. The technical criteria include the degree of rule-basedness, human intervention, digitalisation, and the structuredness of data. The potential criteria evaluate labour intensity, the number of systems involved, the number of process task exceptions, the number of task steps, current costs, and process task maturity. P57 proposes a method to prioritise process tasks while maximising RPA benefits. Based on different indicators of the process task, i.e., execution frequency, execution time, degree of standardisation, stability (i.e., small number of exceptions in the process task), failure rate, and automation rate, the automation potential of the process task is assessed. Furthermore, the profitability of process task automation is measured through fixed and variable costs of human labour as well as fixed and variable costs of RPA. Finally, P57 maximises the economic value and provides recommendations to support the decision of selecting appropriate processes for RPA initiatives.

Product Design Stage. P44 highlights advantages and challenges of organising RPA in local business units. On the one hand, enthusiasm for digitalisation and local ownership are built. On the other, there is a lack of control mechanisms and end-to-end business process views. P44 proposes to loosely couple the IT department and the RPA team.

Coding Stage. P07 suggests a method for implementing RPA projects in an agile way: instead of documenting a process task completely with clicks and text-based description, the users themselves record a video when performing the process task and store the latter in the backlog. The developers create a test case for this video and checks whether the current solution passes the test (Test Driven Development). If not, they modify the RPA solution until the test case is fulfilled. Then, they move on to the next video. P27 proposes the use of digital twins for RPA development. In this context, a digital twin corresponds to a virtual shadow of an IT system. The idea allows developing RPA externally without having access to the real system.

Testing Stage. P35 has the vision to develop a method 'to automatically train the RPA bots'. Research has not progressed far enough. P08 proposes a method for automated testing in RPA projects, which has been validated with a prototype. The approach is to modify the RPA life cycle. Compared to the life cycle model depicted in Figure 11, the third stage is called development and not coding, operation is named monitoring, and a fourth stage, i.e., deployment, is inserted before the testing phase. The modified life cycle not only includes design in the second stage, but test environment construction as well. During development, automatic testing can be performed serving as new input for the analysis phase. P24 extends the idea of P08 by providing technical details on test cases and the algorithm as well as by evaluating the approach of automatically generating a testing environment.

Operation Stage. P16 mentions that process mining can be used to monitor the results of an RPA project. P21 proposes a middleware system for controlling the execution of multiple RPA bots. The system includes a job-scheduling algorithm to efficiently distribute multiple tasks among available bots. In turn, P52 solves an optimisation problem to determine the optimal number of required bots while minimising costs. Then, the optimal task assignment among the bots is solved.

Some publications cannot be assigned to solely one stage and are, therefore, placed in the centre of Figure 11. P15 and P36 cover the first three stages, i.e., Analysis, Product Design, and Coding. To be more precise, P15 presents an end-to-end approach that allows deducing RPA rules from user behaviour. The idea is based on the Form-to-Rule approach: First, tasks of the user are identified by observing interactions with systems and identifying forms used within the systems. Second, rules are deduced from relations between the different tasks. Third, RPA is implemented based on those rules. P36 combines the approaches presented in P34, P35, and P37 and proposes a Robotic Process Mining pipeline (cf. Figure 12). After recording UI logs, noise filtering, segmentation, and simplification steps are applied to identify candidate routines. In these routines, executable (sub)routines are discovered and compiled to obtain RPA scripts. P36 emphasises that there are still many challenges to successfully apply the proposed pipeline. However, as main advantage, the pipeline presents a first end-to-end automation. Therefore, it serves as a reference for other approaches with process mining.

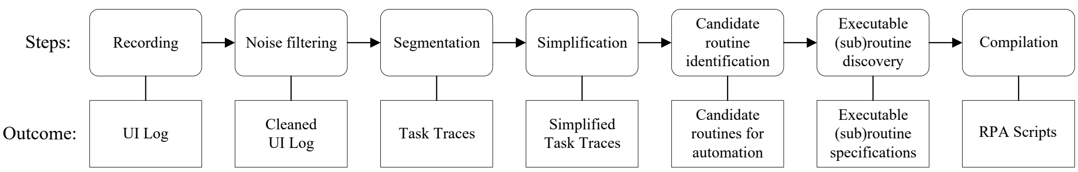

Figure 12. Robotic Process Mining Pipeline according to (Leno et al. 2020b).

Stages Product Design, Coding, and Testing are addressed by P49. A framework is developed to transform a human-centred routine into a robot-automated one. The framework of routine automation can be empirically applied to different areas, including RPA, and provides implementation guidelines.

One publication, i.e., P20, addresses the complete life cycle of RPA and proposes a framework for introducing RPA in auditing. The first stage is process task selection based on the evaluation of different criteria, e.g., RPA criteria (cf. Section 4.2), process task complexity, and compatibility of the data used in the task automated with RPA. Second, the process task is modified, e.g., considering data standardisation, i.e., to unify data from multiple sources. In a third step, the process task is implemented and, finally, evaluated and operated. The last step consists of evaluating effectiveness, assessing detection risk (i.e. the risk that auditing 'will not detect a misstatement' (P20)), and monitoring the RPA operations.

4.5. *RQ 5: Is AI used in combination with RPA?*

Due to the growing importance of AI in automation, RQ 5 investigates whether AI is used in combination with RPA and - if yes - how RPA can profit from AI. To get an idea whether AI has already been used in combination with RPA, our insights from literature are summarised in the following.

Some works **briefly mention** the use of AI and its potentials. P40 and P43 state that with AI it becomes possible to understand semi-structured data. This can be used to extract data relevant for the RPA bot from unstructured data and to relax the restriction on structured input data (cf. Section 4.2). P56, in turn, emphasises that AI helps to interpret changing user interfaces and to improve the robustness of RPA solutions. Using chat bots, P43 presumes that the interaction between humans and computer systems becomes facilitated.

