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Architecture and Governance of Digital Business Ecosystems: A Systematic Literature Review

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ABSTRACT

The purpose of this study is to examine the reported architectural approaches and governance mechanisms for digital business ecosystems (DBEs). A systematic literature review is employed, in which 92 relevant articles are selected for analysis. This study provides an overview of articles, reports the formal modeling notations, modeling viewpoints, and design patterns used for DBEs in the reviewed articles, discusses DBE governance mechanisms, and provides evidence of the alignment between DBE architecture and DBE governance.

KEYWORDS

Digital business ecosystem; collaborative network; value co-creation; architecture; governance

Introduction

Business ecosystems are economic communities of interacting organisms, such as firms and individuals in the business environment (Moore, 1996, p. 26). With the increased digital innovations, business ecosystems have started to be developed around digital platforms, which mediate transactions among business ecosystem actors (Gawer, 2009). Digital business ecosystems (DBEs) are introduced and defined as "*digital environments populated by digital species, which could be software components, applications, services, knowledge, business models, training modules, contractual frameworks, laws, …* " by Nachira (2002, p. 12). DBE organizations create and deliver products or services together in a partly or fully digital environment and DBE actors communicate through digital information and communication technologies (Baumann, 2022). Furthermore, digital platforms are one of the key characteristics of DBEs (Senyo et al., 2019).

There are many successful DBEs, such as Amazon, Apple, Google; however, not all business ecosystems can sustain themselves over time. This issue is highlighted by Reeves et al. (2019) who examined the success of 57 business ecosystems in various industries. Their findings indicated that more than 85% failed in their first 15 years, where failure was defined as being dissolved, declining into insignificant market share, or being acquired for significantly less than the initial seed funding. Pidun et al. (2020) examined 110 failed ecosystems in order to investigate the reasons for failure, and found that 85% are related to weaknesses in ecosystem design issues, such as ecosystem configuration, governance choices, monetization strategy, launch strategy, defensibility, and problem-solving. In comparison, only 15% stem from weakness in execution. According to their study, the most prevalent reason for failure relates to wrong governance choices (34%) and the biggest challenge in ecosystem governance is deciding on the right level of openness.

In addition to DBE governance, DBE architecture is also an important issue for DBE design since all DBEs are built due to architectural decisions regarding modeling and design, which potentially affect the development process and the system's properties. While various architecture modeling and design approaches are available for developing DBEs, deciding appropriate architectural decisions can avoid introducing regressions and architectural inefficiencies later (Shahbazian et al., 2018). This precaution is notable because the need for maintaining and evolving the decisions made in the past becomes critical for the success of the evolution of a system (Capilla et al., 2007).

Moreover, DBE is defined as a socio-technical network to co-create value (Senyo et al., 2019). The DBE architecture defines technological interactions among sides of the ecosystem (Hein et al., 2020) and governance mechanisms are used to govern organizational interaction among these sides (Senyo et al., 2019). Therefore, for a successful design, these two perspectives, DBE architecture and DBE governance, are expected to be aligned. Some researchers propose

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that DBE architecture and DBE governance complement each other (Mikalef et al., 2020; Tiwana, 2014). Such a complementarity makes it important to consider the architectural and governance design considerations of sustainable DBEs together.

The significance of developing appropriate design approaches or governance mechanisms for a sustainable and healthy DBE has led to an increasing number of studies in the field of DBE. Many of these studies provide notable guidelines on designing DBEs, governance mechanisms, or both. Different approaches, however, are scattered over various studies that impede the adoption of the best practices to avoid the failures as reported in the literature. Therefore, gathering and analyzing these approaches is valuable to guide best practices. Yet, to date, there are limited attempts at creating a systematic literature review (SLR) focusing on DBEs. The published SLRs focus on the themes and trends in DBEs literature (Senyo et al., 2019), the capabilities and creating value collaboratively in DBEs (Chekfoung et al., 2020), the roles and responsibilities in DBEs (Tsai & Zdravkovic, 2020), key management theories, and key thematic areas or topics in DBE literature (Mukhopadhyay & Bouwman, 2019), the prerequisites, challenges, and benefits for DBEs in the manufacturing industry (Suuronen et al., 2022), the boundaries and goals of different ecosystems (Cobben et al., 2022), key concepts in platform design and governance (Schreieck et al., 2016), and the governance mechanisms for software ecosystems (Alves et al., 2017). However, current SLR articles in the literature either do not deal specifically with DBE architecture approaches and DBE governance mechanisms or are not DBE-focused. Moreover, the DBE architecture defines technological interactions among sides of the ecosystem (Hein et al., 2020) and governance mechanisms are used to cooperate, coordinate, and integrate these sides (Jovanovic et al., 2021). Therefore, the architecture and governance mechanisms of a DBE are expected to be aligned. Although some researchers indicate an alignment between DBE architecture and DBE governance (Mikalef et al., 2020; Tiwana, 2014), at the time of writing this article, no study has yet presented an SLR on the relationship between architectural approaches and governance mechanisms for DBEs. Therefore, this study aims to synthesize existing architectural approaches and governance mechanisms of DBEs, as well as evidence for the relationship between them and the importance of this relationship for DBE design and evolution. The main research questions of this study are:

(RQ1) What are the existing architecture approaches for DBEs?

(RQ2) What are the addressed governance mechanisms behind DBEs?

(RQ3) What are the relationships addressed between the architectural approaches and governance mechanisms?

This study considers both the architecture and governance aspects that impact a DBE's success. Findings will support managers' decision-making on DBE architecture and governance by presenting a comprehensive overview of possible approaches and help efficiently moving from knowledge discovery to application. The study will indicate which fields are worthwhile to prompt further research.

To address the research questions, the remainder of this paper is organized as follows. The next section presents the study background. Afterward, the adopted research method in terms of review protocol and analysis method is explained. Consecutively, the results to address the research questions are presented. Next, a discussion of the results, the research contributions, and the future study suggestions are provided. Finally, the paper is concluded in the last section.

Background

The background of DBEs consists of overlapping types of ecosystems like business ecosystems, innovation ecosystems, platform ecosystems, and digital ecosystems, digital business ecosystems (Gupta et al., 2019; Yablonsky, 2020). This section provides the context for DBEs by providing the necessary definitions and characteristics of business ecosystems.

Business ecosystems

Ecosystems are formed by communities of different species, which interact with one another and their environments (Whittaker, 1970). Business ecosystems are defined by Moore (1996, p. 26) as economic communities of interacting organisms like firms and individuals in the business environment. Solution-focused business ecosystems (e.g., credit card systems) offer value to customers by coordinating various contributors such as universities, research centers, government organizations, financial institutes, agencies, and business associations. Whereas transaction business ecosystems tend to link participants relating to suppliers, buyers, intermediaries, etc., through a (digital) platform (e.g., Uber, Airbnb, and eBay) instead (Pidun et al., 2019). There are hybrid companies that have both innovation platforms and transaction platforms to facilitate innovation on the platform while enabling exchange or transaction across sidesfor example, Apple's Apple App Store and Apple IOS platforms, Amazon's Amazon Marketplace, and Amazon Web Services platforms, and Google's Google Play and Google Android platforms (Cusumano et al., 2020). A business ecosystem is a broad concept and includes marketplaces (e.g. Alibaba, Airbnb, and Uber), information technology platforms (e.g. Microsoft Windows and Apple iOS); and other systems that offer integrate components from different players (video games, smart home systems), or integrate services from different providers (credit card systems, disease management platforms, farming, or mining solutions) (Pidun et al., 2019).

Successful examples for business ecosystems include Alibaba and Amazon in e-commerce, Spotify, YouTube, and Netflix in media and entertainment, PayPal in mobile payments, Uber in transportation, Airbnb, and Booking in hospitality, Philips HealthSuite in healthcare, to name but a few. Iansiti and Levien (2004) identified three success factors for business ecosystems including i) productivity, ii) robustness, which means capabilities of surviving across threats and changes, and iii) the ability to create niches and opportunities. In this context, keystones, dominators, hub landlords, and niche players have roles in structuring a successful business ecosystem. Keystones improve the health of the business ecosystem, which also affects their development; dominators enable vertical or horizontal integration and have rights to manage the network; hub landlords have a low physical presence with few network nodes and provide little value to ecosystems, and niche players constitute a large part of the ecosystem both in mass and variety. This structure leads to network effects. That is, there will be an exponential increase in the benefits provided by a network node as the total number of nodes increases considering the effect of one actor's actions on the well-being of the other (Nachira et al., 2007).

Modularity, customization, multilateralism, and coordination are core characteristics of business ecosystems (Pidun et al., 2019). In contrast to vertically integrated models or hierarchical supply chains, business ecosystems, according to Pidun et al. (2019), have high modularity, meaning that the parts of the offer are developed separately to complement each other. Customers have the option to choose the necessary components. Additionally, although they are not fully hierarchically controlled, there are some coordination mechanisms. Moreover, business ecosystems demand dynamic and collaborative connections between partners (Fuller et al., 2019).

Digital business ecosystems

The DBE concept builds on Moore's business ecosystem (Graça & Camarinha-Matos, 2017). Nachira (2002, p. 12) defined the DBE as "*a digital environment populated by digital species, which could be software components, applications, services, knowledge, business models, training modules, contractual frameworks, laws, . . .* ." With the integration of the value chain and platform logics, value co-creation is enabled (Nucciarelli et al., 2017) and aggregated services are provided to customers in DBEs. These platforms present a socio-technical environment based on collaboration and competition among actors and provide technological infrastructures to create value (Senyo et al., 2019). They allow collaborations among heterogeneous members from different geographical regions via digital opportunities for a common purpose (Nachira et al., 2007). Therefore, they support collaborative value creation (Nucciarelli et al., 2017) and enhance product innovation (Ben Arfi & Hikkerova, 2021). Moreover, through digital transaction ecosystems, end customers and suppliers can now eliminate retailer and established value-chain interaction patterns, such as by shipping goods directly from the factory to the end customer (Hänninen, 2020). Whereas Briscoe (2010) described the properties of DBEs as *self-organization*, *scalability*, and sustainability, according to Senyo et al. (2019), *platform*, *symbiosis*, *co-evolution*, and *self-organization* are key DBE characteristics.

Since business ecosystems have started to be developed around digital platforms and platforms are one of the key characteristics of DBEs (Senyo et al., 2019), they have also come to be referred to in the literature from various perspectives as DBEs, digital ecosystems, multi-sided (digital) platforms, (digital) collaboration platforms, or (digital) platform-based ecosystems (Suuronen et al., 2022). According to Suuronen et al. (2022), *digital platforms* are studied by information systems scholars (Tiwana, 2014), whereas economics scholars focused *on multi-sided markets* (Boudreau & Hagiu, 2009). On the other hand, management scholars used the term *ecosystems* instead of platforms or markets, and they studied value creation in innovation ecosystems (Adner & Kapoor, 2010).

One of the consequences of digitalization is more complex and dynamic ecosystems and it is clear that DBEs are governance structures as well as technical systems or neutral arbiters (Kenney et al., 2020). The architecture and the governance structures are two constituents of a DBE (MacCormack et al., 2012).

Architecture approaches

The term *system architecture* is defined as "*fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution*" by ISO/IEC/IEEE 42011 (2011). The attributes, behaviors, and relationships in a system are represented using various notations. According to the standards, architecture descriptions are used to express architecture and architecture views, which describe architectures, are comprised of one or more architecture models. These models are constructed in accordance with architecture viewpoints, which are sets of framing conventions and include methods, kinds, languages, and notations of modeling. A coherent set of architecture viewpoints define an architecture framework. Architectural design is defined as the "*process of defining a collection of hardware and software components and their interfaces to establish the framework for the development of a computer system*" by IEEE (1990) and architectural patterns command a fundamental role in this process.

