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Low-Code Development Platforms – A Literature Review

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Completed Research

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Abstract

Market research institutes forecast a growing relevance of *Low-Code Development Platforms* (LCDPs) for organizations. Moreover, the rising number of scientific publications in recent years shows the increasing interest of the academic community. However, an overview of current research focuses and fruitful future research topics is missing. This paper conducts a first scientific literature review on LCDPs to close this gap. The socio-technical system (STS) model, which categorizes information systems into a social and a technical system, serves to analyze the identified 32 publications. Most of current research focuses on the technical system (technology or task). In contrast, only three publications explicitly target the social system (structure or people). Hence, this paper enables future research to address the identified research gaps. Additionally, practitioners gain awareness of technical and social aspects involved in the development, implementation, and application of LCDPs.

Keywords

Low-Code Development Platform, literature review, socio-technical system model

Introduction

Nowadays, information technology (IT) is a key driver of digital transformation, and thus an important factor for the success of an organization. As a result, the need for new, innovative, and comprehensive software solutions and automated workflows that companies must deliver on time, on budget, and with high quality is increasing (Richardson and Rymer 2014). Having said that, in 2019, there were 124.000 vacant IT positions in German economy according to Bitkom Research (2019), which represents a subsequent increase of 51% compared to the previous year. Almost a third of them were software developers (Bitkom Research 2019). International studies on the shortage of IT specialists show similar results (Cushing 2019; Harvey Nash and KPMG 2018). To counteract this shortage and satisfy the increasing need for IT solutions, contemporary software and process development should be simple, efficient, and enable less qualified employees (in terms of their programming skills) to participate in IT development tasks (Richardson and Rymer 2014). These empowered employees are called *citizen developers* and are mainly either power users, developers in a business department or regular employees in the business department (McKendrick 2017). Enterprise IT development platforms help them to develop business applications or workflows independently from the corporate IT department (Rollings 2012). To establish a hypernym for these platforms, Forrester Research (Richardson and Rymer 2014) first coined the term "Low-Code Development Platform" (LCDP) in 2014. The authors characterize LCDPs as an enormous reduction of hand-coding, as faster deployment of applications with the help of visual tools, and as the ability to prepare data effectively to create multi-level workflows. A further publication (Tisi et al. 2019) defines it as software development platform in the cloud, offering a Platform-as-a-Service (PaaS) model that enables users to build turnkey operational applications using declarative languages, dynamic graphical user interfaces (UI), and visual diagrams. In this context, studies and vendors (McKendrick 2017; OutSystems 2019) frequently mention the term "No-Code Development Platform" (NCDP). However, Vincent et al. (2019) consider these NCDPs primarily as a marketing and positioning statement and part of the LCDP market. Despite the described benefits of LCDPs, studies show that these platforms create new technical and social challenges (McKendrick 2017; OutSystems 2019). To find out whether current research covers these challenges, we review and classify the current state of research regarding LCDPs and propose possible future research fields by identifying research gaps.