First **AI-based applications** have emerged in the RPA field: P26 presents a Cognitive Automation Robots Platform, which is able to understand data, generate insights, and use the latter as learning experiences. P33 uses the cognitive virtual agent 'Amelia', which understands chat messages. In P19, a cognitive RPA prototype is presented, which can automatically identify, extract, and process data. Once the classification model is trained (for details see P19, pp. 68-69), new unseen documents are classified and relevant objects, e.g., address fields, are detected and extracted.

We discovered four publications that combine AI with RPA in greater detail. P41 provides building blocks for intelligent process automation by explaining and providing implementations on how to extract intentions from audio, classify emails, detect anomalies, find cross correlations in time series, and understand traffic patterns. P62 describes how machine learning methods contribute to further improve RPA, e.g., using image processing to scan letters or invoices or using classification algorithms to label documents. The task of **classifying emails** correctly is picked up by several publications: P45 proposes the use of an Support Vector Machine and a Text Rank Algorithm to read emails and to automatically process them. P09 develops an algorithm, named Sure-Tree, for email classification, which produces a minimum of false positives to ensure that an incorrect action is never triggered.

5. Deriving a Framework for Analysing and Comparing RPA Publications

This section synthesises the results obtained by the SMS. More precisely, we present a classification framework for **An**alysing and **Co**mparing existing as well as upcoming **Pu**blications in **R**PA (ANCOPUR for short). ANCOPUR gathers the results along the derived research questions (cf. Section 3.1). The section presents the framework and explains it with an example (cf. Section 5.1). Furthermore, researchers in a large automotive enterprise use the framework in their daily work. We illustrate its usefulness and practical relevance with this practical application (cf. Section 5.2).

5.1. *Explanation of ANCOPUR*

Tables 8 and 9 depict the schema of the ANCOPUR framework we derived: The first column shows the main aspect for comparison, e.g., meaning, criteria for selecting process tasks, or use case. In the following columns the aspect gets detailed. The publication can be assigned to several rows depending on the aspects it covers. If a new feature is found, it can be added to ANCOPUR as well, i.e., we consider our classification and evaluation framework as extensible. To demonstrate its usefulness and applicability, all 63 publications from the SMS are categorised with ANCOPUR. Note that this significantly facilitates the comparison of any new publication with existing knowledge as well. We illustrate and explain ANCOPUR by assigning P17 exemplarily to it. This publication was one of the 63 identified as relevant by the SMS.

Publication P17 is read to detect information depositing on the first column of the ANCOPUR framework. We discover the aspects *criteria for selecting process tasks*, *Effects*, and *Use Case*. Concerning the criteria for process tasks to be automated, P17 emphasises that '1) the processes should be simple enough so that the robots could be implemented quickly and 2) improved process efficiency resulting from RPA implementation should be clearly visible' (Hallikainen, Bekkhus, and Pan 2018). Therefore, the process tasks are selected depending on their **complexity** and the **duration of process task** execution. Applying ANCOPUR, P17 is indeed assigned to those two rows in the criteria for selecting process tasks column (cf. Table 8). Regarding the case study, the aspects *Business Area*, *Business Process Task*, and *Automation Tool* are all covered by P17: the general business area is BPO and the concrete processes are '1) new employment relationships and 2) changes in employee payment details', which are both swivel-chair processes. UiPath was used for automating the business processes. Therefore, P17 is added as reference to rows **BPO**, **swivel-chair process**, and **UiPath** in the use case section of ANCOPUR (cf. Table 8). The following wording is found for RPA effects: 'there were some fears about losing jobs [...] people would no longer have to carry out the boring work and could concentrate on more interesting tasks' (P17). The first statement expresses a negative effect on humans and is assigned to **fear to lose the job** in ANCOPUR. The second statement describes positive effects on humans and covers both aspects in ANCOPUR, namely **relieved from non-value adding tasks** and **focus on cognitively more demanding tasks** (cf. Table 9).

The assignment of P17 to ANCOPUR eases its systematic comparisons with other publications. Assume that one is interested in RPA Case Studies and has read P17 and classified it with the framework. There is another publication using the same automation tool, i.e., UiPath, namely, P03. Hence, one can read P03 and compare it with P17. Further, one becomes aware of other automation tools. Concerning RPA Effects, P17 only covers effects on humans. Here, one can find further publications covering the same (e.g., P02, P55) or different aspects (e.g., P14). Additionally, effects on the company are not covered in P17, therefore, with ANCOPUR one can determine relevant publications covering this aspect.

5.2. *ANCOPUR Application in Practice*

The classification framework is initially presented to researchers in a large automotive company to assess its applicability and complexity. The researchers are asked to assign a publication randomly excluded in the results of the SMS to the framework (Flechsig, Lohmer, and Lasch 2019). For *Meaning*, *Use Case*, *Effect*, and *Combination with AI*, no new aspects or no information are found at all. Concerning *Differences of RPA to Related Technologies*, *BPM* is compared to RPA. All aspects in ANCOPUR are covered, only the formulations differ a bit, e.g., 'Redesign of extensive processes with high strategic relevance and added value' (Flechsig, Lohmer, and Lasch 2019) is assigned to the row **changes 'how' work is done**. Regarding *criteria for selecting process tasks*, the researchers find several questions that aim to identify processes suitable for an RPA implementation (Flechsig, Lohmer, and Lasch 2019, p. 111). These criteria include **repetitiveness**, **rule-based**, **duration of process task** execution, and **high effects of business failure**. Therefore, (Flechsig, Lohmer, and Lasch 2019) may be added to the corresponding rows in the ANCOPUR framework. Additionally, (Flechsig, Lohmer, and Lasch 2019) proposes choosing processes relevant for **compliance**, an aspect not considered yet. The researchers discuss and decide to expand ANCOPUR by this process task selection criterion aspect. (Flechsig, Lohmer, and Lasch 2019) suggests a method for combining BPM and RPA, which can be assigned to the *Product Design Stage* with a new row, namely **combination of BPM and RPA**. The idea is to have a common Analysis Stage for BPM and RPA projects as well as to decide in the Product Design Stage whether to implement a BPM or an RPA solution. Overall, the researchers agree that ANCOPUR provides a useful overview for RPA research and is easy to use and, especially, to expand.