The characteristics of a business ecosystem are impacted by its basic configuration design. A business ecosystem is comprised of a centralized, decentralized, or distributed architecture structure. In a centralized structure, users are connected to a central node for data access. A single data center enhances consistency and rationality; however, the data availability problem occurs if the server fails. In addition, they have higher security and privacy risks since data are stored in one node; however, maintenance costs are lower advantageously. In a decentralized structure, there are multiple central nodes, and each node in the framework makes its own decision that ultimately affects the behavior of the system. Users can access a copy of the resources in each node; for this reason, they are more fault-tolerant during server failures. Furthermore, decentralized approaches have other advantages, such as improved access time to the data and vertical scaling for extensibility. However, they still have security and privacy challenges and a higher maintenance cost than a centralized approach. Distributed systems eliminate centralization, and the resource is shared with other nodes. The independent failure of individual components does not affect the other components, and a high geographical spread improves the response time since the distributed storage is close to physical devices (Khanagha et al., 2020); hence, uptime is higher in these systems. A further advantage is that both horizontal and vertical scaling is possible in distributed systems (Xi, 2020).

On the other hand, integrated and modular architectures are two architectural approaches related to the coupling feature of interfaces. Their concern whether interfaces connect modules in the system tightly or loosely, thus impacting the design (Fujimoto, 2018; Tatsumoto, 2018). In modular systems, interfaces are coupled loosely to modules that have weak dependencies among themselves. Whereas interfaces are coupled tightly to modules that have strong dependencies among themselves in integrated systems, and there are strong dependencies among their modules. For this reason, the design options are expandable by adding modules in modular-based systems. Yet, integrated systems have problems in terms of the changeability of modules and expandability of systems (Tatsumoto, 2018). In short, business ecosystems are complex and modularization (that is the encapsulation of the design factors into modules) is just one of the characteristics that reduces the complexity and enables interdependent organizations to be coordinated without a full hierarchical structure (Jacobides et al., 2018).

Governance mechanisms

Governance mechanisms for a platform ecosystem are defined as "*mechanisms necessary to cooperate, coordinate and integrate a diverse set of organizations, actors, activities, and interfaces*" (Jovanovic et al., 2021). Relational and contractual governance mechanisms are two types of governance mechanisms frequently discussed by scholars to coordinate business relationships (Pomegbe et al., 2021). Contractual governance is associated with formal agreements, whereas relational governance is based on trust (Poppo & Zenger, 2002). According to A. Q. Li et al. (2022), managing the interplay between contractual and relational governance mechanisms is one of the challenges of value co-creation and developing psychological governance is also required for guiding individual-based co-creation.

Business ecosystems adopt a different governance model compared with approaches, such as i) a vertically integrated organization, ii) a hierarchical supply chain, or iii) an open-market model. They foster innovation and cater for scalability and adaptability features compared to others, and the general characteristics of good ecosystem governance are consistency, fairness, effectiveness, and flexibility (Pidun et al., 2021). Choosing appropriate governance mechanisms is required for maintaining the balance between organizations in value creation, co-ordination of players, and organizational openness and control and is crucial for ecosystem health (Alves et al., 2017).

Researchers studied some architecture approaches and governance mechanisms for DBEs. In this SLR study, the modeling notations and viewpoints, and the design patterns as architectural approaches for DBEs are examined as well as DBE governance mechanisms. The interplay between DBE architecture and governance in literature is also investigated and the findings are explained in the result section.

Research methodology

In this study, an SLR methodology is adopted for the synthesis of knowledge from related literature, identification of knowledge gaps, and advocation of future research avenues (Rowe, 2014). An SLR contributes to the literature by facilitating theory development and uncovering research areas (Webster & Watson, 2002). Therefore, the research designs proposed by Okoli and Schabram (2010) are employed for the information systems research, which has the following steps: purpose, protocol, searching for the literature, practical screen, quality appraisal, data extraction, data synthesis, and writing the review, and Webster and Watson's (2002) style and structure recommendations for writing literature review in information systems.

Based on the work definition, a review protocol is devised, which outlines the procedure to be followed in order to minimize the possibility of researcher bias and establish a degree of objectivity (Jesson et al., 2011; Okoli & Schabram, 2010; Tranfield et al., 2003). In the following sub-sections, the search strategy is defined, including search terms, data sources, and inclusion and exclusion criteria. Once the related databases were determined, the search query was created using the search terms, which are obtained from the literature. The study selection criteria were determined to select the relevant studies. For the selected articles, the data extraction strategy was developed, and the data synthesis process was explained.

Search strategy

To address the research questions of this study, a search strategy is adopted that includes the scope, search term, and restrictions for the review (Snyder, 2019). In this study, the journal articles that were published between 2012 and 2021. The last 10 years were searched because this article aims to highlight the emerging approaches to DBE architecture and governance and rapidly changing technology affects these approaches. Conference papers, book chapters, technical reports, and dissertations were not included because of the quality appraisal procedure of this study, which is later clarified in the study selection section. The articles searched from four databases: ABI/Inform Complete, EBSCOHost, Scopus, and Web of Science (WoS), which are among the most commonly used for literature reviews in information system and include highly ranked IS journals (Baghizadeh et al., 2020; Bélanger & Crossler, 2011; Lacity et al., 2009) and adequately represent the topic of digital business ecosystems. The search terms are adopted from a prior literature review on DBEs (Mukhopadhyay & Bouwman, 2019; Schreieck et al., 2016; Senyo et al., 2019), including a list of synonyms and alternative spellings. The other related terms can be obtained by considering subject headings used in journals and databases (Kitchenham & Charters, 2007). To find the related keywords, the subject headings of the Scopus database were searched using the "business ecosystem" and "digital business ecosystems" terms. Then, the following search strings were constructed:

> ((digit* AND ("business ecosystem*" OR "platform* ecosystem*" OR "innovation ecosystem*")) OR (digit* AND business AND (collaborat* OR multi-actor OR multiactor OR multi-sided OR multisided OR co-creation OR cocreation) AND (network* OR platform* OR environment*)) OR (business AND "digital ecosystem*")) AND (architect* OR design* OR model* OR framework* OR manag* OR govern* OR orchestrat*)

The query was employed on title, abstract, and keyword/subject heading. Only the articles written in English were included in the search. The initial search resulted in a total of 1560 articles, with 147 from ABI/Inform Complete, 296 from EBSCOHost, 638 identified in Scopus, and 479 from the WoS databases.

Study selection

To select relevant articles, exclusion criteria, quality appraisal, and backward and forward snowballing techniques filter the 1560 articles to those relevant to the study. Exclusion criteria have been defined to select the primary studies of this review (Table 1).

The number of studies after applying the exclusion criteria (EC) is presented in Table 2. After EC1, 893 papers remained. Articles whose abstracts are not related to the architecture or governance of DBEs (EC2) and articles that are not based on primary data (EC3) are eliminated by reviewing the titles, abstracts, keywords, and sometimes the whole article. With the control of EC2 and EC3, 772 articles are rejected. The full texts of the remaining 121 articles were checked and reviewed for EC4, EC5, and EC6, and 18 articles were

Table 1. Study exclusion criteria.

Number of exclusion criteria	Explanation for exclusion criteria
EC1	Duplicate publications found in different search sources
EC2	Abstracts do not relate to the design or governance of DBEs
EC3	Articles that are not based on primary data
EC4	Articles where the full text is not available
EC5	Articles do not explicitly discuss the architectural or governance approaches for DBEs
EC6	Articles do not present a framework/model for DBE architecture or DBE governance, or a related approach for DBE architecture and governance

Table 2. Article selection results for the review.

	Total Number of Articles	DBE Architecture Articles	DBE Governance Articles	DBE Architecture & Governance Articles
Initial search	1560			
After EC1	893			
After EC2 and EC3	121	66	37	18
After EC4	111	59	34	18
After EC5, and EC6	103	54	31	18
After quality appraisal	85	44	27	14
After backward and forward snowballing	92	44	27	21

eliminated. At the end of this step, 103 relevant articles were obtained for the SLR process.

Quality assessment is one of the steps proposed by (Okoli & Schabram, 2010) to judge the quality of the review articles. Other researchers also suggest preparing quality appraisal items to assess the quality of articles selected for SLR, namely (Jesson et al., 2011; Kitchenham & Charters, 2007; Petticrew & Roberts, 2008). However, they reference some limitations to assess the quality of each selected studies, such as failure to define a good quality (Okoli & Schabram, 2010), differences in quality appraisal methods of quantitative or qualitative research (Kitchenham & Charters, 2007; Okoli & Schabram, 2010), the difficulty of specifying assessment items for qualitative research (Tranfield et al., 2003), the existence of plenty of poorly reported primary studies and confidentiality of software data (Kitchenham & Charters, 2007). Management researchers have a tendency to rely on journal quality ratings rather than the quality assessment of studies in management research (Tranfield et al., 2003). For these reasons, the adopted approach is to assess the study quality by journal quality indicators. The Journal Citation Report (JCR) and the Scimago Journal & Country Rank (SJR) are indicators of journal quality used for quality appraisal (Lim et al., 2021; Suárez et al., 2017). To evaluate the quality of the obtained articles, the related journals were ranked based on their quartile classification on the JCR and SJR. The journal quality threshold is decided as > Q4 since it corresponds to the thresholds recommended by Bouncken et al. (2015) (as JCR impact factor <0.7) and by Köhn (2018) (as excluding the lowest quartile, Q4). A total of 18 articles published in journals not ranking in Q1, Q2, or Q3 were excluded. After the quality appraisal, the number of articles that only proposed an architectural framework for DBEs is 44, while 27 articles study only DBE governance. The number of articles that includes both DBE architecture and governance issues is 14 after the quality appraisal.

Due to the small number of articles covering both the DBE architecture and governance topics, "go backwards" and "go forwards" (also known as snowballing) techniques are applied by reviewing the references of the selected articles and the citations for them (Webster & Watson, 2002). Seven relevant articles were added for the review considering the exclusion and quality criteria; therefore, a total of 21 articles covering both architecture and governance concepts are obtained. Finally, 92 articles were selected as primary studies for the SLR.

Data extraction

Data is extracted to review articles and address the research questions. For the overview, the articles were classified following the research design classification (Creswell, 2003), the research methodology classifications (Cooper & Schindler, 2003), and the research application domain (United Nations, 2018). During data extraction for architectural modeling and design patterns, the expressions used by the authors were considered. For governance mechanisms, coding was applied since different expressions with similar meanings could be used in the literature. Since there is no researcher-generated and predetermined list of codes or a "start list" before the data extraction, holistic coding is applied as a preparation to a unit of data before the categorization process instead of hypothesis coding or provisional coding (Dey, 2003; Saldaña, 2016). The main themes in the data are absorbed by digesting them as a whole rather than by dissecting them line by line (Dey, 2003)

Data synthesis

Synthesizing literature data is one of the purposes of SLR research. In this study, Webster and Watson's (2002) suggestions were applied for data synthesis. For the RQ1 and RQ3, concept-centric data synthesis was performed since it aids in locating connections and coherence between papers among research papers and supports the researchers in structuring the review (Dam et al., 2020). It is also helpful in defining future research lines that still need to be addressed (Cavallaro & Nocera, 2022). Each article was read, and key concepts were uncovered and grouped using a logical approach. Finally, the synthesized findings were presented with concept matrixes and each identified concept was discussed.

For the RQ2, the inductive qualitative content analysis technique was used as a synthesis method to reduce texts to relevant data and classify the data (Weber, 2011). Elo and Kyngäs (2008) advise using inductive content analysis when there is no prior knowledge of the phenomena or in case it is fragmented. This method is suitable to analyze the DBE governance articles since the knowledge of DBE governance mechanisms is fragmented. For the analysis, 48 DBE governance articles were reviewed, and a total of 38 topics were obtained after excluding the recurring and aggregating the similar topics. For these topics, five categories are specified for the DBE governance mechanisms, considering the dimensions mentioned in DBE governance articles. An example of the inductive content analysis is given in Appendix A as a data structure, which explicate the induction of categories for demonstrating rigor in qualitative research (Gioia et al., 2013).

For the reliability analysis, whether the 38 topics were associated with the same categories was tested by two independent judges, who are unfamiliar with the study in the field of management information systems. They assigned each topic to one of the five categories by working independently. The extent of agreement achieved between the two judges was expressed using the percentage match to check the intercoder reliability. SPSS was used to calculate the agreement level and obtain the mismatched topics, where the Cohen's kappa value was found as 0.861, which corresponds to the required agreement coefficient (Kassarjian, 1977) and the final version of the categorization has been determined. Intercoder agreement percentages is computed as another way to increase the confidence in the assertions and findings (Gioia et al., 2013). Intercoder reliability agreement coefficients are given in the Appendix B.

