Complex Systems Informatics and Modeling Quarterly (CSIMQ)
eISSN: 2255-9922
Published online by RTU Press, https://csimq-journals.rtu.lv
Article 168, Issue 30, March/April 2022, Pages 1–30
https://doi.org/10.7250/csimq.2022-30.01

Modeling Digital Business Ecosystems: A Systematic Literature Review

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Abstract. The changing business landscapes urge organizations to collaborate and combine their expertise to stay competitive. Organizations establish partnerships and collaborate via the Internet, which often happens dynamically and at fast pace resulting in formation of Digital Business Ecosystems (DBEs). DBEs are complex and their management requires having explicit and up-to-date information about them. Modeling enables thorough visual analysis and facilitates the understanding and formation of DBEs. It also allows viewing DBEs through multiple perspectives, as well as exploring alternatives in the course of DBE formation or management. This systematic review aims to synthesize existing studies pertaining to Conceptual Modeling for analysis, design, and management of DBEs. A total of 94 studies were included in the review. The findings suggest that there is a scarcity of existing Conceptual Modeling methods and tools supporting DBEs. Additionally, the extensive emphasis on DBEs' actors in modeling leads to an urgent need for the methods to be extended to support the establishment of holistic views for integrating multiple perspectives of DBEs. Future research should focus on these areas to facilitate the transformation of how organization's collaborations are viewed – from a single-organization to a multitude of viewpoints on organizational networks of collaboration, coexistence, and competition. Such models also need to support the key features of DBEs, such as resilience and automation.

Keywords: Digital Business Ecosystem, Enterprise Modeling, Conceptual Modeling, Systematic Review.

1 Introduction

To take a collaborative approach when conducting business has become the norm for organizations. It is a way of addressing the increased competition on the global market. By joining forces and partnering with each other, organizations combine their expertise and capabilities as a

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Reference: C. H. Tsai, J. Zdravkovic, and J. Stirna, "Modeling Digital Business Ecosystems: A Systematic Literature Review," Complex Systems Informatics and Modeling Quarterly, CSIMQ, no. 30, pp. 1–30, 2022. Available: https://doi.org/10.7250/csimq.2022-30.01

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way to attain agility and resilience. Given the advancement of information and communications technologies, many collaborations happen via the Internet, which fosters efficiency and enables easy entrance of new partners. This, in essence, leads to forming of a *Digital Business Ecosystem* (DBE).

A DBE, based on Moore's concept of *Business Ecosystem* [1], [2], emerges as an environment where socio-economic developments of interconnecting organizations and individuals are facilitated by information and communications technologies [3]. DBE has some characteristics that mark it off from traditional organizational networks: inclusion of digital environment, heterogeneity, symbiosis, co-evolution, and self-organization and self-optimization, which enables it to span different industries and exhibit diverse interests while being complied with collective actions [3], [4]. This raises the potential and significance of a DBE for meeting emerging business requirements, opportunities, changes, and threats. For most organizations, the concept of DBE presents a novel collaborative approach to leverage resources across multiple actors and even different industries to meet elaborated needs of customers [5].

A highly collaborative aspect of DBE also enhances the heterogeneity and the complexity of interactions and interrelationships among actors, such as partners and customers. Unforeseen events or business decisions taken by one actor influence a DBE's interrelated symbiotic actors and thus the whole DBE. Such complexity in DBEs makes it difficult to manage them as a whole, especially in real-time due to partial information provided by individual actors or suppliers. These issues reflect some of the many challenges related to DBEs, such the analysis, measurement, and management for DBE actors' interdependence optimization [5].

An example of a DBE can be drawn from the telecommunications industry. Many telecommunications companies are reinventing their traditional business models by establishing digital business ecosystems. Building upon their existing business network and assets, they bring in new actors, integrate their own and the new capabilities, and create and deliver new services. An instance of this development is the many newly-integrated home services, including a homecare service, which could be easily reached by consumers, families, and homes through the existing web-portal of the telecommunication operators. Contrary to a more traditional way of organizational collaboration, the independent entities join forces by bringing their assets and capabilities, such as the web-portal, the homecare expertise, and the understanding of digital homecare gadgets, into the environment of a digital business ecosystem. A significant aspect of such collaborations is that some actors, products or services exit the DBE and their offerings need to be either substituted or the loss mitigated. By ensuring the transparency and flexibility of the collaboration within the environment of a DBE, the replacement of entities with others who owns similar assets or capabilities can occur. This also facilitates the innovation, creation, and management of new products and services fulfilling new customer needs across markets.