After this initial positive contact with the framework, we spread ANCOPUR throughout the enterprise. Since then, it has been helpful in various situations:

- Colleagues from the IT department investigated which task selection criteria can be found in literature to adapt the identification of tasks suited for automation to the state-of-the-art. Relevant publications were selected from ANCOPUR.
- Employees from different business areas, e.g., banking asked to what extent RPA has been used successfully in this area. Thanks to ANCOPUR, the request could be answered and specific publications could be named.
- Managers are always interested in what benefits automation has on the enterprise. With ANCOPUR, known RPA effects can be easily given.
- The works council was interested in which effects on people have to be considered in RPA projects. We were able to provide specific information here.

Therefore, accompanying different RPA initiatives over a longer time, we recognise that the framework is highly appreciated and used. The people working with it are convinced of its advantages and recommend ANCOPUR to their colleagues.

Altogether, ANCOPUR uses criteria and sub-criteria to classify RPA publications. The framework is useful for systematically analysing, assessing, and comparing existing as well as upcoming RPA works.

6. Discussion

The main motivation of conducting this SMS was to provide a holistic RPA overview (cf. Section 1.1) covering different disciplines. The obtained results enable us to not only answer the five research questions (cf. Section 3.1), but also to derive a classification and mapping framework that is useful for both academics and practitioners. In the following, the results are discussed and interpreted along the seven discovered **thematic clusters** (cf. Section 4). The role of RPA is to automate selected process tasks or parts, and thus constitutes a crucial tool fostering business process optimisation due to the automation of individual tasks. The paper explains for which tasks RPA is best suited (cf. Section 4.2), how RPA projects can be carried out (cf. Section 4.4), and what effects can be achieved with RPA (cf. Section 4.3). Altogether, this has enabled a profound positioning of the RPA technology.

More precisely, we identified, categorised, and analysed 63 publications belonging to

Table 8. Classification Framework ANCOPUR.

ANCOPUR			Ref
Meaning	software-based solution		(IEEE 2017), P02, P33, P40, P43, P51, P58, P59, P60
	mimics human behaviour		P06, P40, P43, P45, P51, P53, P56, P59, P60
	characteristics of the automated process task	rule-based	(IEEE 2017), P01, P10, P29, P45
		structured data	P01, P10, P29, P53
		routine tasks	P01, P03, P06, P10, P51
	non-invasive		(IEEE 2017), P06, P46, P51
	goal of implementation	deliver result/service	(IEEE 2017)
	humans handle exceptions		(IEEE 2017)
Differences of RPA to Related Technology	RDA	no own identity	P40
		attended automation	P40
	Intelligent/Cognitive Automation	low degree of standardisation	P58
		unstructured data	P51, P54
		knowledge/experience-based decisions	P06, P19, P51
		probabilistic outcome	P01, P54
		exceptions trigger machine learning	P43, P54
	BPM	re-engineer process tasks to optimise them	P07
		changes 'how' work is done	P07, P44, P53
		creates new business applications	P01, P07, P46, P60
		highly complex and expensive	P44, P46, P53
	STP		P56
Criteria for selecting process tasks	repetitive		P06, P10, P14, P28, P31, P50, P58, P59, P62, P63
	rule-based		P02, P06, P14, P28, P31, P46, P62, P63
	high manual effort		P06, P14, P28, P51
	complexity		**P17**, P50, P58, P59
	duration of process task execution		P14, **P17**
	digital and structured inputs and outputs		P10, P28, P46
	limited number of human intervention		P14
	access to multiple applications		P14, P28
	high effects of business failure		P14, P63
Use Case	Business Area	BPO	P01, **P17**, P30
		Shared Services	P32, P58
		Telecommunication	P50, P59
		Banking	P40, P53
		Digital Forensics	P03
		Auditing	P10
		Energy Supplier	P31
		Manufacturing	P47
		Corporate Service Provider	P61
		Software Testing	P63
	Process Task	swivel-chair process	P01, P03, P10, **P17**, P30-P32, P40, P47, P50, P53, P58, P59, P61, P63
	Automation Tool	Blue Prism	P30, P53, P58, P59
		UiPath	P03, **P17**
		Redwood	P32
		Bluepond	P50
		Workfusion	P63
		Roboplatform	P40

Table 9. Framework ANCOPUR - Continuation.