Results

The statistics for the selected articles are presented in this section, along with the results for the research questions of this study. First, descriptive statistics of the selected articles are presented, then the results on DBE architectural approaches, governance mechanisms for DBEs, and the relation between DBE architecture and DBE governance are given.

Overview of selected articles

Publication year

As previously stated, only articles published in the last 10 years (2012–2021) were included in the SLR. The publication year of the articles is categorized for different contexts and ordered by year (Figure 1). Since the articles that included DBE architecture, DBE governance, and both were analyzed for RQ1, RQ2, and RQ3, respectively, separate statistics were provided for each in addition to the publication years of all studies. It is evident that governance studies have started to give place as much as architectural studies in recent years. Few articles were published at the beginning of the years under review; however, there is an increase in the number of studies in all categories for the following years. The increase in the numbers indicates that the fields of DBE architecture and DBE governance are gaining in importance. In 2014, no relevant articles can be found, whereas all categories have the highest number of articles in 2020, demonstrating that this investigation is timely.

Publication source

The profiles of the journals indicate the importance of articles within the studied fields. For this study, the first three noteworthy publication sources were Electronic Markets, Information Systems Frontiers, and International Journal of Computer Integrated Manufacturing (Figure 2).

Research design and research method

The selected articles were examined and grouped according to the employed research design and research method. Creswell's (2003) research design classification was used to classify the articles by research design. The results indicated that 61% of the studies have a qualitative research design, while the percentages of

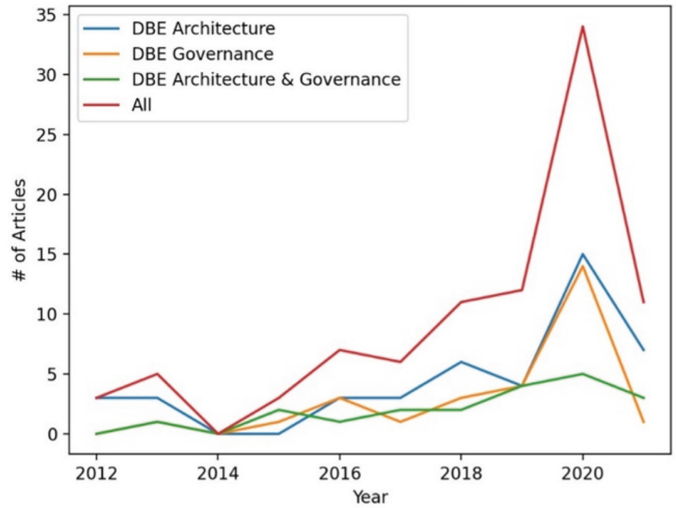

Figure 1. Publication years of reviewed articles.

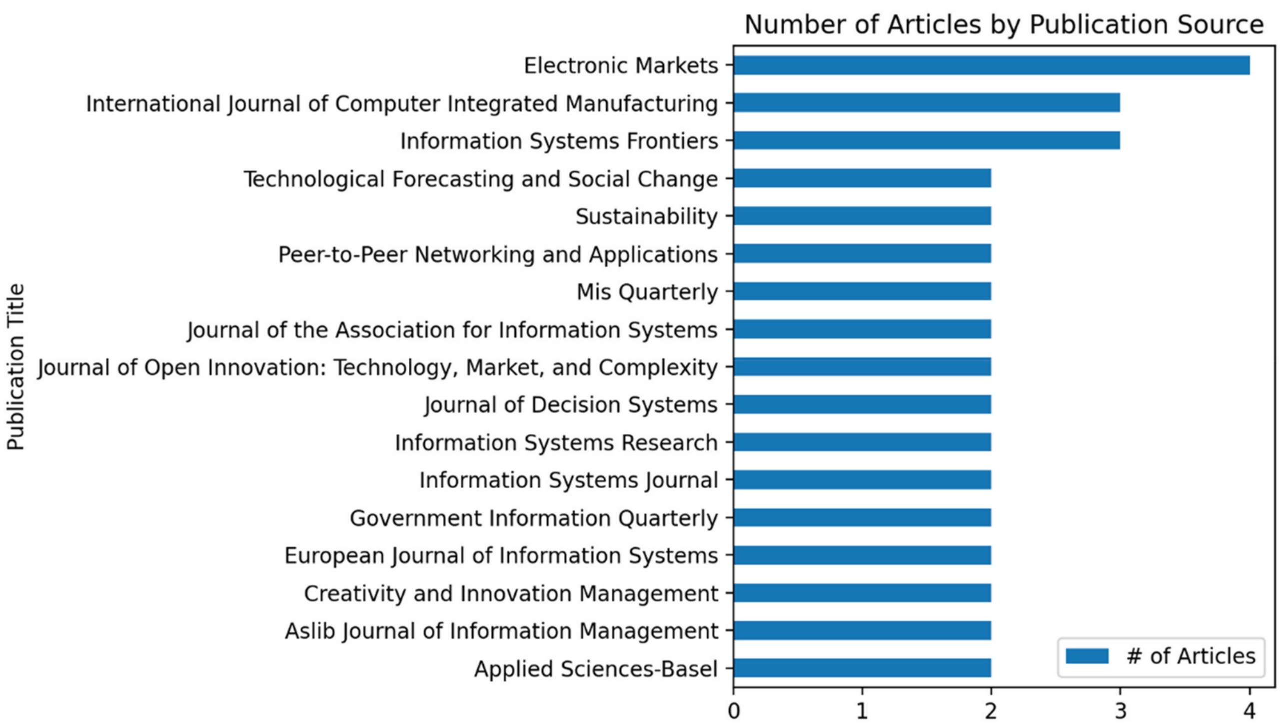

Figure 2. Journal profiles of reviewed articles.

quantitative and mixed studies are 27% and 12%, respectively.

The research methods used in DBE architecture and governance articles were also scrutinized in our study. The research methods, which Cooper and Schindler's (2003) stated, were used for this classification. Since "action research" and "design science research" can both be considered as similar research approaches (Iivari & Venable, 2009), these categories were combined. The category "multiple" for the combination of methods and the category "other" for other methods that are used in small numbers are added for the classification. Moreover, case studies examining a single case or multiple cases were grouped separately in this study. The results indicate that the most predominant research methods in the DBE architecture and governance articles are "case study" (27 single-case studies and 19 multiple-case studies) and experimental research (15 articles) as depicted in Figure 3.

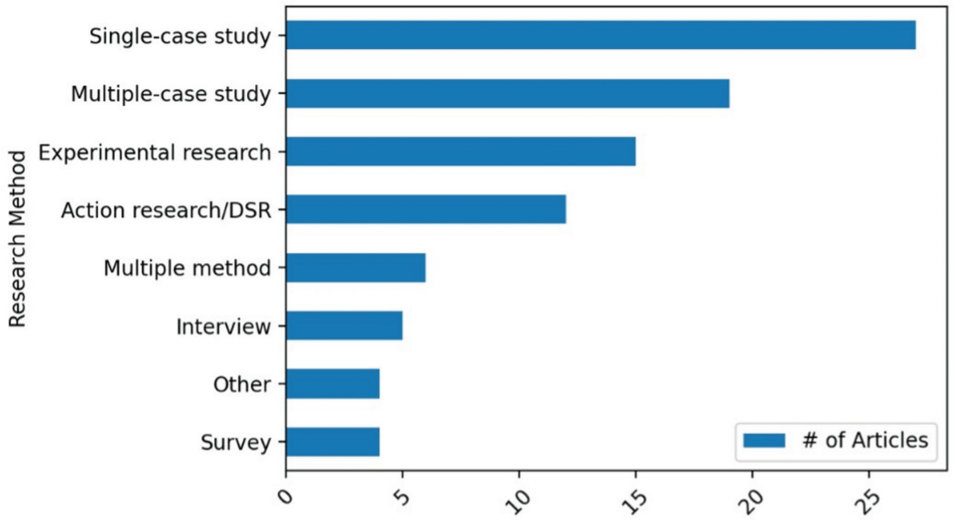

Figure 3. Research methods of reviewed articles.

Research application domain

Industry architectures create industry solutions by discovering and describing industry reference models, standards, specifications, strategic constructs, and industry-specific services within the reference model (Jacobides et al., 2006; Perks & Beveridge, 2004). Changing the industry architecture through the ecosystem approach is required to create value for customers and capture enough value for all industry actors (Jacobides et al., 2018; Tutuba et al., 2019).

The industries of the selected articles were reviewed following the ISIC classification (United Nations, 2018). The number of articles by research application domain is shown in Figure 4. The main research application areas can be listed as follows: manufacturing (22 articles), public administration (10 articles), and information and communication (9 articles). While no specific application domain was specified in 11 studies, research was conducted on more than 1 area in 10 articles. Research applications in the fields of agriculture, mining, and quarrying, transportation and storage, waste management, professional, scientific, and technical services, utilities, and extraterritorial activities are quite a few (only one article for each).

RQ1: architecting DBEs

To address the RQ1, in total 64 articles that presented an architectural approach for DBEs were reviewed. Architectures are comprised of one or more architecture models, which are described with the attributes, behaviors, and relationships and represented from

Figure 4. Research application domains of reviewed articles.

architecture viewpoints using various notations (IEEE, 1990). In addition, architectural patterns command a fundamental role in the defining architecture design process. For these reasons, architectural approaches, both architectural modeling and architectural design approaches, which are important for building complex systems (Tianual & Pohthong, 2019), were focused by analyzing the modeling notations and viewpoints and synthesizing the design patterns together with their characteristics.

Architectural modelling notations

The selected DBE articles were examined in terms of the architecture modeling notations. Notations used in reviewed articles are named and listed in this study as mentioned in the articles. In 19 articles, the following formal notations are used to model DBE architectures: Unified Modeling Language (UML), Business Process Modeling Notations (BPMN), flow chart, Petri Nets, ArchiMate, EXPRESS, and Integrated Definition (IDEF) (Table 3). In the remaining 44 articles, authors have preferred to use boxes and lines or other informal modeling notation like conceptual maps, layered diagrams, lists, organizational charts, social network analysis graphs, tables, Venn diagrams, and 2D/3D/4D charts.

Researchers developed several architectural artifacts using formal notations for describing the DBEs from different viewpoints. From a use case viewpoint, UML use case diagrams were developed for DBEs architectures to evaluate the fundamental use cases for cloud-based platforms (Alreshidi et al., 2016) or to describe the main use cases in the digital service ecosystems core (Immonen et al., 2018). In some instances, the approach was also adopted to show use cases of business software transformation in the mining technology collaboration platform (J. Wang et al., 2019) and to illustrate the business process functions in collaborative distributed environments (Demichev et al., 2021). From a structural viewpoint, UML class diagrams were used to describe the business process model in collaborative distributed environments (Demichev et al., 2021), and to present a core model for cloud-based platforms (Alreshidi et al., 2016). From a process viewpoint, UML sequence diagrams were preferred by many authors, for example, to describe composition and support services (Bellini et al., 2018; Immonen et al., 2018), transformation, or horizontal integration processes (J. Wang et al., 2019; Javed et al., 2020), and interactions among units (Vatankhah Barenji, 2022), and to exemplify the general processes in DBEs (Demichev et al., 2021). A UML activity diagram was constructed for the process of project submission in a multi-agent enterprise system by Sadigh et al. (2017).

Other process modeling techniques and tools were also preferred. For example, BPMN workflow diagrams are used to illustrate the business procedures and setup activities in a cloud-based platform (Alreshidi et al., 2016) or represent the process model in a cloud-based business environment (Shamsuzzoha et al., 2017). BPMN is also employed to exemplify the collaborative business processes in collaborative industrial ecosystems (Kannisto et al., 2018). J. Wang et al. (2019), however, developed a flowchart for modeling business processes of a mining technology collaboration platform. IDEF0 diagrams were developed for the main node decomposition of multi-agent virtual enterprise systems (Sadigh et al., 2017) and the decomposition of a collaboration platform's business process model (J. Wang et al., 2019). Vatankhah Barenji (2022) make use of Petri-nets process diagrams to demonstrate the interactions among the units and block trust in peer-to-peer network prototyping. The authors also described the architecture from other viewpoints like development and deployment. However, a few of them were modeled using formal notations. A UML component diagram, for example, was developed to show the components of a smart city innovation ecosystem by Javed et al. (2020), and a UML deployment diagram catered for the design of a testbed architecture from a deployment viewpoint by Demichev et al. (2021). Aulkemeier et al. (2019) described the architecture of platform-based collaborative ecosystems using ArchiMate notations, by illustrating the components, actors, and interaction mechanisms in the platform.