Gartner Inc. (Vincent et al. 2019) predicts that by 2024, three-quarters of all large companies will use at least four low-code development tools and that more than 65% of all application development will take place via low-code development platforms. Similarly, other market studies predict significant growth in the coming years: they expect the market potential to be 21.2 billion US dollars in 2022 (Compound Annual Growth Rate (CAGR) of 41% between 2017-2022) (Rymer and Koplowitz 2019), rising to 45.5 billion US dollars in 2025 (CAGR of 28.1% between 2020-2025) (Markets and Markets 2020). These numbers show very clearly that the field of LCDPs will become more and more important in the future and is currently only at the beginning of its development. Triggered by the increasing practical importance (demonstrated by the industrial reports and market studies), scientific publications investigating LCPDs have increased in recent years, which indicates a growing interest of the academic community (see Figure 1). All publications were published in the years 2017-2020, more than 62% of them even in 2020. Nevertheless, according to a study by OutSystems (2019), only 41% of all surveyed companies used LCDPs in 2019. In contrast, half of the companies are not sure (21%) or do not plan to do so yet (29%) (OutSystems 2019). Thereby, the main obstacles for non-IT application development are data security concerns, lack of knowledge, lack of trust in the app or the data delivered, and insufficient governance (McKendrick 2017). Additionally, Klotz et al. (2019) highlight the necessity for research on governance approaches for LCDPs. Thus, further research should focus on solving these problems for both science and practitioners. So far, two existing studies conduct a literature review on LCDPs: firstly, Ihirwe et al. (2020) highlight the current state of the art in model-based development for internet of things systems. Thereby, they analyze the LCDPs of the most recent Gartner report but do not examine current scientific publications. In contrast, Sanchis et al. (2019) focus on scientific publications by conducting a literature review on LCDPs. However, the analysis does not follow a rigorous research method based on all relevant scientific databases, which is why they could not identify a significant number of current publications. Having said that, this paper is the first scientific and structured literature review on LCDPs. Thus, research questions are: (1) *Which research fields do currently exist? (2) Which research gaps should be the target of future research?* The findings contribute to research by shedding light on future research directions. Additionally, practitioners gain awareness of technical and social aspects that play a role in developing, implementing, and applying LCDPs in a holistic manner.

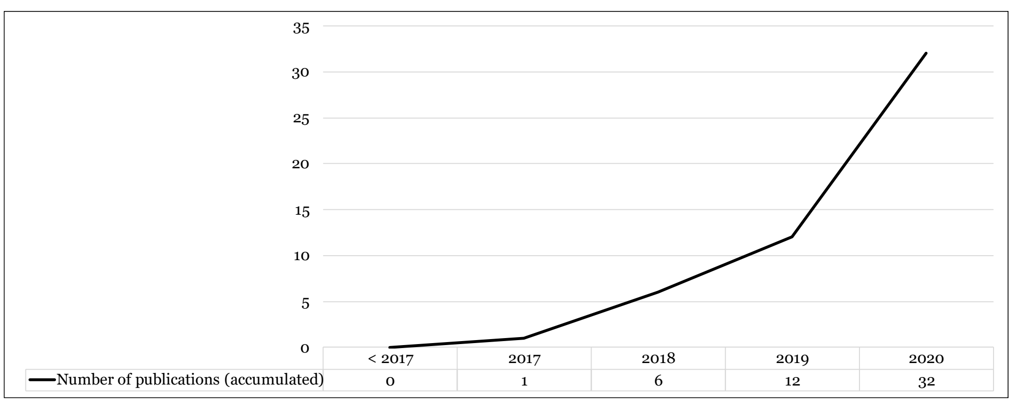

Figure 1. Number of publications in the context of LCDPs

The procedure of the paper is as follows: first, we introduce the research method. Then, we sequentially conduct the data collection, evaluation, and analysis. Thereby, we classify the relevant publications. Finally, we present our findings, discuss them, and end with the conclusion.

Research Method

According to Cooper (1982), a literature review is a five-phase process that consists of the sequential phases *problem formulation*, *data collection, data evaluation*, *analysis and interpretation,* and *public* *presentation*. Thereby, the goals are the establishment of a foundation for further theoretical development and the advancement of knowledge in this new field of research (Webster and Watson 2002).

Data collection and Evaluation

Based on the problem formulation and related work presented in the last section, the first step of our process was data collection. For a complete overview of current research, we examined seven academic databases in the fields of both information systems (IS) and computer science (CS) (see Figure 2). Thereby, we searched for the terms "Low-Code" and "Low Code" in quotation marks and limited it to abstract, title, or keyword. All publications up to the end of 2020 were taken into account. It resulted in a total of 232 publications.