Another DBE example is the Digital Vaccine DBE [6] consisting of heterogeneous actors such as multiple health service providers and health product suppliers, a digital health platform company, public organizations, investors, and citizens/consumers as individual users of the digital health platform. The complex interactions and co-evolution occurring among the interconnected symbiotic actors within the Digital Vaccine DBE in the interests of providing collective outcome − good quality preventive care to the citizens, involve various roles, tangible and intangible resources, products, services, capabilities, and public regulations.

There are many other DBE examples which are equally or more intricate. A key challenge is to capture and analyze them in order to support their design and management. Considering the complexity of DBEs, this cannot be done without raising the level of abstraction and without methodological guidance.

Conceptual Modeling as a means of capturing and depicting abstract representations of reality can be a good support for addressing the complexity and challenges related to DBEs. Enterprise Modeling (EM) being a part of Conceptual Modeling is focusing on capturing manifold perspectives of organizations in an integrated way and supporting management of organizations [7]. Considering the multi-perspective and multi-actor characteristics of DBE, EM has the potential of contributing to the development and management of DBEs [8]. Despite the much attention to DBE in the information system (IS) scientific literature, e.g., [5], [9], [10], limited efforts have been made to systematically investigate the use of Conceptual Modeling to DBEs development life cycle where the main activities include analysis, design, and management. Therefore, this study aims to address this gap by conducting a systematic literature review and synthesizing current studies on DBEs and the support of Conceptual Modeling for the DBE life cycle. The research questions for this study are:

RQ1. What Conceptual Modeling methods have been proposed for design, analysis, and management of DBEs?
With this question, we seek to investigate the modeling methods, consisting of modeling languages and modeling procedures, as well as the modeling tools, which have been used or proposed to support design, analysis, and management of DBEs.

RQ2. What is the intended purpose of modeling of DBEs in these studies? With this research question, we are interested in learning the different purposes in focus and various perspectives concerning modeling of DBEs. The reason we choose to investigate this aspect is because modeling purposes and the chosen perspective(s) are used by practitioners and domain experts to guide the overall modeling process and related activities. Hence, we are interested in knowing what are the purposes and perspectives that have been considered in the current research.

Concerning the aspect of management, this study focuses on investigating the support of modeling methods and tools for runtime management of DBEs.

This systematic review will advance scientific knowledge on the approaches for DBE modeling which is a highly relevant concern for improving continuous transformation from single to multi-organizational models with enabled mechanisms for horizontal and collective designs, management, and evolution.

The rest of this article is organized as follows. Section 2 gives background on the business ecosystem and DBE. Section 3 presents the methods of conducting this systematic literature review. In Section 4, results are synthesized and described. Section 5 provides a discussion on the research questions and the identified scientific gaps. Finally, concluding remarks are presented in Section 6.

2 Background

Moore in [1] suggested a new idea of cooperative networks which resembles an ecological ecosystem: a *business ecosystem*. A *business ecosystem* bears similarity to an ecological ecosystem as being a complex system involving evolution and co-evolution. Later, the concept of '*business ecosystem*' was further defined in [2] as: "an economic community supported by a foundation of interacting organizations and individuals– 'the organisms of the business world'." Various actors, suppliers, competitors, and others exist in the ecosystem. Customers, as members of the ecosystem, consume goods and services produced by the economic community. With time, co-evolution occurs, i.e., involved organizations and individuals evolve their roles and capabilities.

In recent years, the concept of ecosystem has gained awareness and significance in many fields, including information systems (IS). Several IS engineering-related applications have emerged such as *digital ecosystem* and *digital business ecosystem*. Briscoe and Wilde [11] extended a Service-Oriented Architecture with Distributed Evolutionary Computing and proposed a new distributed optimization architecture: a *digital ecosystem*. They argued that this was the first interpretation of a *digital ecosystem* that was more than a metaphor since the proposed architecture possessed some of the properties of an ecological ecosystem, such as robustness, self-organization, scalability, and sustainability. It also demonstrated emergent behaviors as observed in complex systems, such as being able to provide software services more than the constituent parts could offer. The *digital ecosystem* architecture incorporated a twofold optimization process as a part of the innovative form of distributed evolutionary computing. This enhanced the capability of solving more dynamic and complex problems through evolution of software services in the ecosystem by searching and forming new algorithms automatically in the scalable architecture.