Table 3. Formal modeling notations in reviewed articles.

Modeling Notations	# of Articles	Architectural Artifact	Author(s)
UML	9	Use Case Diagram, Class Diagram, Activity Diagram, Sequence Diagram, Deployment Diagram, Component Diagram	(Alreshidi et al., 2016; Appio et al., 2018; Bellini et al., 2018; Demichev et al., 2021; Immonen et al., 2018; Javed et al., 2020; Sadigh et al., 2017; Vatankhah Barenji, 2022; J. Wang et al., 2019)
BPMN	4	Business Process Diagram/Workflow Diagram	(Alreshidi et al., 2016; Appio et al., 2018; Kannisto et al., 2018; Shamsuzzoha et al., 2017)
Flow Chart	2	Flow Chart	(J. Wang et al., 2019; Shamsuzzoha et al., 2017)
IDEF	2	IDEF0 (Decomposition Diagram)	(J. Wang et al., 2019; Sadigh et al., 2017)
ArchiMate	1	Business Network Diagram	(Aulkemeier et al., 2019)
Petri Nets	1	Process Diagram	(Vatankhah Barenji, 2022)

Architectural viewpoints

In literature, the DBE architectures were described from various viewpoints. Table 4 includes the specified viewpoints of DBE architectures by the authors for DBE architecture articles. While four articles did not specify a viewpoint, the most addressed viewpoints are the process viewpoints and business viewpoints with 24 and 10 articles, respectively (Table 4). Process viewpoints describe the system processes and their communication (Smolander et al., 2002), while business viewpoints include business aspects like stakeholders, business models, vision, value framework, and objectives (Hilliard, 2001; Lin et al., 2015).

There are different viewpoints classifications in the literature and many studies include static/structural or dynamic/behavioral categories (Immonen et al., 2018; Mili & Steiner, 2008). In the reviewed articles, it is referred to both structural viewpoints like data, logical, component, decomposition, physical, deployment, and implementation viewpoints and behavioral viewpoints like process, interaction, and operational viewpoints (Table 4). A system architecture can also be modeled from business and/or information technology aspects (Hinkelmann & Pasquini, 2014). Some DBE viewpoints addressed business concerns, using operational, business process, and capability viewpoints, while some of them are used to describe information technology concerns such as infrastructure, technological, application, data, implementation, deployment, and physical viewpoints (Table 4).

As referenced in Table 4, DBE architectures are studied from multiple viewpoints sequentially since more than one viewpoint can be required separately depending on the complexity of the ecosystem. Some researchers studied on multiple viewpoints also in combination and proposed architectural frameworks, which are developed by a coherent set of viewpoints to model the overall architecture of a system. They are mostly described with layers or tiers, for example, the architecture of a mining technology collaboration platform involves data, data exchange, collaboration platform, business software, and business layers (J. Wang et al., 2019). Whereas the enterprise application architecture of a digital collaborative manufacturing network includes the presentation, business, and data stores layers (Figay et al., 2012).

In summary, mostly informal notations, such as box and lines are used in DBE modeling, while UML and BPMN are widely preferred formal modeling notations. Furthermore, it has been seen that modeling has been done from various viewpoints, but predominantly from the process, business, and structural viewpoints. Moreover, the DBEs are described from multiple viewpoints in 23% of the DBE architecture articles.

Table 4. Modeling viewpoints of reviewed articles.

Viewpoint	# of Articles	Author(s)
process	24	(Alreshidi et al., 2016; Appio et al., 2018; Aryan et al., 2021; Bellini et al., 2018; Blaschke et al., 2019; Cui et al., 2019; Hanseth & Modol, 2021; Jovanovic et al., 2021; Kannisto et al., 2018; Khanagha et al., 2020; Kim & Kim, 2018; Lombardi et al., 2020; Marmolejo-Saucedo, 2020; Matopoulos et al., 2012; Merschbrock, 2012; Nepal et al., 2017; Rukanova et al., 2020; Saadatmand et al., 2019; Saarikko, 2016; Sadigh et al., 2017; Shamsuzzoha et al., 2017; Vatankhah Barenji, 2021; J. Wang et al., 2019; Yang et al., 2020)
business	10	(Ardolino et al., 2020; Autiosalo et al., 2021; F. T. C. Tan et al., 2020; Hoch & Brad, 2021; Kuk & Janssen, 2013; Mancha & Gordon, 2021; Schiavone et al., 2021; X. Li et al., 2020; Xu et al., 2019; Zhao et al., 2020)
multiple viewpoints	10	(Alreshidi et al., 2016; Appio et al., 2018; Autiosalo et al., 2021; J. Wang et al., 2019; Kannisto et al., 2018; Matopoulos et al., 2012; Nepal et al., 2017; Sadigh et al., 2017; Shamsuzzoha et al., 2017; X. Li et al., 2020)
structural	9	(Alreshidi et al., 2016; Beliaeva et al., 2019; Demichev et al., 2021; Immonen et al., 2018; Jardim-Goncalves et al., 2013; Menzel & Teubner, 2020; Mikalef et al., 2020; Yablonsky, 2018)
component	7	(Barrios-Rubio & Gutiérrez-García, 2017; Bellini et al., 2018; Javed et al., 2020; Sadigh et al., 2017; Shamsuzzoha et al., 2017; Vatankhah Barenji, 2022; Yablonsky, 2020)
implementation	5	(Javed et al., 2020; Kannisto et al., 2018; Kim & Kim, 2018; Nepal et al., 2017; Vatankhah Barenji, 2022)
infrastructure	5	(Barkat et al., 2018; Henfridsson & Bygstad, 2013; Kuk & Janssen, 2013; Mitra & Gupta, 2020; Reforgiato Recupero et al., 2016)
interaction	5	(Aryan et al., 2021; Javed et al., 2020; Kassen, 2020; Sadigh et al., 2017; Vatankhah Barenji, 2022)
use case	5	(Alreshidi et al., 2016; Demichev et al., 2021; Immonen et al., 2018; J. Wang et al., 2019; Lombardi et al., 2020)
application	4	(Amoretti et al., 2016; Autiosalo et al., 2021; Figay et al., 2012; Lombardi et al., 2020)
development	4	(Adi & Heripracoyo, 2018; Cui et al., 2019; Drewel et al., 2020; Lombardi et al., 2020)
functional	4	(Demichev et al., 2021; Javed et al., 2020; Merschbrock, 2012; Wei et al., 2019)
unspecified	4	(Aulkemeier et al., 2019; Bazarhanova et al., 2020; Immonen et al., 2018; J. Wang et al., 2019)
technological	4	(Jardim-Goncalves et al., 2013; Lombardi et al., 2020; Matopoulos et al., 2012; Reforgiato Recupero et al., 2016)
data/ information	3	(Matopoulos et al., 2012; Sadigh et al., 2017; Schreieck et al., 2017)
deployment	3	(Adi & Heripracoyo, 2018; Demichev et al., 2021; Hilbolling et al., 2021)
capability	2	(Beetson et al., 2020; Figay et al., 2012)
conceptual	2	(Pranata et al., 2013; Tiwana, 2014)
decomposition	2	(J. Wang et al., 2019; Sadigh et al., 2017)
operational	2	(Demichev et al., 2021; Ju et al., 2019)
physical	2	(Lombardi et al., 2020; Saarikko, 2016)
logical	1	(Adi & Heripracoyo, 2018)

Architectural design patterns

The selected DBE articles were also reviewed in terms of architectural design. Various architectural patterns, such as client-server, peer-to-peer (P2P), service-oriented architecture (SOA), layered, cloud, publish-subscribe (Pub/Sub), Representational State Transfer (REST), hub-and-spoke, and fog-based, reported either singly or combined in 32 DBE architecture articles. The client-server architecture, also known as a two-tier architecture application, involves a server application that is reached directly by multiple clients, receives client request and respond to the clients (Javed et al., 2020). Multitier (n-Tier) architecture, is a client-server architecture that functions are separated more than two tiers (Figay et al., 2012). In a P2P architecture, every participating system can play the client as well as the server role, the roles can be changed dynamically so that it does not depend on the central server (Kim & Kim, 2018). SOA integrates software components that have been separately deployed, and traditionally has an integration strategy based on the enterprise service bus (ESB) technology for communication among software applications in different modules (Appio et al., 2018; Kuk & Janssen, 2013; Reforgiato Recupero et al., 2016).

The layered architecture comprises three or more layers, with each providing services to another in a defined order and focus solely on its responsibility (J. Wang et al., 2019). Cloud-based architecture involves the collection of virtualized resources as a service, such as Infrastructure as a service (IaaS), Platform as a service (PaaS), and Software as a service (SaaS) (Mitra & Gupta, 2020). Mostly frontend applications are moved to the cloud since the backend applications may have complex dependencies. Pub/Sub is an asynchronous, point-to-multipoint messaging model, which allows subscribers to subscribe for a specific event, and event producers to publish specific events that reach specific consumers (Lombardi et al., 2020). REST is an architecture where clients are separated from servers by a computing interface that includes endpoints for client authorization and access, and for business resources (Aulkemeier et al., 2019). Hub-and-speak is an architecture that a central "hub" or "middleman" that is connected to multiple spokes and coordinates the activity and information flow within the system (Merschbrock, 2012). The fog-based architecture uses edge devices for processes and ensures data collection and analysis between the Edge and the Cloud (Khanagha et al., 2020). Model-driven architecture (MDA) enables the translation of information at different meta-levels for gradual and sustained system interoperability (Jardim-Goncalves et al., 2013). The referred architectural patterns and their characteristics or advantages are provided in Table 5. Other reviewed DBE architecture articles did not report on architectural patterns they adopted.

When we consider common architectural patterns, the characteristics modularity, scalability, and trustworthiness for P2P architectures; interoperability,

Table 5. Architecture approaches and patterns of reviewed articles.

Architecture patterns	Characteristics/Advantages	Author(s)
Hub-and-spoke	transformational capability	(Merschbrock, 2012)
Point-to-point	integration speed	(Kuk & Janssen, 2013)
Pub/Sub	traceability	(2020)
P2P	modularity, scalability, trustworthiness, transparency	(Aryan et al., 2021; Demichev et al., 2021; Kassen, 2018; Kim & Kim, 2018; Pranata et al., 2013)
Mediator-based	interoperability, communication efficiency, scalability	(Kannisto et al., 2018)
Broker, Layered	modularity, interoperability	(Bazarhanova et al., 2020)
Cloud-based	flexibility, confidentiality, integrity, availability, scalability, robustness, cost effectiveness, practicality, accessibility	(Aulkemeier et al., 2019; Autiosalo et al., 2021; Barkat et al., 2018; Marmolejo-Saucedo, 2020; Mitra & Gupta, 2020; Nepal et al., 2017; Shamsuzzoha et al., 2017)
Fog-based	predictive	(Khanagha et al., 2020)
MDA	interoperability	(Jardim-Goncalves et al., 2013)
SOA	interoperability, transparency, trustworthiness, quality of service, quality of open data, flexibility	(Adi & Heripracoyo, 2018; Appio et al., 2018; Immonen et al., 2018; Kuk & Janssen, 2013; Saarikko, 2016)
P2P, SOA (Hybrid)	trustworthiness, interoperability, cost-effectiveness	(Matopoulos et al., 2012)
n-Tiers, SOA (Hybrid)	interoperability	(Figay et al., 2012)
Cloud-based, SOA	cost-effectiveness, portability, interoperability, smartness; time efficiency	(Reforgiato Recupero et al., 2016)
Cloud-based, P2P	reliability, performance efficiency, adaptability, availability, cost-effectiveness	(Amoretti et al., 2016)
Cloud-based, P2P, SOA	privacy	(Vatankhah Barenji, 2022)
Cloud-based, SOA, Multitier, MVC	availability, accessibility, scalability, reliability, security, cost-effectiveness	(Alreshidi et al., 2016)
Client-server, Pub/Sub, Cloud-based	interoperability, security, incentive	(Javed et al., 2020)

quality of service, and trustworthiness for SOA stand out. In order to benefit from the advantages of different design pattern, hybrid patterns, such as P2P-SOA (Matopoulos et al., 2012), and n-Tiers-SOA (Figay et al., 2012) are used in DBEs. While some DBEs continue to operate applications, processes, systems of record, and data on premises, some move a part of them that are not sensitive to the cloud. This is a cloud-based hybrid approach, and most articles on hybrid architecture patterns point to this approach (Alreshidi et al., 2016; Amoretti et al., 2016; Javed et al., 2020; Reforgiato Recupero et al., 2016; Vatankhah Barenji, 2022). The cloud gives them a cost-effective solution for service, infrastructure, application, interface, identity and access control, and data management needs through different cloud formats, while it enhances the availability and accessibility. Transformational capabilities of hub-and-spoke and point-to-point architectures and interoperability of mediator-based architecture and MDA are mentioned (Table 5).