In the next step, we removed duplicates and irrelevant publications by applying different exclusion criteria (Brocke et al. 2009; Cooper 1998): first criterion was that the respective publication focuses on the topic of LCDPs. Since we searched for the more general terms "Low-Code" and "Low Code", most of the publications did not address the topic of LCDPs, but rather used the term "low code" in a different context (e.g., "low code quality"). Moreover, our focus was on papers published in major conferences or journals, a common practice in IS research (Brocke et al. 2009). In doing so, we used accepted rankings of IS and CS (ABDC 2019; CORE 2020; VHB 2015) to evaluate the relevance of the respective publications. Additionally, our research only considered publications in English or German language. We then conducted both backward and forward search (Webster and Watson 2002) to avoid missing important references. In the end, we identified 32 relevant publications throughout the process.

Database search

Data base	"Low-Code" **OR** "Low Code" in **title**, **abstract** or **key word**	Relevant
ACM Digital Library	13	1
AISEL	6	0
EBSCOhost Web	12	2
IEEE Xplore Digital Library	112	8
JSTOR	1	0
Web of Science	54	4
Sciencedirect	34	3
Total	**232**	**18**

Backward/Forward search (Webster and Watson 2002)

Iteration	Results	Relevant
1	24	2
2	13	12
Total	**37**	**14**

Total result:

32 relevant publications (18 from database search and 14 from backward/forward search)

Figure 2. Literature search results

Analysis and Interpretation

Next, to uncover independent research fields and potential research gaps, we carried out a categorization of the publications. In doing so, we used the socio-technical system (STS) model (Bostrom and Heinen 1977) (see Figure 3). As this is a universal model with various applications in IS research, such as change management in IT (O'Hara et al. 1999), modeling in systems engineering (Oosthuizen and Pretorius 2014), and optimization of customer relations using IT (Piccoli et al. 2005), we assume that it also serves to structure research in the field of LCPDs. Having said that, a socio-technical system describes an information system that consists of the four strongly interconnected components *People*, *Structure*, *Task,* and *Technology*. These four components fit to either the social (*people* and *structure*) or the technical (*task* and *technology*) system. (Bostrom and Heinen 1977) Nevertheless, they are interdependent (O'Hara et al. 1999). *People* function as carriers of a *task* (organizational or business process) that an information system should solve (Heinrich et al. 2011). T*echnology* provides the means, methods, or devices to successfully implement this information system (Heinrich et al. 2011), whereas the *structure* is the type of communication, authority, and workflow within the system (O'Hara et al. 1999). Moreover, the social system includes IT governance structures (Chong and Tan 2012) like decision-making structures (roles and responsibilities), alignment processes, and formal communication (Weill and Ross 2005) as well as human behaviors (attitudes, skills, and values (O'Hara et al. 1999)) to perform and coordinate the organization work system (Chong and Tan 2012). In contrast, the technical system deals with the efficient and effective use of IT resources to successfully carry out organizational tasks (Trist 1981). The development, implementation, and application of an information system can only be successful if the four components interact seamlessly with each other (Mumford 1995).

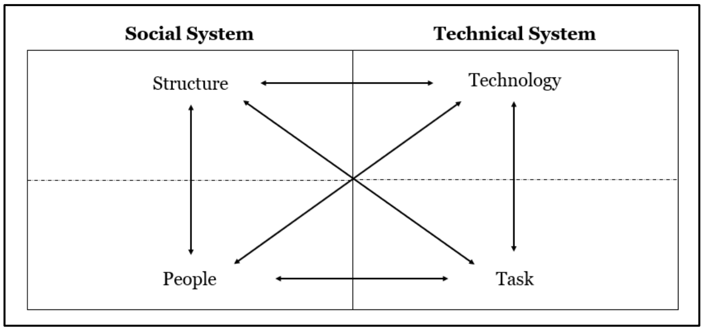

Figure 3. Socio-technical system (STS) model (Bostrom and Heinen 1977)