Effect	on humans and future worklife	positive	relieved from non-value adding tasks	**P17**, P25, P33, P47, P51, P55, P58
			focus on cognitively more demanding tasks	P02, P03, P10, P12, P13, **P17**, P28, P29, P32, P41, P54, P58
		negative	fear to lose the job	P02, P13, **P17**, P18, P30, P55
			afraid to learn new technology, acceptance problems	P13, P14, P18
			less tasks, lay-off	P11, P12, P14, P32, P42, P54, P61
	on company	positive	speed	P01, P12, P14, P18, P28, P29, P35, P47, P50, P54, P55, P58, P61
			availability	P01, P06, P14, P29, P33, P43, P50, P51, P59, P62
			compliance	P29, P32, P33, P35, P43, P51, P59
			quality	P06, P12-P14, P28, P35, P43, P47, P50, P51, P54, P55, P58, P59, P62
		controversially discussed	inability to make decisions	P43, P46, P50
			costs	P03, P06, P13, P14, P18, P31-P33, P35, P46, P47, P50, P54, P55, P59
			non-invasiveness	P03, P46, P54
		negative	workaround, temporary solution	P02, P18, P19
			incompatibility of software with RPA solutions	P03
Method	Analysis Stage	process task insights	automation rate	P16
			classify tasks based on textual business process description	P38
			discover business process models	P25, P34, P35, P37
		process task standardisation	framework for process task re-engineering	P22
		process task selection	multi-criteria process task evaluation model	P48
			analyse process tasks based on criteria	P39
			prioritise process tasks, maximise benefits	P57
			analyse UI logs to find deterministic actions	P05
	Product Design Stage	organise RPA in local business units		P44
	Coding Stage	agile development		P07
		development with digital twin		P27
	Testing Stage	automatic testing		P08, P24
		automatic training		P35
	Operation Stage	process mining to monitor results		P16
		algorithm for job-scheduling and task assignment		P21
		optimal number of licences and task assignment		P52
	Several Stages	RPA rule deduction from user behaviour		P15
		generate RPA scripts from UI logs		P36
		framework to transform human-centred into robot-automated routine		P49
		framework for RPA in auditing		P20
Combination with AI	briefly mention AI			P40, P43, P56
	present prototype			P19, P26, P33
	machine learning methods			P41, P62
	classify emails	Support Vector Machine, Text Rank		P45
		Sure-Tree		P09

the following seven clusters: RPA Meaning, Differences of RPA to Related Technologies, Criteria for selecting process tasks, RPA Use Cases, RPA Effects, RPA Project Methods, and Combination of RPA with AI. As main result we obtain the ANCOPUR framework, which enables a structured overview of existing work on RPA as well as the identification of research gaps. More specifically, the ANCOPUR classification framework provides a fast and easy way to identify and categorise publications in the RPA area. Hence, the main goal of conducting an SMS is fulfilled (Petersen et al. 2008). Note that some publications cover several components of the framework, whereas others focus on one specific aspect. For example, P08 presents a method for testing, no other aspect is covered. In P29, the meanings of RPA and effects of RPA projects are discussed. However, the focus is on effects on the company (organisational/management aspect). P59 covers nearly all aspects, i.e., RPA is defined, criteria for selecting process tasks are provided, the tool used for automation is explained, and effects on the company resulting from the RPA project are presented. ANCOPUR merges the different aspects of all publications and provides a holistic overview on RPA literature. In particular, comparing new works with existing knowledge becomes much simpler and more structured. Moreover, ANCOPUR can be easily expanded. If new publications reveal unconsidered aspects, those can be added to evolve the framework and keep it up to date. The added value of ANCOPUR has been confirmed by engineers in a large automotive company working with the classification framework. In detail:

1. **RPA Meanings.** It is emphasised that RPA is a software-based solution mimicking human behaviour. These aspects are crucial for indicating the difference of RPA to hardware bots.
2. **Differences of RPA to Related Technologies.** Most papers emphasise the differences between RPA and Intelligent Automation as well as between RPA and BPM.
3. **Criteria for selecting process tasks.** Best suited for an RPA automation are repetitive, rule-based, and complex process tasks demanding for high manual efforts.
4. **Use Cases.** The majority of use cases stem from business areas such as BPO and Shared Services. Note that this is reasonable as those areas possess many repetitive, rule-based process tasks as, for example, *generation of payment receipt* (Aguirre and Rodriguez 2017). Anyway, it would be interesting to encounter more RPA projects in knowledge-intensive business areas, e.g., in the research and development field or in healthcare. Furthermore, current literature only reports on successful RPA projects, leaving room for further research on failed projects. Concerning the RPA tools used in the case studies, Blue Prism and UiPath are dominating. According to (Gartner 2019), however, there are other tools that should be considered: Automation Anywhere, EdgeVerve Systems, NICE, Workfusion, Pegasystems, and Another Monday. The application of the different tools to one concrete use case as well as a systematic comparison of tool performance should be subject of further research studies.
5. **RPA Effects.** The positive effects of RPA are widely discussed in literature. Only a minority is critical towards RPA. A potential reason for this is the novelty of RPA (cf. Figure 5 in Section 4), due to which the technology is hyped and negative effects do not want to be seen. It is emphasised that employees are relieved from non-value adding tasks, and instead may focus on cognitively more demanding tasks. Finally, process tasks become faster, better available, more compliant, and improved in quality.

6. **RPA Project Methods.** Most methods improving RPA implementation were published in 2019 and 2020 (16 of 22 papers). The vast majority of methods tries to improve the analysis stage, only some publications address the other life cycle stages. The analysis stage is the one that differs mostly from other software development projects. Product design, coding, and testing are not differing that much when either implementing an RPA project or any other software project. We expect that more publications adding analysis issues will appear as well as methods to fully automate the discovery of RPA-suitable process tasks. Furthermore, the operation stage should be addressed, e.g., it should be monitored whether the bots are accepted or employees fear to lose their job and, therefore, refuse the use of the bots.
7. **Combination of RPA with AI.** The use of AI in the context of RPA is still at a rather early stage. Six publications deal with this combination from a general point of view and emphasise that it might create a big impact. Only four concrete use cases are discovered, the majority focuses on the problem of classifying emails correctly. While the use cases are still scientific in nature, it will be interesting to learn more about industry-driven approaches and projects. The publications are from the last years only, therefore, we hope for more research in the coming years.