The integration and transmission strategy of an MDA model is related to multiple standards, such as meta-object facility (MOF), EXPRESS language, UML, Extensible Markup Language (XML), XML metadata interchange (XMI), the Web Ontology Language (OWL), and ATLAS Transformation Language (ATL) (Jardim-Goncalves et al., 2013). The integration strategy of SOA architectures is traditionally based on ESB, (Adi & Heripracoyo, 2018; Appio et al., 2018; Figay et al., 2012; Kuk & Janssen, 2013; Lombardi et al., 2020; Reforgiato Recupero et al., 2016). For web services, application program interfaces like Representational State Transfer Application Programming Interface (REST API), Simple Object Access Protocol (SOAP) interface, and Hypertext Transfer Protocol (HTTP)/ WEB API are implemented. As the SLR authors also reported, these are supported by the architectural styles, and communication protocols and standards, such as REST (Aulkemeier et al., 2019; Autiosalo et al., 2021; Reforgiato Recupero et al., 2016), SOAP (Adi & Heripracoyo, 2018), HTTP (Adi & Heripracoyo, 2018; Autiosalo et al., 2021), Message Queuing Telemetry Transport (MQTT) (Lombardi et al., 2020), Open Messaging Interface (O-MI)/Open Data Format (O-DF) (Javed et al., 2020), Open Platform Communications Unified Architecture (OPC UA) (Autiosalo et al., 2021; Marmolejo-Saucedo, 2020), Security Assertion Markup Language (SAML) and OpenID Connect (Bazarhanova et al., 2020), XML (Adi & Heripracoyo, 2018; Jardim-Goncalves et al., 2013; Kannisto et al., 2018), Extensible Messaging and Presence Protocol (XMPP) (Shamsuzzoha et al., 2017), and OWL (Jardim-Goncalves et al., 2013). The most common protocols are SOAP and HTTP for Client/ Server, MQTT for Pub/Sub, and O-MI/O-DF for both Pub/Sub and Client/Server architectural patterns.

In addition to the identified design patterns, different configurations for DBEs and common architectural patterns used in these configurations were identified. Overall, five articles corresponded to centralized systems (Immonen et al., 2018; Kuk & Janssen, 2013; Lombardi et al., 2020; Merschbrock, 2012; Saarikko, 2016) and three articles employed a decentralized approach (Demichev et al., 2021; Kannisto et al., 2018; Pranata et al., 2013). A total of 18 articles in Table 5 adopted a distributed system approach. The remaining articles did not report their structure. Common architectural patterns are client-server patterns and hub-and-spoke for centralized systems (Kuk & Janssen, 2013; Merschbrock, 2012), P2P for decentralized systems (Pranata et al., 2013), and SOA (Appio et al., 2018; Hamel, 2000; Kuk & Janssen, 2013), P2P (Aryan et al., 2021; Demichev et al., 2021; Kassen, 2018; Kim & Kim, 2018), layered/multitiered/n-tiered (Alreshidi et al., 2016; Bazarhanova et al., 2020; Figay et al., 2012) for distributed systems. While cloud architecture was initially used in centralized systems, distributed "mini clouds" near physical devices began to be deployed in distributed systems (Khanagha et al., 2020).

RQ2: governance mechanisms for DBEs

To address the RQ2, a total of 48 DBE governance articles were examined to identify DBE governance mechanisms. Governance mechanisms are required to cooperate, coordinate, and integrate ecosystem actors, activities, and interfaces.

In order to provide a guidance to governance mechanisms, some of the articles reviewed refer to theories like business ecosystem theory (Mukhopadhyay et al., 2019; Yang et al., 2020), actor-network theory (Henfridsson & Bygstad, 2013), assemblage theory (Hanseth & Modol, 2021), complexity theory (Henfridsson & Bygstad, 2013), control theory (Mukhopadhyay et al., 2019), internalization theory (Zeng et al., 2019), network theory (Zeng et al., 2019), platform theory (Bonina & Eaton, 2020; Mukhopadhyay et al., 2019), punctuated equilibrium theory (Gregory et al., 2018), resource orchestration theory (Cui & Taohua-Ouyang, 2017), social exchange theory (Benitez et al., 2020), and value theory (Schreieck et al., 2017).

As a result, 20 DBE governance mechanisms were identified and classified under five main dimensions, using an inductive content analysis approach. The governance mechanisms were collected under the five governance mechanism categories, which are discussed in the following subsections.

Governance structure

The major DBE governance structure mechanism that the selected studies covered are related to the overall governance structure, decision rights/power, ownership status, and division of roles (Table 6). Overall governance structures for DBEs are referred in the reviewed articles mostly as centralized (Hanseth & Modol, 2021; Henfridsson & Bygstad, 2013; J. Wang et al., 2019; Reim et al., 2019; Schmitt & Gill, 2020; Schreieck et al., 2017), decentralized (Henfridsson & Bygstad, 2013; Mikalef et al., 2020; Renwick & Gleasure, 2021; Sadigh et al., 2017; Schmitt & Gill, 2020; Schreieck et al., 2017; Shahzad et al., 2020; Zeng et al., 2019), and distributed (Hanseth & Modol, 2021; Henfridsson & Bygstad, 2013), which concern decision rights distribution, power structure, ownership status, and division of roles (Korpela et al., 2013; Schreieck et al., 2017). Decision rights distribution refers to the partitioning of decision-making power among actors (Tiwana et al., 2010), and the power structure influences the distribution.

In centralized governance, decisions are made by a person or small group, whereas authorities at various levels have a decision-making power in decentralized governance (King, 1983). Centralized decision-making creates cross-unit synergies, whereas decentralized decision power creates flexibility (Zacharewicz et al., 2017). A single company can own a platform to implement governance mechanisms, or ownership is shared between multiple actors (Bonina & Eaton, 2020). Ownership depends on the degree of power centralization (2020). Centralized platforms are governed by a single owner, decentralized platforms are controlled by peer-to-peer communities, and a consortium is formed by a group of actors for distributed platforms governance (Hein et al., 2020). Moreover, making roles and responsibilities clearer is a useful way to strengthen governance (Pikkarainen et al., 2020; Sawy et al., 2016). The following governance approaches and management styles are associated with the DBE governance: autocratic (Schreieck et al., 2017), hierarchical (Zeng et al., 2019), multi-lateral, (Hurni et al., 2021) democratic (Kassen, 2020; Schreieck et al., 2017), semi-autonomous (Sadigh et al., 2017), federated (Bazarhanova et al., 2020), autonomous (Hilbolling et al., 2021), self, formal/government-based and informal/platform-based (Han, 2020), collaborative network (Zeng et al., 2019), and lead organization (F. T. C. Tan et al., 2016) governance.

Access & controls

Another DBE governance mechanism category is access and controls (Table 7). Control mechanisms, which are

Table 6. Governance structure.

Governance mechanism	Description	Author(s) referring to the mechanism
governance structure	governance mechanisms that are used to govern a system and coordinate inter-organizational relations	(B. Tan et al., 2015; Bazarhanova et al., 2020; F. T. C. Tan et al., 2016; Reim et al., 2019; Renwick & Gleasure, 2021; Sadigh et al., 2017; Schmitt & Gill, 2020; Schreieck et al., 2017; Shahzad et al., 2020; Zeng et al., 2019)
decision rights/power	about who participates in decision-making, how decision power is shared among actors	(Benešová et al., 2020; Benitez et al., 2020; Gregory et al., 2018; Kassen, 2020; Saadatmand et al., 2019; Schreieck et al., 2017; Tiwana, 2015b)
ownership status	about that the platform has a single owner or multiple owners	(Bonina & Eaton, 2020; Schreieck et al., 2017)
division of roles	determination of roles and responsibilities of actors	(Alreshidi et al., 2016; Hilbolling et al., 2021; Korpela et al., 2013; Pikkarainen et al., 2020; Schreieck et al., 2017)

Table 7. Access and controls.

Governance mechanism	Description	Author(s) referring to the mechanism
openness	the level of openness for the entry of the new actors into the ecosystems	(B. Tan et al., 2015; Benešová et al., 2020; Bonina & Eaton, 2020; Hilbolling et al., 2020; Kassen, 2018; Mukhopadhyay et al., 2019; Pikkarainen et al., 2020; Schreieck et al., 2017; Yang et al., 2020)
access rights	rights that determine access to the platform and usage restrictions for various roles within the ecosystem	(Alreshidi et al., 2016; Bellini et al., 2018; Jovanovic et al., 2021; Wei et al., 2019)
controls	rules and standards which screen and regulate the behavior of complementors and their inputs (products, services, etc.) before entering the digital platform and focus understanding, and outputs for quality to secure both interests of complementors and platform owners	(Croitor & Benlian, 2019; Croitor et al., 2021; Hilbolling et al., 2021; Hurni et al., 2021; Korpela et al., 2013; Mukhopadhyay et al., 2016, 2019; Sadigh et al., 2017; Schreieck et al., 2017; Wei et al., 2019)
conflict resolution	rules and procedures for resolving conflict among actors	(Schreieck et al., 2017)

based on control theory, refer to formal and informal mechanisms to control the behavior of actors (Tiwana et al., 2010). A platform can be open or closed, or openness can be restricted for involvement approval (Mukhopadhyay et al., 2019). The extent of openness can be settled by the number of complementors and the competition level and balanced with input controls, which screen and regulate complementors and their inputs (products, services, etc.) before entering the digital platform (Croitor et al., 2021). Closed platforms do not allow innovation, while trust and quality issues are likely in open platforms; therefore, controlled openness is preferred at different levels by platform owner(s) to benefit from the advantages of both (Mukhopadhyay et al., 2019). Different levels of openness provide different benefits for solution providers in terms of module quality, offering variety, dependency among actors, resource sharing, etc. (Wei et al., 2019). Platforms are open to outside for value co-creation with complementary products, services, or technologies (Schreieck et al., 2017).

Output controls focus on understanding, evaluating, and monitoring the outputs (Mukhopadhyay et al., 2016). Another control mechanism to set and enforce standards in a DBE is access controls mechanism, which determines who can access the platform and what the restrictions on participation will be (Schreieck et al., 2017). Accessibility can be high or low depending on the levels of restrictions or authorization (Wei et al., 2019). The permissions of access, composition, and modification can be controlled by licenses and authorizations (Bellini et al., 2018). Platform owners need rules and procedures also to regulate the behaviors of actors in DBEs, for example, to resolve conflicts among actors (Hurni et al., 2021; Mukhopadhyay et al., 2019; Sadigh et al., 2017).