The concept of *digital business ecosystem* was introduced, based on Moore's *business ecosystem* [2], in the Directorate General Information Society of the European Commission report on DBEs [12]. After the launch of the European Union Framework VI Information Society Technologies project Digital Business Ecosystems (grant ID 507953), the concept has been further defined and started to be widely used. A DBE captures the co-evolution between the business aspect and its partial digital representation in the ecosystem. It emerges as an environment, aiming for evolution, self-organization, and self-optimization, where interconnecting organizations and individuals in an economic community co-evolve their capabilities and roles by means of information and communications technologies [3]. As a biological metaphor emphasizing the interdependent actors in the ecosystem, the digital aspect of a DBE considers technical infrastructures distributing any useful digital representations, such as software applications, services, descriptions of skills, laws, etc., while the business aspect is similar to Moore's idea [2]. In this light, the key DBE elements are the actors (individuals and individual organizations), their roles and capabilities, the relationships or interdependencies among the actors, and the digital components.

Characteristics of DBEs are digital environment, heterogeneity, symbiosis, co-evolution, and self-organization and -optimization [3], [4]. Digital environment refers to platforms or technical infrastructures where a collection of digital tools, services, other digital representations, and information can be shared and used by DBE actors to create innovations and enhance performance [3], [4]. Heterogeneity denotes the constitution of DBEs with different features and types of companies, organizations, and actors. Symbiosis emphasizes the relationships among DBE actors that depend on each other in particular ways [13] and get benefits or co-create greater value through the interdependencies. Co-evolution refers to the collective transformation of DBE actors from one stage to another, especially their capabilities and roles, while facing opportunities and threats. Self-organization and -optimization indicate DBEs' ability to learn from their environments and accordingly respond by adjusting to the changing contexts [5], [14].

Following the characteristics of DBEs, this study adopted the aforementioned scope. We followed the phases of evolution of ICT adoption described in [12] and dedicated this study solely to the notion of "digital ecosystems", omitting the concepts and terms related to other types of "networked organizations", and related terms, such as, value chain, value constellation, value web.

The lifecycle of DBEs draws inspiration from Moore's interpretation [1], namely the first stage in satisfying consumers, the second stage in testing the potential of the DBE, the third stage in reaching profitability and stability, and the fourth stage of self-renewal or death. Based on this interpretation and findings reported in [5], [15], [16], the DBE lifecycle essentially consists of three phases, namely the emergence and formation, the stabilization, and the evolution. The emergence and formation phase is the initiation of a DBE which concerns the designing of the DBE, such as the architectures, platforms, technologies, processes, and services. During the stabilization phase, the DBE is improved with analysis of its different aspects and reaches its mature state. After that, the mature DBE is managed and monitored during the evolution phase in order to facilitate the changes in the DBE which can lead to a positive outcome, meaning the DBE and its actors co-evolve into a new stage, or a negative outcome of the dissolution of the DBE.

3 Research Methods

Kitchenham and Charters [17] constructed the guidelines for systematic review in software engineering based on various materials, including the Cochrane Handbook [18], the main source for conducting systematic review for healthcare professional and researchers.

We followed the guidelines and principles suggested by Kitchenham and Charters [17] and the Cochrane Handbook [18] as well as the PRISMA checklist for this study. The study protocol was developed with the support of a librarian and approved by all the authors. For the identification of studies, the search strategy was used in the selected electronic databases. Inclusion and exclusion criteria were applied during study selection, including the screening of titles and abstracts and the assessment of full-text articles. Data collection was performed with a defined extraction form. Qualitative analysis was conducted to present descriptive synthesis of the studies and extracted data relevant to the research questions. Additionally, forward and backward searches were conducted to compensate the risk of missing relevant studies due to the design and structure of electronic databases and search engines not being supportive for conducting systematic literature reviews in the fields of Computer Science and Information Systems [19]. Due to the lack of establishment of hierarchy of evidence and the variation of study design in Computer Science and the IS field, quality assessment was not performed in this study.

3.1 Study Identification

Systematic searches were conducted in Scopus, IEEE Xplore, ACM Digital Library, Web of Science, EBSCOhost, and ProQuest to retrieve candidate records. Table 1 shows the search fields used for each electronic database and the dates of conducting the searches. In this study, we retrieved candidate records in the six databases without setting a publication timeframe, meaning all records published from the oldest existing dates in the databases up till the dates of searches were considered in the identification and selection processes. A manual retrieval of candidate records was done with forward and backward searches based on the eligible full-text articles.