In general, research on RPA is still at its beginning. Though being increasingly present in industry, scientific works on this topic are rather scarce and mainly consider qualitative issues. Moreover, it is noteworthy that quantitative research is missing. We expect that there will be a lot more publications in the coming years. In order to assess and compare those publications with the existing body of knowledge, the present paper provides a fundamental framework based on concepts of RPA.

7. Summary and Outlook

RPA is a novel technology that emerged in 2015. By means of an SMS, we provide an overview of the most relevant publications until June 2020. We discover seven thematic clusters answering fundamental questions such as 'What meaning is attached to RPA in literature?', 'Which process tasks can be automated with RPA?', and 'What are the RPA effects?'. Furthermore, we investigate the differences between RPA and related technologies, methods for improving the implementation of RPA projects, and whether AI is used in combination with RPA. Additionally, we provide a review of case studies including the business area, process task, and the automation tool.

The SMS results in ANCOPUR, a framework for systematically analysing and comparing emerging publications in the RPA area. With the help of criteria and sub-criteria, publications can be classified. The framework provides a robust and expandable systematics to categorise and evaluate trends and further developments in the RPA area. It is already in use in a large automotive company for these reasons. Therefore, it will help both scientists and users from industry to assess and compare upcoming RPA publications.

As discussed, due to the novelty of RPA, the research focus lies on analysing and understanding the RPA technology. The Combination of AI with RPA and the development of Methods for RPA implementation are still in their beginning. Regarding the publication dates of the respective publications, there is a clear trend in this direction visible: nine of ten publications combining RPA and AI and 20 of 22 method papers were published in 2018, 2019, and 2020.

References

Aguirre, Santiago, and Alejandro Rodriguez. 2017. "Automation of a Business Process Using Robotic Process Automation (RPA): A Case Study." In *Workshop on Engineering Applications*, 65–71. Springer, Cham.

Asatiani, Aleksandre, and Esko Penttinen. 2016. "Turning robotic process automation into commercial success - Case OpusCapita." *Journal of Information Technology Teaching Cases* 6 (2): 67–74.

Asquith, Alisha, and Graeme Horsman. 2019. "Let the robots do it! - Taking a look at Robotic Process Automation and its potential application in digital forensics." *Forensic Science International: Reports* 1.

Auth, Gunnar, and Frank Bensberg. 2019. "Impact of Robotic Process Automation on Enterprise Architectures." In *INFORMATIK 2019: 50 Jahre Gesellschaft für Informatik - Informatik für Gesellschaft (Workshop Beiträge)*, Gesellschaft für Informatik eV.

Bosco, Antonio, Adriano Augusto, Marlon Dumas, and Marcello La Rosa. 2019. "Discovering Automatable Routines From User Interaction Logs." In *International Conference on Business Process Management*, 144–162. Springer, Cham.

Bruno, Jerry, Sam Johnson, and Josh Hesley. 2017. "Robotic disruption and the new revenue cycle." *Healthcare Financial Management* 71 (9): 54–62.

Cewe, Christoph, Daniel Koch, and Robert Mertens. 2017. "Minimal Effort Requirements Engineering for Robotic Process Automation with Test Driven Development and Screen Recording." In *International Conference on Business Process Management*, 642–648. Springer, Cham.

Chacón-Montero, J., A. Jiménez-Ramírez, and J. G. Enríquez. 2019. "Towards a Method for Automated Testing in Robotic Process Automation Projects." In *14th International Workshop on Automation of Software Test*, 42–47. IEEE Press.

Chalmers, Eric. 2018. "Machine Learning with Certainty: A Requirement for Intelligent Process Automation." In *17th IEEE International Conference on Machine Learning and Applications, ICMLA*, 299–304. IEEE.

Cohen, Michael, Andrea M. Rozario, and Chanyuan Abigail Zhang. 2019. "Exploring the Use of Robotic Process Automation (RPA) in Substantive Audit Procedures." *The CPA Journal* 89 (7): 49–53.

Eikebrokk, Tom, and Dag Olsen. 2019. "Robotic Process Automation for Knowledge Workers - Will It Lead To Empowerment or Lay-Offs?" In *Norsk konferanse for organisasjoners bruk at IT*, Vol. 27, 2015–2017.

Eikebrokk, Tom Roar, and Dag Håkon Olsen. 2020. "Robotic Process Automation and Consequences for Knowledge Workers; a Mixed-Method Study." In *Conference on e-Business, e-Services and e-Society*, 114–125. Springer.

El-Khawaga, Ghada, Mervat Abuelkheir, Sherif I Barakat, Alaa M Riad, and Manfred Reichert. 2020. "CONDA-PM—A Systematic Review and Framework for Concept Drift Analysis in Process Mining." *Algorithms* 13 (7): 161.

Enriquez, J. G., A. Jimenez-Ramirez, F. J. Dominguez-Mayo, and J. A. Garcia-Garcia. 2020. "Robotic Process Automation: A Scientific and Industrial Systematic Mapping Study." *IEEE Access* 8: 39113–39129.

Fernandez, Dahlia, and Aini Aman. 2018. "Impacts of Robotic Process Automation on Global Accounting Services." *Asian Journal of Accounting and Governance* 9: 123–132.

Flechsig, Christian, Jacob Lohmer, and Rainer Lasch. 2019. "Realizing the Full Potential of Robotic Process Automation Through a Combination with BPM." In *Logistics Management, Lecture Notes in Logistics*, edited by C. Bierwirth, T. Kirschstein, and D. Sackmann, 104–119. Springer, Cham.