Resource orchestration

Resource orchestration deals with how a company organizes its resources to gain competitive advantages in a dynamic environment (Sirmon et al., 2011). Table 8 includes the resource orchestration mechanisms, which were compiled from primary research articles. The concept of boundary resources, which is an important DBE governance mechanism (Schreieck et al., 2016), refers to all types of resources like tools, rules, documentation, tutorials, etc. that DBEs provide for actors to enable value co-creation (Schreieck et al., 2019). According to boundary object theory, boundary resources maximize communication and autonomy by the standardizing of interfaces among actors who have different interests (Star & Griesemer, 1989). APIs and software development kits (SDK), for example, serve as the interface between owners and third-parties of platform ecosystems; whereas licensing agreement contracts control the quality of third-party offers (Bonina & Eaton, 2020; Schreieck et al., 2017). The combination of internalization and network theories shed light on orchestrating internal and external resources (Zeng et al., 2019). Firms can acquire, integrate, and share resources to form capabilities for value creation (Cui & Taohua-Ouyang, 2017; Cui et al., 2019). Integrating the internal and external networks of knowledge and sharing resources in a multi-sided platform provides a sustainable competitive advantage (Benešová et al., 2020; Schmitt & Gill, 2020). Another key concept is the transparency of resource management and platform (Kassen, 2018), which refers to topics, such as the customer's understanding of module creation or the vendor's understanding of module deployment, and the level of communication among relevant parties (Wei et al., 2019).

Value co-creation and appropriation

The co-creation of value by the actors in the innovation ecosystem by interacting, integrating resources, and exchanging values can be explained with the social exchange theory and collective action theory (Benitez et al., 2020; Mukhopadhyay & Bouwman, 2019). Table 9 shows the co-creation mechanisms that the primary research articles referred to. Governing the intensive collaboration is an essential mechanism for DBE success (Hilbolling et al., 2020). Collaboration is sharing knowledge or services with others for a related problem, event, or product. Working together or equal contribution is not compulsory for collaboration, but it requires sharing

Table 8. Resource orchestration.

Governance mechanism	Description	Author(s) referring to the mechanism
resource orchestration	integrating, sharing, and managing resources to form capabilities for value creation	(Bellini et al., 2018; Benešová et al., 2020; Costa et al., 2020; Cui & Taohua-Ouyang, 2017; Cui et al., 2019; Kassen, 2018; Schmitt & Gill, 2020; Schreieck et al., 2017)
boundary resource	all kinds of resources like tools, rules, documentation, tutorials, training etc. that platforms provide for actors to enable value co-creation	(Benešová et al., 2020; Bonina & Eaton, 2020; Jovanovic et al., 2021; Schreieck et al., 2017)
transparency	transparency of resource management and platform	(Kassen, 2018, 2020; Wei et al., 2019)

Table 9. Value co-creation and appropriation.

Governance mechanism	Description	Author(s) referring to the mechanism
collaboration/ cooperation	with/without a common goal, sharing knowledge or services with others for a related problem, event, or product	(Benešová et al., 2020; Benitez et al., 2020; Costa et al., 2020; F. T. C. Tan et al., 2016; Hilbolling et al., 2020; Kassen, 2018; Linde et al., 2021; Olsson & Bosch, 2020; Roukouni et al., 2020; Yang et al., 2020) (Benešová et al., 2020; Benitez et al., 2020; Costa et al., 2020; F. T. C. Tan et al., 2016; Hilbolling et al., 2020; Kassen, 2018; Linde et al., 2021; Olsson & Bosch, 2020; Roukouni et al., 2020; Yang et al., 2020)
co-innovation	innovation resulting from collaborative or collaborative activities carried out	(Benešová et al., 2020; Pikkarainen et al., 2020; Yang et al., 2020)
competition	competition between platform leaders and complementors and competition among complementors offering similar value proposition	(B. Tan et al., 2015; Mukhopadhyay & Bouwman, 2019; Olsson & Bosch, 2020)
value appropriation	a balanced sharing of the revenue of the co-created value among the actors	(B. Tan et al., 2015; Mukhopadhyay & Bouwman, 2019; Yablonsky, 2020)

for other actors' goals (Costa et al., 2020; Kassen, 2020). Digital platforms enhance the effectiveness of the collaboration of actors in an ecosystem (Roukouni et al., 2020). AI technologies, for example, that are integrated into digital platforms enhance collaboration among members by supporting knowledge sharing (Yang et al., 2020). Collective actions, which is a part of the collaboration, require close coordination for a common goal and more or less equal contribution (Costa et al., 2020).

Establishing collectivism, particularly in a nascent stage of platform development, is important for the platform's long-term sustainability (F. T. C. Tan et al., 2016). From the seller side, building cooperative alliances develop synergies in markets and collectivism among actors empowers sellers (F. T. C. Tan et al., 2016). Cooperation is another value-creation mechanism that does not require a common goal with another person or group, but cooperation with others for networking, knowledge sharing, and innovation opportunities (Benitez et al., 2020). Co-innovation is aimed at a collaborative business ecosystem with the collaborative or cooperative activities carried out for the purpose of innovation (Benešová et al., 2020; Yang et al., 2020). Moreover, the competitiveness of the platforms should be contributed by platform owners for value creation (B. Tan et al., 2015). As innovation ecosystems focus on creating shared value, they involve innovation competition among complementors, but in transaction ecosystems, there is marketing competition between actors and this competition is more fierce (Olsson & Bosch, 2020). Controlled competition provides variety and attracts customers while uncontrolled competition may reduce innovation (Mukhopadhyay & Bouwman, 2019). A firm's competitive strategy is related to mobilizing user groups and balancing interests among actors with the right-value appropriation strategies (B. Tan et al., 2015; Linde et al., 2021; Yablonsky, 2020). The revenue of co-created value must be shared fairly among the actors because fairness in value appropriation improves the ecosystem health (Mukhopadhyay & Bouwman, 2019). Platform leaders have a higher share of value in DBEs, and if multiple complementors have similar skills, the chance of those complementors for a higher share may decrease (Mukhopadhyay & Bouwman, 2019).

Trust and commitment

The importance of building trust among actors has been highlighted in the DBE governance studies (Table 10). Strengthening trust and minimizing risk are vital to platform ecosystems since platform ecosystems require

Table 10. Trust and commitment.

Governance mechanism	Description	Author(s) referring to the mechanism
trust	an expectation of actors to consider mutual benefit from each other	(B. Tan et al., 2015; Bellini et al., 2018; Benešová et al., 2020; Benitez et al., 2020; F. T. C. Tan et al., 2016; Han, 2020; Papadonikolaki & Wamelink, 2017; Schreieck et al., 2017)
privacy and security	protecting users' sensitive information and ensure confidentially, integrity, authentication, and non-repudiation	(Renwick & Gleasure, 2021; Schmitt & Gill, 2020; Shahzad et al., 2020)
complementor dedication	faithfulness of complementors to continue value co-creation	(Croitor et al., 2021; Hilbolling et al., 2020; Hurni et al., 2021)
communication and interaction	methods used for communication and interaction among ecosystem actors	(Papadonikolaki & Wamelink, 2017; Pikkarainen et al., 2020; Roukouni et al., 2020; Yablonsky, 2020)
motivation and organizational support	encouragements for ecosystem actors to participate, adopt, and co-create value	(Benešová et al., 2020; F. T. C. Tan et al., 2016; Jovanovic et al., 2021; Korpela et al., 2013; Schmitt & Gill, 2020; Wei et al., 2019; Yablonsky, 2020)

the continuous interaction of actors (Hein et al., 2016; Hurni et al., 2021; Schreieck et al., 2017). Benitez et al. (2020) defined trust as an expectation of actors to consider mutual benefit from each other (Benitez et al., 2020). Trust in the platform and community motivates the participation of potential third parties interested in contributing to the platform (Schreieck et al., 2017). It is related to reputation and formed gradually as the platform develops (Han, 2020).

Ensuring trust between actors develops synergies in the platforms and is indispensable for customer loyalty (2016). Transparency of transactions, contracting, and consensus mechanisms for decision-making are two ways of strengthening trust (Papadonikolaki & Wamelink, 2017; Schmeiss et al., 2019). Privacy (Renwick & Gleasure, 2021; Schmitt & Gill, 2020; Shahzad et al., 2020) and security, mainly confidentiality, authentication, integrity, and non-repudiation (Shahzad et al., 2020) are other concepts that should be ensured for building trust for the environment. Complementor dedication, which refers to the faithfulness and willingness of complementors to continue to work with the platform owner for value co-creation, depends on trust and commitment (Hurni et al., 2021). Owners may lose control over the user experience (Hilbolling et al., 2020), or input controls negatively impacts complementors' continuance intentions (Croitor et al., 2021). Rule adequacy and considering the needs of complementors when designing standardized rules affects complementor dedication (Hurni et al., 2021). Moreover, business ecosystems require actors in the ecosystem to communicate strategically.

Digital platforms enhance communication and facilitate interactions among actors (Pikkarainen et al., 2020; Roukouni et al., 2020; Yablonsky, 2020). Communications among actors built trust and enhanced collaboration in the platform (Papadonikolaki & Wamelink, 2017). Motivations [11,105,122,125,134] and organizational supports (Benešová et al., 2020; Jovanovic et al., 2021) are other concepts that support to strengthen the relationships.

Holistic view of DBE governance mechanisms

As a result, many DBEs fail because of governance problems and the literature review demonstrates that conflicts of ownership or decision rights among ecosystem partners and poor setting of platform openness are the main problems hence, the most addressed governance mechanisms are governance structure and access and control mechanisms. When the governance mechanisms discussed in the literature are examined, it is understood that different mechanisms are emphasized in different research areas. Business, strategy, and management literature, for example, predominantly focus on access and controls, governance structure, value creation and appropriation, commitment, and coordination (Bazarhanova et al., 2020; Croitor & Benlian, 2019; Croitor et al., 2021; Hilbolling et al., 2020, 2021; Jovanovic et al., 2021; Linde et al., 2021; Saadatmand et al., 2019). In addition, the contracting literature questions the trust and commitment mechanism (Papadonikolaki & Wamelink, 2017), while emphasizing formal governance with legally binding agreements like intellectual property and market contracts (Han, 2020). On the other hand, computer science and information systems articles draw an emphasis on trust and commitment and resource orchestration mechanisms (Bellini et al., 2018; Benitez et al., 2020; Cui & Taohua-Ouyang, 2017; Kassen, 2020; Shahzad et al., 2020) as well as access and control and governance structure (J. Wang et al., 2019; Sadigh et al., 2017; Shahzad et al., 2020). Information and library science literature addresses access, control, and governance structure mechanisms (B. Tan et al., 2015; Bonina & Eaton, 2020; Mukhopadhyay et al., 2019; Renwick & Gleasure, 2021).

Research also shows that there are different types of ecosystems and there is no single perfect governance structure for these ecosystems. Each ecosystem exists within a unique community context and should develop its own mechanisms with its own unique purpose and partnership relations; however, there is alignment between some mechanisms and ecosystem types. Most transaction ecosystems, for example, have a centralized authority-based decision-making mechanism, whereas most solution ecosystems prefer a decentralized and orchestrator-led decision-making mechanism. Considering the access and control mechanism, often transaction ecosystems, especially online marketplaces, are open to all value providers and customers. Some ecosystems, such as technology ecosystems, are the most closed to new partners. While others allow complementors to participate based on qualification, there are usually no restrictions for clients. The challenge of establishing control mechanisms for DBEs is controlling actor behavior without constraining the generativity and considering the maturity stages and whether there is a profit motive. The need for collaboration and cooperation is emphasized more for solution and innovation ecosystems and the trust mechanism is especially important for these DBEs because actors are in an intense relationship to create value collaboratively in these types of DBE. Moreover, the competition mechanism needs to work well for transaction ecosystems.

The results indicate some differences in the governance mechanisms of specific DBEs. According to

Schreieck et al. (2017), the governance of commercial and nonprofit platform ecosystems is different, especially in terms of governance structure, access and control, trust, and boundary resources. One of the significant differences stated is that nonprofit platform ecosystems are governed decentrally and legitimation by expertise is essential in these ecosystems, while legitimization is based on ownership and market power in commercial platform ecosystems. In addition to trust between the owner and actors, trust among complementors should be developed in nonprofit platform ecosystems, while individual boundary resources should be provided instead of standardized boundary resources. Moreover, some mechanisms are prominent in the governance of externally regulated ecosystems. Bazarhanova et al. (2020) investigated the pre and post-phases of the electronic identification (eID) ecosystem in Finland due to external changes from EU and national regulation. Before the regulation, each bank had full autonomy in terms of interface control, access rights, data ownership, etc. With the regulation, a layer of service brokers into the scheme of the eID was added for intermediaries between the platform and its users, and the governance in the ecosystem shifted from a centralized control structure to a more federated and distributed governance approach. The enlargement of the orchestration group weakened the dominant platform owners (banks) by reducing controls of them over their own ecosystem. Lombardi et al. (2020) used record management systems, in which organizations centrally, securely and electronically manage their records, to handle administrative and bureaucratic practices. The regulatory and compliance mandates allowed traceability and measurement of the circular economy processes in the digital recycling services platform.