Table 1. Electronic databases used for study retrieval

Electronic database	Search fields	Date of search	Other
Scopus	article title, abstract, and keywords	14 Oct 2019, 29 Sep 2021	
IEEE Xplore	metadata (includes abstract, title text, and indexing terms)	14 Oct 2019, 29 Sep 2021	
ACM Digital Library	title, abstract, and author keyword	21 Oct 2019, 29 Sep 2021	searched in ACM Full-text collection
Web of Science	TOPIC/TS (title, abstract, author keywords, keywords plus)	21 Oct 2019, 29 Sep 2021	searched in Web of Science Core Collection
EBSCOhost	title, abstract, heading or keyword (phrase indexed, i.e., subject headings and author-supplied keywords), and subject terms (word indexed)	22 Oct 2019, 29 Sep 2021	searched in all EBSCOhost databases for only peer reviewed journals/materials
ProQuest	document title, abstract, and keywords/identifiers	22 Oct 2019, 29 Sep 2021	searched in all ProQuest databases for only peer reviewed journals/materials

3.2 Search Strategy

A search strategy was developed based on the key components of the research questions. As shown in Table 2, the four key components (digital business ecosystem, design, analysis, and management) were used to derive keywords and synonyms that were used for the search strategy.

Table 2. Key components and the matching keywords used for developing search strategy

Key component	Keyword and synonym used for search strategy
Digital business ecosystem	"digital business ecosystem" OR "digital ecosystem" OR "business ecosystem" OR "microservice AND ecosystem"
Design	design OR model OR architecture OR composition OR configuration OR development
Analysis	analysis OR evaluation
Management	management OR control OR governance OR monitoring OR measurement OR benchmarking OR assessment

For the key component "digital business ecosystem", "microservice AND ecosystem" were included as keywords given the current research trend in the IS field and the digital aspect of DBE (cf. Section 2). The synonyms "digital ecosystem" and "business ecosystem" were included as they were often used interchangeably with "digital business ecosystem". Design and analysis encompass a wide range of meanings but we concentrated on what they mean in information system development or Software Development Life Cycle. A broad range of keywords for the component management was used to capture the studies focusing on specific support for management of DBEs. The keywords for the search strategy did not contain "conceptual modeling" because the inclusion of it significantly narrowed the scope of the study identification and record retrieval in the databases, which is against the essence of conducting a systematic literature review aiming for a wide search and to be exhaustive.

The search strategy was used to conduct searches in each of the chosen electronic databases. Table 3 shows the total retrieved number of records in these databases. As the search syntax used across different databases were similar, the one used for Scopus is shown as follows: (TITLE-ABS-KEY ("digital business ecosystem" OR "digital ecosystem" OR "business ecosystem" OR "microservice AND ecosystem") AND (TITLE-ABS-KEY (design OR model OR architecture OR composition OR configuration OR develop*) OR TITLE-ABS-KEY (analy* OR evaluat*) OR TITLE-ABS-KEY (manag* OR control OR governance OR monitor* OR measur* OR benchmark* OR assess*))) AND (LIMIT-TO (LANGUAGE , "English")). Truncations in the syntax were used for eight of the keywords, including development, analysis, evaluation, management, monitoring, measurement, benchmarking, and assessment, for all these databases except the IEEE Xplore for which only five truncations were allowed. Also, the English language filtering was applied to all of the databases except the IEEE Xplore and the ACM Digital Library which do not support language filtering.

Table 3. Retrieved number of records in each database

Electronic database	Total number of records
Scopus	2355
IEEE Xplore	579
ACM Digital Library (the new ACM DL interface)	162
Web of Science	1170
EBSCOhost	429
ProQuest Platform	332

3.3 Study Selection

The total number of retrieved candidate records, including the electronic database searches (on 14, 21, 22 Oct 2019 and 29 Sep 2021) and manual searches (on 24 Apr 2020), was 5047. After removing the duplicates, each title and abstract of the 3031 records were independently screened against the selection criteria by two of the authors (C.H.T. and J.Z or C.H.T. and J.S.). Table 4 shows the inclusion and exclusion criteria of this study. Upon conflicts for each record, the one author who was not initially involved for the record was called in to conduct screening in order to reach consensus.