Fung, Han Ping. 2014. "Criteria, Use Cases and Effects of Information Technology Process Automation (ITPA)." *Advances in Robotics & Automation* 3 (3).

Gao, Junxiong, Sebastiaan J. van Zelst, Xixi Lu, and Will M.P. van der Aalst. 2019. "Automated robotic process automation: A self-learning approach." *Lecture Notes in Computer Science* 11877 LNCS: 95–112.

Gartner. 2019. *Magic Quadrant for Robotic Process Automation.* Technical Report. Gartner.

Geyer-Klingeberg, Jerome, Janina Nakladal, and Fabian Baldauf. 2018. "Process Mining and Robotic Process Automation: A Perfect Match." In *BPM (Dissertation/Demos/Industry)*, 124–131.

Gotthardt, Max, Dan Koivulaakso, Okyanus Paksoy, Cornelius Saramo, Minna Martikainen, and Othmar M. Lehner. 2019. "Current State and Challenges in the Implementation of Robotic Process Automation and Artificial Intelligence in Accounting and Auditing." *Journal of Finance & Risk Perspectives* 8: 31–46.

Hallikainen, Petri, Riitta Bekkhus, and Shan L Pan. 2018. "How OpusCapita Used Internal RPA Capabilities to Offer Services to Clients." *MIS Quarterly Executive* 17 (1): 41–52.

Hindel, Julia, Lena M Cabrera, and Matthias Stierle. 2020. "Robotic Process Automation: Hype or Hope?" In *15th International Conference on Wirtschaftsinformatik*, .

Houy, Constantin, Maarten Hamberg, and Peter Fettke. 2019. "Robotic Process Automation in Public Administrations." In *Digitalisierung von Staat und Verwaltung*, edited by M. Räckers, S. Halsbenning, D. Rätz, D. Richter, and E. Schweighofer, 62–74. Gesellschaft für Informatik eV.

Huang, Feiqi, and Miklos A. Vasarhelyi. 2019. "Applying robotic process automation (RPA) in auditing: A framework." *International Journal of Accounting Information Systems* 35.

Hwang, Myeong Ha, Ui Kyun Na, Seungjun Lee, Byung Joo Cho, Yeri Kim, Dong Hyuk Lee, and Ji Kang Shin. 2020. "MIORPA: Middleware System for open-source robotic process automation." *Journal of Computing Science and Engineering* 14 (1): 19–25.

Ian, Herbert, Aravindhan Dhayalan, and Scott Andy. 2016. "The future of professional work: Will you be replaced or will you be sitting next to a robot?" *Management Services Journal* 60 (2): 22–27.

IEEE. 2017. "IEEE Guide to Terms and Concepts in Intelligent Process Automation." *IEEE Std 2755-2017* 1–16.

Issac, Ruchi, Riya Muni, and Kenali Desai. 2018. "Delineated Analysis of Robotic Process Automation Tools." In *2nd International Conference on Advances in Electronics, Computers and Communications*, 1–5. IEEE.

Ivančić, Lucija, Dalia Suša Vugec, and Vesna Bosilj Vukšić. 2019. "Robotic Process Automation: Systematic Literature Review." In *Business Process Management: Blockchain and Central and Eastern Europe Forum, BPM 2019, Lecture Notes in Business Information Processing*, edited by C. et al. Di Ciccio, Vol. 361, 280–295. Springer, Cham.

Jalali, Samireh, and Claes Wohlin. 2012. "Systematic literature studies: database searches vs. backward snowballing." In *Proceedings of the 2012 ACM-IEEE international symposium on empirical software engineering and measurement*, 29–38.

Jiménez-Ramírez, A., Hajo Reijers, Irene Barba, and Carmelo Del Valle. 2019. "A Method to Improve the Early Stages of the Robotic Process Automation Lifecycle." In *International Conference on Advanced Information Systems Engineering*, 446–461. Springer, Cham.

Jiménez-Ramírez, Andres, Jesús Chacón-Montero, Tomasz Wojdynsky, and José González Enríquez. 2020. "Automated testing in robotic process automation projects." *Journal of Software: Evolution and Process* 1–11.

Khanra, Sayantan, Amandeep Dhir, AKM Najmul Islam, and Matti Mäntymäki. 2020. "Big data analytics in healthcare: a systematic literature review." *Enterprise Information Systems* 14 (7): 878–912.

Kin, Goon Wooi, Rosnin Mustaffa, M.A.J. Johari, and A.Y. Amruddin. 2018. "Cognitive Automation Robots (CAR)." In *E-Proceeding of the 7th International Conference on Social Science Research*, 1–11.

Kitchenham, B., and S. Charters. 2007. *Guidelines for performing systematic literature reviews* *in software engineering*. Technical Report. Technical report, EBSE Technical Report. EBSE-2007-01.

Koch, Julian, Michael Trampler, Ingo Kregel, and André Coners. 2020. "'Mirror, Mirror, on the Wall': Robotic Process Automation in the Public Sector using a Digital Twin." In *28th European Conference on Information Systems (ECIS2020)*, .

Kokina, Julia, and Shay Blanchette. 2019. "Early evidence of digital labor in accounting: Innovation with Robotic Process Automation." *International Journal of Accounting Information Systems* 35.

Lacity, Mary, and Leslie Willcocks. 2017. "A New Approach to Automating Services." *MIT Sloan Management Review* .

Lacity, Mary, Leslie Willcocks, and Andrew Craig. 2015a. "Robotic process automation at Xchanging." *The Outsourcing Unit Working Research Paper Series* 15 (3): 1–26.