RQ3: architecture and governance relation in DBE design

In this section, 21 articles that cover both architecture and governance topics in the context of DBEs were examined to address the RQ3. In 14 articles, the authors have defined relationships between different architecture approaches and different concepts of governance mechanisms or indicated how the internal fit between DBE architecture approaches and governance mechanisms are important for DBE design (Table 11).

According to the review results, there is an alignment between DBE architecture approaches and DBE governance mechanisms and this alignment is based on specific DBE goals instead of DBE types. Through centralized storage and centralized management and control, stakeholders collaborate efficiently, and interoperability is achieved (J. Wang et al., 2019). Whereas

Table 11. DBE architecture and governance alignment for specific DBE goals.

Architecture Approach	Governance Mechanism	DBE Goal(s)	Author(s)
centralized storage	centralized management and control	collaboration efficiency and interoperability	(J. Wang et al., 2019)
decentralized peer-to-peer architecture	openness	democratic collaboration and trust by ensuring transparency	(Kassen, 2020; Yang et al., 2020)
distributed architecture	semi-autonomous decentrally organized	flexibility in data storage and management	(Sadigh et al., 2017)
	distributed, interdependent but formally autonomous network	complement quality	(Hilbolling et al., 2021)
modular architecture	decentralized control structure	innovation	(Henfridsson & Bygstad, 2013)
	more federated, distributed governance	weakening in the dominance of platform owners and enlargement of the orchestration group	(Bazarhanova et al., 2020)
	input controls	complementor autonomy, interoperability, and quality	(Tiwana, 2015a)
	openness (transparency, accessibility, and involvement)	supply certainty, product variety, complementor quality, service quality	(Wei et al., 2019)
flexible architecture through modular architecture	decentralized governance	adaptability and alertness	(Mikalef et al., 2020)
complex architecture through integral architecture	multihoming (competition)	low-quality performance	(Cennamo et al., 2018)
core-extension coupling & interface confirmability	allocation of decision rights	complementor engagement	(Saadatmand et al., 2019)
decoupling & interface standardization	decision rights delegation	coordination costs	(Tiwana, 2015b)
integration, standardization and centralization/modularization, variation, and decentralized	consolidation, long term focus, planned change, and centralized control/local optimization, innovation, short term focus, emergent change, and distributed control	stability in the evolution/change in the evolution	(Hanseth & Modol, 2021)

the combination of decentralized peer-to-peer architecture with an open network provides a more democratic way to collaborate and enhances trust by ensuring transparency (Kassen, 2020; Yang et al., 2020). In distributed systems, the data access mechanism and governance structure became more federated, semi-autonomous decentrally organized, due to the need for flexible data storage and management (Sadigh et al., 2017). Distributed platform ecosystems, in which actors become increasingly interdependent but are formally autonomous, are also suggested for managing complement quality (Hilbolling et al., 2021).

In platform ecosystems, the combination of modular architecture and a decentralized control structure enables adoption, scaling, and innovation, whereas the combination of tightly integrated architectures and centralized governance structures does not trigger innovations (Henfridsson & Bygstad, 2013). Moreover, modularization engenders complementor autonomy, while input controls let the owner quickly review the interoperability and quality, thus controls and modularization complement each other to improve market performance (Tiwana, 2015a). According to Wei et al. (2019), the platform modules, which have different features, can be configured by diverse openness levels (low, medium, and high) and dimensions (transparency, accessibility, and involvement) to have varied control gains. Low-level openness adjusts supply uncertainty in a core module. A greater level of transparency provides product variety in a peripheral module, while medium-level accessibility controls complementor quality. For service modules, low openness controls service quality. According to Bazarhanova et al. (2020), extending the platform to service brokers, who are intermediaries among actors, with a technical implementation change in a layered modular system weakens the dominance of platform owners and the enlargement of the orchestration group. Therefore, platform evolution, which takes place from a dominance stage with a centralized governance structure to a distributed structure, requires an architectural change.

Furthermore, Mikalef et al. (Mikalef et al., 2020) argue that architecture flexibility and governance decentralization have a complementary relation. Flexibility drives to form IT-enabled dynamic capabilities with its adaptability and hence it increases competitive performance, and information technology governance decentralization strengthens this relationship with its alertness (Mikalef et al., 2020). Cennamo et al. (2018) handled the degree of complexity of the platform technology as platform architecture dimension and they found that multihoming, sequentially or simultaneously, causes lower-quality performance on more complex platforms.

Saadatmand et al. (2019) stated that the interplay between governance and architecture produces different levels of complementor engagement. Combining high core-extension coupling and low interface confirmability with the allocation of decision rights to a single ecosystem complementor results in low complementor engagement. This is because the complementor is also a competitor, creating uncertainty in other complementors' value capturing ability. Low core-extension coupling and low interface confirmability, with distribution of decision rights among ecosystem complementors, produces a high complementor engagement due to equal interests of complementors. Whereas modular organizations with low core-extension coupling and high interface confirmability with allocation of decision rights to a dominant complementor decreases complementor engagement since the complementors who are unwilling to provide more embedded parameters to other modules, leave. Furthermore, if the platform owner delegates decision rights to complementors, standardizing application interfaces reduce coordination costs more (Tiwana, 2015b).

Hanseth and Modol (2021) investigated how the interaction between architecture and governance evolves digital platforms. Stability in digital platform evolution is the outcome of "integration, standardization and centralization" as architectural elements and "consolidation, long-term focus, planned change, and centralized control" as governance elements. The combination of the architectural elements "modularization (flexibility), variation, and decentralized" and the governance elements "local optimization, innovation, short-term focus, emergent change, and distributed control" drives change in the evolution of digital platforms.

To summarize, the analysis of the few articles in this area indicates an alignment between some DBE architecture approaches regarding centralization, modularization, flexibility, interface standardization, etc., and specific DBE governance mechanisms, such as governance structure, decision rights delegation, openness, input controls, competition, etc. This fit is needed for specific DBE characteristics such as complementor engagement, complementor quality, interoperability, innovation capability, transparency, etc.

Discussion

In this section, the main results of the study are discussed for each research question, and the research avenues for future studies are offered.

For RQ1, the focus was on both architectural modeling and architectural design approaches, analyzing the modeling notations and viewpoints, and the design patterns with their characteristics. It has been seen that mostly informal modeling notations including boxes and lines are preferred, and UML and BPMN are mostly used as formal modeling notations. DBEs were delineated from different views, but the most addressed viewpoints are the process, business, and structural viewpoints. Although layered diagrams were also used to illustrate the overall architecture of DBEs, the current literature viewpoints mostly address the business concerns or the information technology concerns separately, or in sequence with multiple viewpoints. According to Kassahun and Tekinerdogan (2016), when dealing with systems of systems involving different organizations, a more feasible approach is required due to the mutual dependency between business process models and the software architecture and the possibility of business-information technology incompatibility. They, for example, proposed a collaboration viewpoint, which uses architectural and business process viewpoints iteratively to address business collaboration concerns and ensure the alignment of business-information technology. Such collaborative perspectives can be useful for describing DBE architecture since the combination of different views and notations for the description of an ecosystem clarifies different aspects of an ecosystem, either structural, or behavioral. It was observed that architectural patterns are related to the structure of DBE architecture. Client-server, for example, in centralized systems, P2P in decentralized systems, and SOA in distributed systems are considered appropriate. The review results indicate that it might not be appropriate to use a specific pattern to architect an end-to-end DBE because of complexity and modularity. Many authors have used hybrid patterns for distributed architectures, and most hybrid architecture are created by connecting the infrastructure to the cloud to benefit from the advantages of cloud computing.

As highlighted in the background section (Section 2.2.), some studies propose specific reference architectures for digital ecosystems (Averian, 2018; Ferronato & Moore, 2007) and they argue that SOA is not sufficient for DBE architecture because of that SOA essentially only supports the service execution phase rather than the entire business service lifecycle, and the need to use dynamic Internet Protocols due to the increase in mobile service and avoid single points of failure. Among the primary studies, no studies were found using ecosystem-oriented architectures as references for DBEs. Currently, existing patterns are being combined; however, it can be predicted that more ecosystem-specific architectural patterns will be applied in the future. Moreover, although they are evolving (Souri et al., 2020), we did not notice a detailed study on hybrid cloud architecture pattern, which connects components placed on public and private clouds, and multi-cloud architecture pattern, which provides computing and storage services by multiple cloud service providers.

To address RQ2, the reported governance mechanisms for DBEs in existing studies were examined. Following an inductive content analysis approach (Section 3.4.), the identified DBE governance mechanisms were collected under five governance mechanism categories: governance structure, access and control, value co-creation and appropriation, resource orchestration, and trust and commitment. Each category was explained with the related governance mechanism. The review results indicate that all these mechanisms have a significant role in the success of DBEs, and all should be designed considering the purpose of the ecosystem. Since each DBE has different purposes and an environment, there is no single recommended best governance model for ecosystems; however, it can be said that the ecosystem type has a role in the design of some governance mechanisms. Most digital transaction ecosystems, for example, aim to match suppliers, intermediaries, and buyers through a platform that is managed by an owner and based on a centralized authority-based decision-making mechanism to govern the ecosystem and coordinate inter-organizational relations.

The purpose of solutions or innovation ecosystems is to create value for customer collaboratively with various contributors. Therefore, more than one firm has a decision right and such a system required a decentralized governance structure, orchestrator-led decision-making mechanism, and division of roles and responsibilities among actors. The entry of the new suppliers and buyers into the ecosystems is usually open in most transaction ecosystems like marketplaces, while innovation or solution ecosystems may be closed to new contributors. DBEs may also be open to the participation of complementors, depending on the quality of the contributors, whereas having no restrictions for clients. Some studies on similar topics in the literature support these findings. Gawer (2014), for example, investigated the interdependence between platform types and governance mechanisms like governance structure, openness, and accessibility and their impacts on innovation and competition. In this instance, platforms evolve from internal to supply-chain to industry platforms, platform interfaces become more open, access to innovating capabilities increases, and a transition from authoritarian governance to collaborative governance takes place. In the end, the potential for innovation increases, while the competition among agents is likely to increase since several innovations will be competitive. Gawer (2020) also explored the interdependence between platform types (transaction platform and innovation platform) and resource boundary decisions (platform's scope, platform's sides, and platform's digital interfaces), considering different platform lifecycle phases (launch phase and maturity phase).

Furthermore, some governance mechanisms are prominent for some specific DBEs like nonprofit and externally regulated DBEs. Nonprofit platforms, for example, tend to rely on a decentralized governance structure that is carefully balanced and trusted (Schreieck et al., 2017). In externally regulated DBEs, the regulatory and compliance mandates provide a more federated governance approach and allow traceability and measurement of processes (Bazarhanova et al., 2020; Lombardi et al., 2020).

For the RQ3, the articles that have studied both DBE architectural approaches and governance mechanisms were examined and whether they are evidence for the relationship between them was investigated. The DBE architecture defines technological interactions among sides of the ecosystem (Hein et al., 2020) and governance mechanisms are used to govern organizational interaction among these sides. Therefore, the architecture and governance mechanisms of a DBE are expected to be aligned. The analyzes of the reviewed articles indicate an alignment between DBE architecture and DBE governance, and they can be configured together for specific DBE goals. DBEs can be designed with a centralized architecture and governance structure for collaboration efficiency and interoperability, whereas decentralized architecture and a decentralized control structure can be combined for innovation. Decentralized architecture with distributed governance provides democratic collaboration and transparency. Distributed architecture with decentralized or distributed governance structure can be preferred for flexibility and complement quality. Moreover, modular architecture can be complemented with input controls and openness levels for flexibility and transparency. Furthermore, DBE architecture and governance evolve digital platforms together. The evolution stems from a change in governance also needs an architectural change. A change may also emerge from the architectural part. Technology is developing extremely rapidly, and this advancement will impact IT-business alignment because organizations must keep up with the latest technology. The ecosystems could integrate new technologies, and a new technology applied will require reconsideration and reanalysis of the alignment between architecture and governance.