Two authors and one expert carried out the categorization, conducting an open peer review (Armstrong 1982; Ford 2013) adhering to the two core elements open identities and open reports (Ross-Hellauer 2017). Hereby, each expert rated each publication by using a Likert scale (Likert 1932). More precisely, the authors and the expert agreed on the respective definition of each of the four components of the STS model and subsequently ranked these four components for each publication from 0-3 (was *not* (0), was *rather not* (1), was *rather* (2), or *was* (3) addressed in terms of context). According to Bendig (1954), a 4-point-scale maximizes reliability. Above all, the even number of selections helps evaluators to decide on a tendency, which has a positive effect on reliability (Cronbach 1950). There was a deviation of two or more scale points of a component in seven publications. The evaluators discussed their assessments of these seven publications collectively, and subsequently had the opportunity to adjust the ratings (Cohen's kappa coefficient (κ) = 0,63). Finally, we aggregated the results and evaluated the mean values (see Table 1).

Publication	Structure	People	Technology	Task
Chang and Ko 2017	0	0,33	3	1,33
Henriques et al. 2018	0	0,33	3	0,67
Op't Land et al. 2018	2	0,33	1,33	2
Ragusa and Henriques 2018	0,33	0,33	3	1,33
Stromsted et al. 2018	0,33	0,33	2,67	2,33
Zolotas et al. 2018	0	0,33	3	1
Hyun 2019	0	0	3	0,33
Jesse 2019	2	1	1,33	1,67
Pantelimon et al. 2019	0	0	3	1,33
Sanchis et al. 2019	0	0	3	2
Tisi et al. 2019	0	0,33	3	0,67
Waszkowski 2019	0	0,33	2,67	2,33
Almonte et al. 2020	0	0,67	2,67	2,67
Arora et al. 2020	0	0	3	1
Brunschwig et al. 2020	2,67	0,33	2,67	1,33
Colantoni et al. 2020	2,33	0	1,33	2,67
Daniel et al. 2020	0	0	3	1,67
Heffner and Mettrick 2020	0	1,67	1	2,67
Horváth et al. 2020	0	0	3	1,33
Ihirwe et al. 2020	0	0	3	1,33
Jahanbin et al. 2020	0	0	2,67	1,67
Khorram et al. 2020	0	1	2,67	2,67
Kourouklidis et al. 2020	0	0	2,67	1,67
Philippe et al. 2020	0,67	0	2,33	2
Rani et al. 2020	0	0	3	1,33
Saay and Margaria 2020a	0	0	3	1,33
Saay and Margaria 2020b	0	0	3	1,33
Sahay et al. 2020a	0,67	0	2,33	2,33
Sahay et al. 2020b	0	0,33	3	1,33
Silva et al. 2020	0	1,67	1,67	2
Ul ain Ali et al. 2020	0	0	3	1
Waszkowski and Nowicki 2020	0,67	0,33	2	2,67

Table 1. Results of the categorization

Next, one author conducted a thematic analysis (Braun and Clarke 2006) of the publications: therefore, the author generated initial codes, searched, reviewed, and defined different themes, and subsequently discussed and adjusted them with the other two experts. Thereby, identified main topics are different LCDPs and their respective tools, programming languages, testing processes and usability problems, low-code environment, frameworks and other technological characteristics, and model-driven engineering. In the following paragraphs, we summarize all publications of these topics, as well as publications that cannot be allocated to one of these topics, and assign them to either the technical or social system.