Table 4. Selection criteria used for the screening process

Inclusion criteria	Exclusion criteria
• original articles and conference proceeding papers • English language • studies focused on DBE	• tutorial, proceeding editorial, and volume editorial • positioning papers without concrete results • studies which are not in the field of information systems (IS), information technology (IT), computer sciences, management/business management • management/business management studies without IS/IT components

Subsequently, 2574 records were excluded based on these criteria. The remaining 457 articles were read in full by two of the authors (C.H.T. and J.Z or C.H.T. and J.S.). The one author who was initially not involved for the record was called in for a discussion on the disagreements when comparing the assessments of eligibility. Finally, a consensus was reached among all researchers on the inclusion of 94 studies in the final qualitative analysis (Figure 1). Full-text articles were excluded with reasons, such as, not being accessible by the authors; meeting the exclusion criteria; being visionary or positioning studies without providing concrete results; containing no aspects related to modeling or no model; or investigating only technical artifacts of a digital ecosystem.

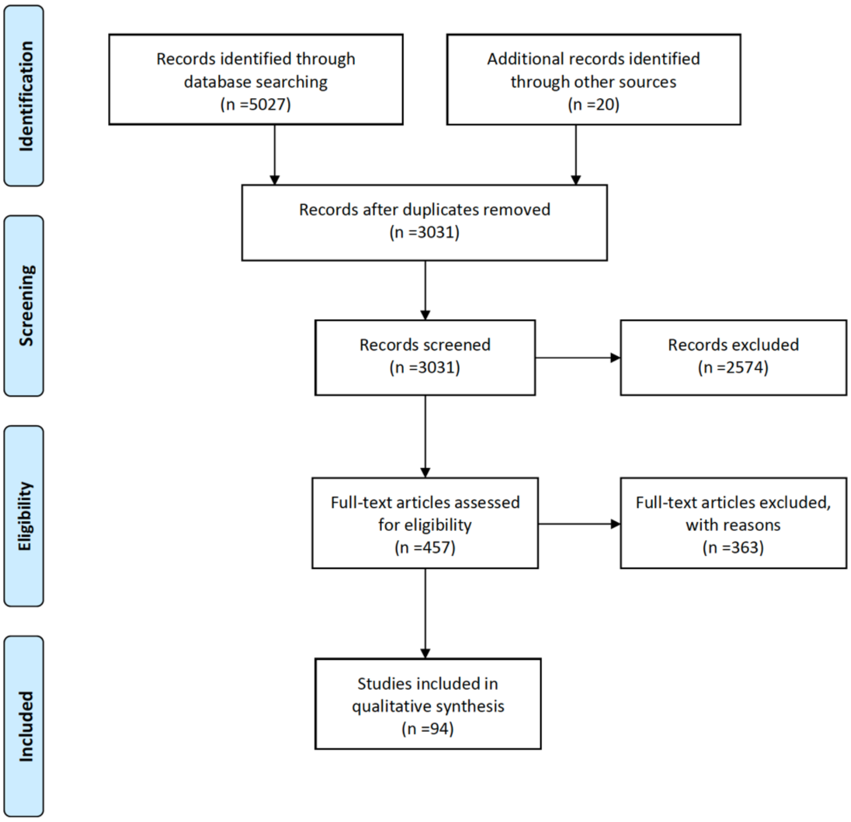

Figure 1. PRISMA flow diagram of the study selection process

3.4 Data Analysis and Synthesis

Based on the research questions, we developed a data extraction form including the predefined known themes: conceptual modeling method, modeling language, metamodel, notation, modeling procedure, tools, model (conceptualization, ontology), requirements for design, and purpose as well as simulation method. Narrative synthesis of the findings was conducted for this review by adopting a thematic analysis approach [20]. Throughout the analysis process, the predefined themes were either verified or revised. "Simulation method" and "model (conceptualization, ontology, etc.)" were removed from the framework and used as checklist items to mark if the studies focused on simulation or if there are any modeling elements in the studies. "Requirements for design" was removed as we did not observe this theme emerging prominently from the included studies.

4 Results

This section presents the results of the analysis. Its structure is based on Karagiannis and Kühn's definition of modeling methods [21], namely, a modeling method consists of a modeling language, containing a notation and a metamodel (or a language construct), and a modeling procedure, describing steps and guidelines for applying the language to create valid models. The topics presented are outlined in Figure 2. Section 4.1 presents the different purposes and perspectives of DBE modeling. Section 4.2 reports the Conceptual Modeling methods used in the context of a DBE, in terms of the modeling languages and the modeling procedures. The supporting modeling tools for DBE modeling are discussed in Section 4.3. Studies having research purposes that are not directly related to modeling of DBEs but still use modeling are presented in Section 4.4.