The number of articles that proposed a relationship between the DBE architecture and DBE governance was relatively few (14 articles); however, the findings of the literature review overlap with similar studies in the literature. Tiwana et al. (2010), for example, investigated the coevolution of architecture, governance, and evolutionary dynamics in business platforms. They argue that the architecture and governance of platforms are in harmony, which also affects the evolution of the platform. An increase in modularity needs more output controls and less process controls and they have a complementary effect on evolutionary dynamics; for example, modularity reduces system integration costs and thus increases the impact of decentralized control in accelerating platform evolution.

Gaps in the literature and avenues for future research

In addition to what we learned from the literature by addressing the research questions, some research gaps that are not covered sufficiently in the reviewed articles were identified, and several avenues for future research were offered.

From the DBE architecture perspective:

(1) The main research application domains are manufacturing, public administration, and information and communication. In future research, industry-specific architectures with an ecosystem approach can be studied in the fields of agriculture, mining and quarrying, transportation and storage, waste management, professional, scientific and technical services, utilities, and extraterritorial activities.
(2) The most preferred modeling notations in literature review studies are informal modeling notations like boxes and lines. In future research, more formal notations in modeling can be used since it is useful for practitioners in terms of understanding and reusability, and executable by machines.
(3) The most addressed architectural viewpoints are the process, business, and structural viewpoints. In future studies, other viewpoints are necessary to provide a more complete overview of a DBE. Moreover, collaborative combined perspectives can be further examined in terms of business-information technology alignment.
(4) In the literature, hybrid architectural patterns are used mostly for DBE architecture design.

Ecosystem-specific design patterns for DBE architecture design are also needed to study. Moreover, DBEs utilize cloud computing services (IaaS, PaaS, and SaaS) as private, public, or hybrid. Future studies can examine different forms of cloud computing like hybrid cloud architecture pattern, in which both private clouds and public clouds are used for different reasons and multi-cloud architecture pattern, in which the services from multiple cloud service providers are leveraged.

(5) The literature points to increased actor participation, DBEs will be more complex in the future. Modularization, that is encapsulating the design factors into modules, reduces this complexity (Fujimoto, 2018; Tatsumoto, 2018) and provides an advantage regarding design changeability and expandability. Modularity is one of the most studied areas in the DBE literature, but more work will be needed to improve modularity and scalability performance for more complex DBEs in future studies.

(6) With the increasing data volume, there is a need for design analytics and design patterns that will facilitate the transfer of data to prevent system performance degradation. Moreover, with diverse data sources, data quality aspects like accuracy, consistency, relevance, and completeness will be challenging; hence, DBEs should invest in data quality during the design phase and ensure data integration. Investigating whether the peripheral firms' architectural capabilities like scalability and integrability impact this performance can be one of the fruitful avenues.

(7) Distribution of data ownership in DBEs is a potential challenge. For data ownership allocation, approaches like data mesh can be studied with a DBE perspective.

(8) There are studies in the literature on how DBE architectural approaches correspond to DBE quality concerns, such as security, privacy, interoperability, etc. In future research, DBE architecture approaches can also be examined in terms of resilience, another key quality concern.

From the DBE governance perspective:

(1) Most studied DBE governance mechanisms (64% of DBE governance articles) are governance structure and access and control mechanisms. More complex DBEs need good governance also in balancing among actors and value appropriation, conflict resolution, and communication and interaction mechanisms. In future research, these mechanisms could be studied more deeply by handling the complexity issue.

(2) The number of DBEs is also continuously increasing, and one related future challenge is the multihoming concept, which refers that complementors participate more than one platform. Multihoming cause competition among DBEs instead of competition among complementors. In future research, multihoming phenomenon can be studied with a DBE governance perspective under competition and commitment mechanisms.

(3) When the widespread use of digital innovations is considered, trust is an essential challenge. Future studies can provide more fine-grained insights about how actors in DBEs based on cloud, blockchain, AI, and IoT build up trust in each other.

(4) In the literature, DBE governance mechanisms have been studied mostly for DBEs for-profit. Only Schreieck et al. (2017) addressed the governance of nonprofit DBEs. Moreover, there are few studies on the governance of externally regulated DBEs (Bazarhanova et al., 2020; Lombardi et al., 2020). In future studies, multiple-case studies can be useful to point out and discuss the differences in governance mechanisms for different types of DBE.

(5) DBE governance studies where different types of actors are considered are few. What the different types of actors, who have various resources and capabilities, and their roles by DBE type are and how these types of actors can be managed differently deserves further research attention.

(6) Most DBE governance studies have one-shot research design. As DBEs change and evolve over time, how governance mechanisms change over time can be examined with the longitudinal case study approach in future studies.

From the DBE architecture and governance alignment perspective:

(1) The overview shows that there is an increase in the number of studies in the fields of DBE architecture and DBE governance; however, few studies cover both fields. The result that these two areas, which are important for DBE design, complement each other, means that more study is required in which they are studied together.

(2) There is a need for a study investigating how different strategic architectural and governance

decisions impact the success of DBEs. It is challenging to reveal the outcome of these decisions with longitudinal multiple case studies because of the complexity of DBEs. As a future study, a dynamic model can be developed using a system dynamic approach, and the dynamic behavior of the model can be examined to understand the results of these strategic decisions and to decide the best strategies for specific contexts. Therefore, the model can provide guidance for selecting the optimal architecture and governance strategies.

(3) A few studies examine whether the moderating variables such as ecosystem type, industry, and evolution stage play an important role in the relationships. Comparative analyses can be developed to provide relevant insights into differences in future research.

(4) Wider research not focused on specific DBE fields, may lead to the identification of typical DBE clusters. In future studies, DBE architecture and governance can be examined by considering these clusters. Based on these clusters, the analysis of the relationships between them may be possible.

(5) Most studies examined DBE architecture and governance from the point of view of leading companies. Due to the complexity and diversity of DBEs, a multi-level analysis (macro, meso, and micro levels) for DBE design is difficult, and it is absent in the current literature. There will be a need for further studies on successful DBE architecture and governance design and alignment from a multi-level perspective (ecosystem, complementors, and individual buyers or sellers). For such research, a dynamic simulation model that intertwines conceptual and mathematical modeling can be studied.

This study gathers the different DBE architectural approaches and governance mechanisms that are divided over the varied studies to synthesis the available evidence on DBE design. The investigation guides managers for decision-making on DBE architecture and governance by presenting a comprehensive overview of possible approaches and helps efficiently moving from knowledge discovery to application. The study shows researchers toward which fields are worthwhile to prompt further research by indicating the gaps in the literature and the fields that were not studied sufficiently.

Threats to validity and limitations

The possible validity threats and related covering strategies are discussed in this part. A review protocol was applied for ensuring a rigorous review; however, unable to access all available databases due to inaccessible databases, there is a possibility of missing some relevant studies. To ensure construct validity, the search terms are adopted from a prior literature review on DBEs by including a list of synonyms and alternative spellings. Other related terms were obtained by considering the subject headings of the Scopus database. The search queries were discussed among researchers and tested via multiple trials. The abstract of the papers was checked manually. These helped ensure that the keywords and queries can obtain relevant studies to review; however, there may be studies that were not utilized due to the search terms (Márton, 2021). In addition, only journal articles were included, not book chapters, technical reports, theses, and conference papers. In result, this might result in the exclusion of some relevant studies within this domain. The threat of screening and selection bias was covered by predefined inclusion and exclusion criteria, and a careful evaluation. All criteria were discussed among the coauthors to ensure their quality. Nevertheless, there may be studies that were excluded (EC3) and could not be utilized due to the fact that they are not based on primary data (Fayoumi, 2016; P. Wang, 2021), although they are relevant and high quality. Publication bias was tried to overcome by including only published papers and applying the study quality assessment. This strategy also might exclude some relevant articles. In the data synthesis process of RQ2, the content analysis technique was used to classify data, and the intercoder reliability was tested. All findings are obtained from the collected data based on an SLR protocol. For the conclusion validity, the conclusions were evaluated by individual authors and improved.

Conclusion

In this study, the DBE literature was examined in terms of architectural approaches and governance mechanisms using the methodology of SLR. After presenting an overview of the reviewed articles, research questions are addressed. According to the SLR result, UML and BPMN are the most preferred notations for DBE architecture modeling, while most researchers have studied DBEs from business, and structural viewpoints. The client-server, P2P, and SOA are considered appropriate design patterns for the centralized, decentralized, and distributed systems, respectively. Hybrid design patterns are also reported by many researchers. On the other hand, the reported DBE governance mechanisms are identified and explained under five categories: governance structure, access and control, value co-creation and appropriation, resource orchestration, and trust and commitment. Similarities and differences in governance may be based on ecosystem types (transaction ecosystems or innovation/solution ecosystems), while in architectural design they may be based on platform configuration (centralized, decentralized, or distributed) linked to ecosystem types. Moreover, the relationships between DBE architecture and DBE governance were elucidated with the evidence in the literature. The findings indicate an alignment between DBE architecture and DBE governance for specific goals. Moreover, the gaps in the field were identified and future research avenues were offered to correspond to these gaps.

Considering the limitations of this study, it is limited by the focus on DBE architecture and governance. Other design considerations that may affect the success of DBEs also can be examined in further research. Additionally, some DBE architecture approaches, and DBE governance mechanisms may be overlooked. This shortcoming can be remedied by increasing the number of data sources in future SLR studies. Quantitative methods would facilitate examination of the relationships. In this study, the number of articles by research application domain is given as an overview of the reviewed articles (Figure 4). The analysis of the architecture and governance of DBEs by industry is not included in the research questions of this study since these data are not considered sufficient to make inferences for this analysis. In future studies, it can be investigated whether the architecture and governance of DBEs in different industries are similar and different, which industries are comparable, and what the differences and similarities are and what they mean. On the other hand, a specific business domain can be focused to test different DBE architecture and governance strategies using a simulation methodology. Moreover, creating a model, which determines the best way for DBE design would aid implementation in the future. Future research could also focus on different DBE types in DBE design. The recognized approaches and gaps from this article could serve as a guidance for next immediate work that could involve modeling DBE for the implementation of resilient DBEs.

Disclosure statement

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Data availability statement

The data that support the findings of this study are available from the corresponding author, ACS, upon request.

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Appendices

Appendix A

Table A1. An example of the inductive content analysis.

Reference	Content	Sub-categories	Main category
Zeng et al. (2019)	decentralized and network governance instead of traditional hierarchical governance	governance structure	governance structure
Bazarhanova et al. (2020)	from centralized control structures to a more federated governance approach	governance structure	
Saadatmand et al. (2019)	allocating decision rights	decision rights/ power	
Benitez et al. (2020)	the power structure shifted from the centrality of business association toward a mechanism of neutral coordination of complex projects	decision rights/ power	
Schreieck et al. (2017)	the platform owner is legitimized by ownership	ownership status	
Bonina and Eaton (2020)	when the platform owner was active in governance, and when the platform owner was not involved	ownership status	
Korpela et al. (2013)	delegating roles and tasks among ecosystem members and setting up schedules	division of roles	
Pikkarainen et al. (2020)	all parties very satisfied with the systemic model; clear roles and responsibilities	division of roles	

Appendix B

Table B1. Case processing summary.

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Judge 1 * Judge 2	18	100.0%	0	0.0%	18	100.0%

Table B2. Judge 1 * Judge 2 cross-tabulation.

		Judge 2					
		Access and control	Governance structure	Resource orchestration	Trust and commitment	Value co-creation and appropriation	Total
Judge 1	Access and control	3	0	0	0	1	4
	Governance structure	0	4	0	0	0	4
	Resource orchestration	0	0	3	0	0	3
	Trust and commitment	0	0	0	3	0	3
	Value co-creation and appropriation	0	0	0	1	3	4
Total		3	4	3	4	4	18

Table B3. Symmetric measures.

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.861	.092	7.325	<.001
N of Valid Cases		18			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.