Technical system

The evaluators assigned almost all publications (29 of 32) primarily to one of the two components of the technical system. Thereby, some publications describe specific LCDPs and their respective tools. In this context, researchers discuss the LCDPs *Aurea BPM* (Waszkowski 2019), *RESTsec* (Zolotas et al. 2018), *Sagitec Software Studio (S3)* (Arora et al. 2020), and *Smart Maker Authoring Tool* (Chang and Ko 2017) as well as the low-code development tools *Xatkit* (Daniel et al. 2020) and *vf-OS* (Sanchis et al. 2019). The application areas vary between manufacturing (Sanchis et al. 2019; Waszkowski 2019), security (Zolotas et al. 2018), and (web)-application development (Arora et al. 2020; Chang and Ko 2017; Daniel et al. 2020). Furthermore, Heffner and Mettrick (2020) summarize the capabilities and benefits of a potential LCDP for financial institutions. For the banking sector and their customers, security, compliance, and quick adaptation to the respective needs are of eminent importance, which, according to them, a respective LCDP would fully cover (Heffner and Mettrick 2020). Moreover, Sahay et al. (2020b) conduct a technical study on eight LCDPs to enable potential customers to find the most suitable platform for their specific requirements. Thereby, researchers state that handing over processes to business departments with the help of LCDPs can reduce costs and implementation time, and thus better meet the respective needs (Sahay et al. 2020b; Waszkowski 2019). An efficiency analysis shows that companies that use LCDPs have more freedom to adapt their activities to the constantly changing market conditions (Waszkowski and Nowicki 2020). Nevertheless, future key challenges of LCDPs can be inoperability, extensibility, steep learning curves, and scalability (Sahay et al. 2020b) but also the integration of machine learning (ML), internet of things (IoT) (Arora et al. 2020), and artificial intelligence (AI) (Chang and Ko 2017).

Some other publications discuss programming languages used for LCDPs, testing processes, and usability problems. Khorram et al. (2020) carry out an analysis of the testing components of five LCDPs. Based on the analysis, they propose a feature list with possible values for low-code testing (Khorram et al. 2020). Ragusa and Henriques (2018) present the web-based tool *VPLreviewer*, which enables to review code of visual programming languages (VPLs). Moreover, Henriques et al. (2018) focus on the domain-specific languages (DSLs) used in the LCDP *OutSystems* to develop web and mobile applications. Another approach is the application of the Dynamic Conditions Response (DCR) concept, which intends to program adaptive case management solutions without traditional coding (Stromsted et al. 2018). The researchers concur with the argumentation that usability problems are currently still a reason why LCDP programming languages have a rather low adoption rate yet (Henriques et al. 2018) as well as could be the reason why a lack of review software is prevalent (Ragusa and Henriques 2018). Silva et al. (2020) develop and evaluate a Descriptive Cognitive Model (DCM) to identify three types of usability problems of a LCDP. According to them, the three types that can occur when using a LCDP for the first time are under-decomposition (underestimation of subtask's complexity), over-decomposition (overestimation of subtask's complexity), and no correspondence conflicts (user is not aware of the appropriate step) (Silva et al. 2020). However, the consistent development of process modeling enhances the developers' experience (Henriques et al. 2018) and helps to identify process improvements even before actual development (Stromsted et al. 2018). Nevertheless, three concerns that may arise in low-code testing are cloud testing, the need for high-level test automation, and the role of citizen developers (Khorram et al. 2020).

Related publications also exist about environments, frameworks, and other technological characteristics related to LCDPs. Saay and Margaria (2020b) employ the low-code development environment *DIME* to design an eLearning broker and, in an additional paper (2020a), present a prototype of an inter-organization bridging application. By using this environment, users can automatically deploy the respective application after the finalization of the prototyping and development process (Saay and Margaria 2020a). Moreover, in a similar context, researchers introduce a new end-to-end low-code mechanism that enables heterogeneous IoT hardware devices to be interconnected with the NETIoT platform (Pantelimon et al. 2019), an environment-based low-code/no-code execution structure that integrates the strengths of hybrid and native applications (Hyun 2019), a generic framework to automate the construction of recommender systems (RS) of LCDPs (Almonte et al. 2020), and a tool called *ROCCO*, which migrates Eclipse-based graphical model editors to the web (Rani et al. 2020). In another publication, Ul ain Ali et al. (2020) aim to efficiently query large models in various formats. For this purpose, they present an optimization strategy based on compile-time static analysis and specific query optimizers/translators (ul ain Ali et al. 2020). Moreover, Kourouklidis et al. (2020) conduct a literature review on the development of low-code solutions for monitoring the performance of a deployed machine learning model. The goal of the researchers is to present a low-code architecture that supports data scientists in performing monitoring over time without providing explicit technical details (Kourouklidis et al. 2020). Colantoni et al. (2020) introduce a conceptual framework (*DevOpsML*) for modeling and combining DevOps processes and platforms. In addition to some preliminary guidelines, they present a research roadmap that aims to combine DevOps and model-driven engineering (MDE) principles and practices (Colantoni et al. 2020).