Lacity, Mary, Leslie Willcocks, and Andrew Craig. 2015b. "Robotic Process Automation: Mature Capabilities in the Energy Sector." *The Outsourcing Unit Working Research Paper Series* 1–19.

Lacity, Mary, Leslie Willcocks, and Andrew Craig. 2016. "Robotizing Global Financial Shared Services at Royal DSM." *The Outsourcing Unit Working Research Paper Series* 16 (2): 1–26.

Lacity, Mary, Leslie Willcocks, and Andrew Craig. 2017. "Service Automation: Cognitive Virtual Agents at SEB Bank." *London School of Economics and Political Science* 1–29.

Leno, Volodymyr, Marlon Dumas, Marcello La Rosa, Fabrizio Maria Maggi, and Artem Polyvyanyy. 2020a. "Automated Discovery of Data Transformations for Robotic Process Automation." *arXiv preprint arXiv:2001.01007* .

Leno, Volodymyr, Marlon Dumas, Fabrizio Maria Maggi, and Marcello La Rosa. 2018. "Multi-Perspective process model discovery for robotic process automation." In *CEUR Workshop Proceedings*, Vol. 2114, 37–45.

Leno, Volodymyr, Artem Polyvyanyy, Marlon Dumas, Marcello La Rosa, and Fabrizio Maria Maggi. 2020b. "Robotic Process Mining: Vision and Challenges." *Business and Information Systems Engineering* .

Leno, Volodymyr, Artem Polyvyanyy, Marcello La Rosa, Marlon Dumas, and Fabrizio Maria Maggi. 2019. "Action Logger: Enabling Process Mining for Robotic Process Automation." In *CEUR Workshop Proceedings*, Vol. 2420, 124–128.

Leopold, Henrik, Han van Der Aa, and Hajo Reijers. 2018. "Identifying candidate tasks for robotic process automation in textual process descriptions." In *Enterprise, Business-Process and Information Systems Modeling. BPMDS 2018, EMMSAD 2018. Lecture Notes in Business Information Processing*, edited by J. Gulden, I. Reinhartz-Berger, R. Schmidt, S. Guerreiro, W. Guédria, and P. Bera, Vol. 318, 67–81. Springer, Cham.

Leshob, Abderrahmane, Audrey Bourgouin, and Laurent Renard. 2018. "Towards a Process Analysis Approach to Adopt Robotic Process Automation." In *15th International Conference on e-Business Engineering*, 46–53. IEEE.

Lewicki, Przemyslaw, Jacek Tochowicz, and Jeroen van Genuchten. 2019. "Are Robots Taking Our Jobs? A RoboPlatform at a Bank." *IEEE Software* 36 (3): 101–104.

Lohrmann, Matthias, and Manfred Reichert. 2016. "Effective application of process improvement patterns to business processes." *Software & Systems Modeling* 15 (2): 353–375.

Masood, Adnan, and Adnan Hashmi. 2019. "Cognitive Robotics Process Automation: Automate This!" In *Cognitive Computing Recipes*, 225–287. Apress, Berkeley, CA.

Moffitt, Kevin C., Andrea M. Rozario, and Miklos A. Vasarhelyi. 2018. "Robotic Process Automation for Auditing." *Journal of Emerging Technologies in Accounting* 15 (1): 1–10.

Mohanty, Soumendra, and Sachin Vyas. 2018. "Intelligent Process Automation = RPA + AI." In *How to Compete in the Age of Artificial Intelligence*, 125–141. Apress, Berkeley, CA.

Mundbrod, Nicolas, and Manfred Reichert. 2017. "Flexible Task Management Support for Knowledge-Intensive Processes." In *2017 IEEE 21st International Enterprise Distributed Object Computing Conference (EDOC)*, 95–102.

Ng, Chun Kit, Chun Ho Wu, Kai Leung Yung, Wai Hung Ip, and Tommy Cheung. 2018. "A semantic similarity analysis of Internet of Things." *Enterprise Information Systems* 12 (7): 820–855.

Osmundsen, Karen, Jon Iden, and Bendik Bygstad. 2019. "Organizing Robotic Process Automation: Balancing Loose and Tight Coupling." In *52nd Hawaii International Conference on System Sciences*, 6918–6926.

Patel, Maharsh, Aastha Shukla, Raunaq Porwal, and Radhika Kotecha. 2019. "Customized Automated Email Response Bot Using Machine Learning and Robotic Process Automation." *SSRN Electronic Journal* .

Penttinen, Esko, Henje Kasslin, and Aleksandre Asatiani. 2018. "How to Choose Between Robotic Process Automation and Back-End System Automation?" *26th European Conference on Information Systems* 1–14.

Petersen, Kai, Robert Feldt, Shahid Mujtaba, and Michael Mattsson. 2008. "Systematic mapping studies in software engineering." In *12th International Conference on Evaluation and Assessment in Software Engineering (EASE) 12*, 1–10.

Petersen, Kai, Sairam Vakkalanka, and Ludwik Kuzniarz. 2015. "Guidelines for conducting systematic mapping studies in software engineering: An update." *Information and Software Technology* 64: 1–18.

Radke, Andreas M, Minh Trang Dang, and Albert Tan. 2020. "Using Robotic Process Automation (RPA) to enhance item master data maintenance process." *LogForum* 16 (1): 129–140.

Reichert, Manfred, and Barbara Weber. 2012. *Enabling Flexibility in Process-Aware Information Systems: Challenges, Methods, Technologies*. Springer, Berlin-Heidelberg.

Riedl, Yannik, and K. Richard Beetz. 2019. "Robotic Process Automation: Developing a Multi-Criteria Evaluation Model for the Selection of Automatable Business Processes." In *25th Americas Conference on Information Systems, Cancun*, .