In one of the other publications, Tisi et al. (2019) introduce a project called *Lowcomote*. They describe it as an Innovative Training Network (ITN) with the aim of providing training for a generation of professionals in the design, development, and implementation of new LCDPs. Thereby, new LCDPs should be scalable (development of large-scale applications), open (based on interoperable and exchangeable programming models and standards) and heterogeneous (integration of models from different engineering disciplines) in order to overcome the current limitations of LCDPs and create Low-Code Engineering Platforms (LCEPs). (Tisi et al. 2019) In the further course of this research project, several publications discuss the topic of model-driven engineering. Therefore, Ihirwe et al. (2020) examine the current state of research for model-driven engineering approaches for IoT. Horváth et al. (2020) identify three scalability and productivity challenges in LCDPs, which are the adoption of multi-tenant architecture patterns for model transformation, parallel reactive model transformations, and multi-tenant, reactive transformation benchmark. Moreover, Philippe et al. (2020) point out an overview of different computational strategies, demonstrate the advantages of a mix of strategies for a single computation, and highlight the need for model-management in LCDPs. Jahanbin et al. (2020) present a model management approach (statistical program analysis of model management programs) that improves system model processing and reduces resource consumption. Furthermore, Sahay et al. (2020a) deal with the specification of complex workflows in LCDPs. Thereby, they want to provide a model construct to the involved citizen developers that can map the goal of the development based on a high-level abstraction (Sahay et al. 2020a).

Social System

In contrast, current research discusses topics related to the social system less frequently. There are only three publications in which the evaluators ranked the component *people* or *structure* as the highest thematical component. Brunschwig et al. (2020) describe an approach for providing role-based access control for collaborative modeling on mobile devices. Using the modeling tool *DSL-comet* as an example, they explain and illustrate collaboration in modeling with DSLs (Brunschwig et al. 2020). Jesse (2019) claims that IT must reorient itself in terms of agility to be successful in business. According to him, LCDPs, along with agile methods such as Scrum, are crucial for success as these approaches accelerate the development of apps enormously and improve the efficiency, quality, and speed of a whole business (Jesse 2019). Moreover, Op 't Land et al. (2018) establish a research program to further enhance, develop and mature Enterprise Design. Thereby, they figure out that they should use low-code platforms for rapid validation of the encountered ED metamodel and apply it to real-life cases (Op 'T Land et al. 2018).

Discussion

This paper creates transparency on research themes concerning Low-Code Development Platforms with a deeper analysis of recent literature. For all 32 publications, the evaluation sum of the two technical components was higher or the same than the respective sum of the components of the social system. Only three publications (9%) received at least their highest score for one component of the social system. Having said that, currently, research focusing on *technology* is particularly noteworthy. But also, current research discusses the *task* component more often than both components of the social system (see Figure 4). This observation indicates that current research is more interested in technical than social aspects of LCDPs. Thus, the following analysis of research gaps primarily focuses on the current state of research of the social system.

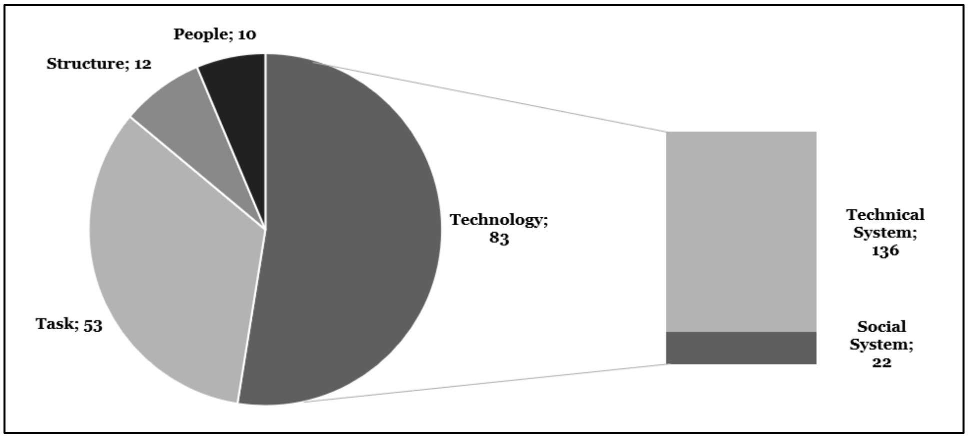

Figure 4. Results of the classification

In the current publications, researchers particularly emphasize the component *structure* whenever they investigate the rapid developmental ability and agile adaptability of LCDPs (Colantoni et al. 2020; Jesse 2019; Op 'T Land et al. 2018). Besides, they also mention the need for clearly defined roles (Brunschwig et al. 2020). Only a few publications briefly discuss the component *people*. Thereby, the main focus of these current publications is to show the potential of LCDPs to empower citizen developers to realize their ideas independently (Heffner and Mettrick 2020; Sahay et al. 2020b; Tisi et al. 2019) as well as point out their usability problems during first usage (Silva et al. 2020) and testing (Khorram et al. 2020). However, we can confirm the necessity of conducting a holistic analysis of IT governance structures of LCDPs (Klotz et al. 2019): although existing research discusses role distribution, it deals exclusively with providing role-based access control for collaborative modeling on mobile devices. Having said that, current publications do not investigate a role distribution for the implementation and application process of LCDPs between business and IT, nor their respective responsibilities, alignment processes, and communication with each other. Furthermore, the required attitudes, skills, and values of people (primarily citizen developers) to develop but above all to implement and apply LCDPs also remain unresearched.

Conclusion

The goal of this study was to review and classify current research on LCPDs. To reach this goal, we conducted a scientific literature review and discussed our findings. The findings indicate that further research on the social system of LCDPs is particularly essential to establish a more holistic view of this research topic. While current research widely investigates topics such as specific LCDPs, its tools, as well as frameworks, programming languages, and other technological characteristics, topics such as communication, human behavior, decision-making structures, and alignment processes related to LCDPs are virtually unresearched.

Having said that, this work has theoretical implications by conducting the first scientific and structured literature review of LCDPs, and thus by identifying potential research gaps. Moreover, practitioners should be aware that they can only develop, implement, and apply an information system, such as LCDPs, in a holistic manner if, in addition to technological characteristics and task management, there also exists clarity about structural and people-related parameters.

However, the study itself has limitations. In this paper, we only examined publications with the specific term LCDP in the fields of both IS and CS. Although the research followed a structured scientific procedure, publications that investigate relevant topics but lack the term itself or are published in different research disciplines might have been overlooked. Additionally, further investigation of the research gaps should include the findings of related topics such as business-managed applications or citizen development to get a broader perspective on the topic. Besides, we focused on research gaps of the social system because much less research has been carried out on this system so far. However, future research could examine research gaps of the technical system in more detail. Moreover, further research should investigate the role that all four components of the STS model play in the successful development, implementation, and application of LCDPs. In this context, scientists should examine communication and cooperation between business and

IT but also key figures and limits of successful cooperation, effects on IT and business, and any potential reorganization that may be necessary for both (IT & business) departments. Furthermore, it is important to investigate which people and departments are currently using and which should actually use LCDPs, as well as the required attitudes, skills, and values of the individuals involved.

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