Royce, Winston W. 1987. "Managing the development of large software systems: concepts and techniques." In *9th international conference on Software Engineering*, 328–338.

Rutschi, Corinna, and Jens Dibbern. 2020. "Towards a framework of implementing software robots: Transforming Human-executed Routines into Machines." *Data Base for Advances in Information Systems* 51 (1): 104–128.

Santos, Filipa, Rúben Pereira, and José Braga Vasconcelos. 2019. "Toward robotic process automation implementation: an end-to-end perspective." *Business Process Management Journal* 26 (2): 405–420.

Schmitz, Manfred, Christian Dietze, and Christian Czarnecki. 2019. "Enabling digital transformation through robotic process automation at Deutsche Telekom." In *Digitalization Cases, Management for Professionals*, edited by N. Urbach and M. Röglinger, 15–33. Springer, Cham.

Schmitz, Manfred, Christoph Stummer, and Gerke Michael. 2019. "Smart Automation as Enabler of Digitalization? A Review of RPA/AI Potential and Barriers to Its Realization." In *Future Telco, Management for Professionals*, edited by P. Krüssel, 349–358. Springer, Cham.

Séguin, Sara, and Imène Benkalaï. 2020. "Robotic Process Automation (RPA) Using an Integer Linear Programming Formulation." *Cybernetics and Systems* 51 (4): 357–369.

Steinau, Sebastian, Andrea Marrella, Kevin Andrews, Francesco Leotta, Massimo Mecella, and Manfred Reichert. 2019. "DALEC: a framework for the systematic evaluation of data-centric approaches to process management software." *Software & Systems Modeling* 18 (4): 2679–2716.

Stople, Annette, Heidi Steinsund, Jon Iden, and Bendik Bygstad. 2017. "Lightweight IT and the IT function: experiences from robotic process automation in a Norwegian bank." *Bibsys Open Journal Systems* 25 (1).

Suri, Vipin K, Marianne Elia, Pavan Arora, and Jos van Hillegersberg. 2018. "Automation of Knowledge-Based Shared Services and Centers of Expertise." In *Digital Services and Platforms, Considerations for Sourcing, Global Sourcing, Lecture Notes in Business Information Processing*, edited by J. Kotlarsky, I. Oshri, and L. Willcocks, Vol. 344. Springer, Cham.

Suri, Vipin K, Marianne Elia, and Jos van Hillegersberg. 2017. "Software bots - The next frontier for shared services and functional excellence." In *Global Sourcing of Digital Services: Micro and Macro Perspectives, Global Sourcing, Lecture Notes in Business Information Processing*, edited by I. Oshri, J. Kotlarsky, and L. Willcocks, Vol. 306, 81–94. Springer, Cham.

Syed, Rehan, Suriadi Suriadi, Michael Adams, Wasana Bandara, Sander J.J. Leemans, Chun Ouyang, Arthur H.M. ter Hofstede, Inge van de Weerd, Moe Thandar Wynn, and Hajo A. Reijers. 2020. "Robotic Process Automation: Contemporary Themes and Challenges." *Computers in Industry* 115.

van der Aalst, Will M.P. 2011. *Process mining: discovery, conformance and enhancement of business processes*. Springer.

van der Aalst, Will M.P., Martin Bichler, and Armin Heinzl. 2018. "Robotic Process Automation." *Business and Information Systems Engineering* 60 (4): 269–272.

Wanner, Jonas, Adrian Hofmann, Marcus Fischer, Florian Imgrund, Christian Janiesch, and Jerome Geyer-Klingeberg. 2020. "Process selection in RPA projects - Towards a quantifiable method of decision making." *40th International Conference on Information Systems, ICIS 2019* 1–17.

Weber, Barbara, Shazia Sadiq, and Manfred Reichert. 2009. "Beyond rigidity–dynamic process lifecycle support." *Computer Science-Research and Development* 23 (2): 47–65.

Weske, Mathias. 2007. *Business Process Management: Concepts, Languages, Architectures*. Springer.

Wewerka, Judith, and Manfred Reichert. 2021. "Robotic Process Automation in the Automotive Industry - Lessons Learned form an Exploratory Case Study." In *15th International Conference on Research Challenges in Information Science*, 1–17.

Willcocks, Leslie, and Mary Lacity. 2015. "Robotic Process Automation: The Next Transformation Lever for Shared Services." *The Outsourcing Unit Working Research Paper Series* 15 (7): 1–35.

Willcocks, Leslie, and Mary Lacity. 2016. "Robotic Process Automation at Telefónica O2." *MIS Quarterly Executive* 15 (1): 21–35.

Willcocks, Leslie, Mary Lacity, and Andrew Craig. 2015. "The IT Function and Robotic Process Automation." *The Outsourcing Unit Working Research Paper Series* 15 (5): 1–39.

William, Woelly, and Linda William. 2019. "Improving Corporate Secretary Productivity using Robotic Process Automation." *Proceedings - 2019 International Conference on Technologies and Applications of Artificial Intelligence, TAAI 2019* .

Wróblewska, Anna, Tomasz Stanisławek, Bartłomiej Prus-Zajączkowski, and Łukasz Garncarek. 2018. "Robotic Process Automation of Unstructured Data with Machine Learning." *Annals of Computer Science and Information Systems* 16: 9–16.

Yatskiv, Solomiya, Iryna Voytyuk, Nataliia Yatskiv, Oksana Kushnir, Yuliia Trufanova, and Valentyna Panasyuk. 2019. "Improved Method of Software Automation Testing Based on the Robotic Process Automation Technology." In *9th International Conference on Advanced Computer Information Technologies (ACIT)*, 293–296. IEEE.