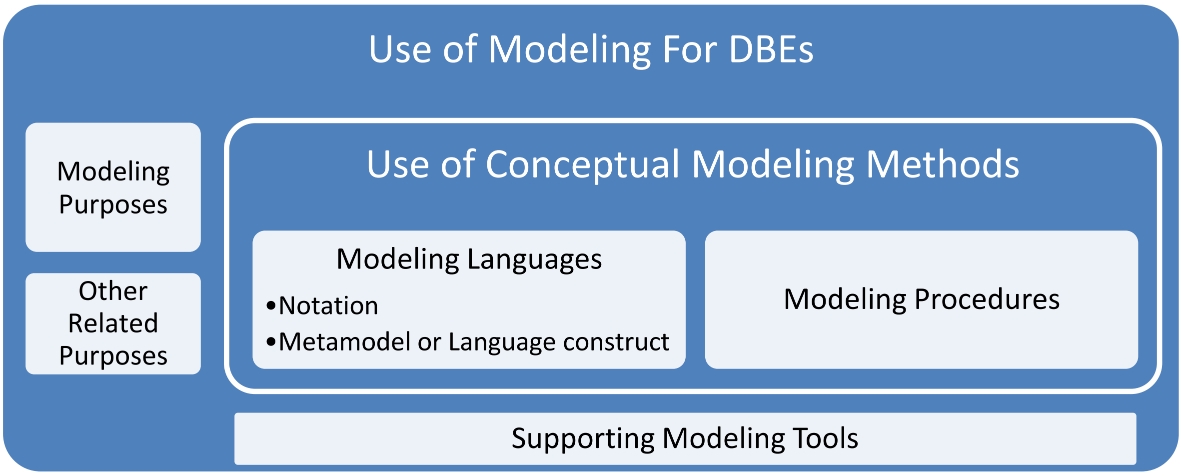

Figure 2. The structure of the results section

4.1 The Purposes and Multi-perspectives of Digital Business Ecosystems Modeling

The modeling purposes of the majority of the studies focusing on DBE modeling concerned the analysis and/or design of a DBE and its elements. A DBE addresses many aspects of organizational and information system integration; thus, it needs to be investigated and designed from various points of view, such as strategies, actor involvement, products, processes, infrastructures. Hence, the studies were categorized by different *perspectives*. A perspective is a psychological construct which constitutes a conception of reality and helps to reduce complexity by constituting sense [22]. In this light, Sandkuhl et al. [23] suggest that a modeling perspective "urges the modeler to look at the enterprise from a specific angle and guides the modeling process in a way that specifically captures and analyzes the perspective." The following perspectives were observed in studies with DBE-related modeling purposes.

Actor/Role perspective: In total, 35 studies (87.5% of the 40 studies with DBE-related modeling purposes) focused on the actor/role perspective [13], [24]–[57]. By actor and role, we mean those who are performing tasks and are responsible for achieving intentions. This is in line with how modeling languages such as UML [58] and 4EM [23] interpret the notion of actors. Of the 35 studies, 23 studies contained models with specified language constructs [26], [28], [29], [33], [35], [37], [40]–[57]. This perspective was used by most of the included studies while modeling DBEs. It aims at a DBE from the perspective of the actors and/or roles involved within the DBE.

For instance, actors in DBEs were emphasized using the term partners in [13] where a modeling methodology for analyzing the partners' interdependencies within DBEs was presented with an example case. The authors further proposed to analyze behaviors within a DBE based on different partner roles in [31].

In [41], actors related concepts in Multi-Agent System-based DBEs were depicted in ontology-based metamodels aiming to support modeling of DBEs.

There are also some other domain-specific examples. In the utility and energy domain, the power exchange among different roles were addressed in a framework based on mathematical models for designing and optimizing MicroGrid by utilizing Alliance Builder in [24]. Energy efficiency was addressed by analyzing inter-actor relationships and how the actors related to energy efficiency gaps within the DBE in [26]. A DBE for multi-commodity energy systems was analyzed and designed from a multi-actor perspective in [38]. In telecom and 5G network, [25] presented an analysis of 5G network business models and ecosystem positions of actors (micro-operators).

Information system architecture and component perspective: This perspective concerns any technical artefacts, components, structures, architecture, such as software and hardware components, interfaces, IT-services, information systems, and technologies (technological devices).

In total, 14 studies (35.0%) looked into this perspective in their models ([28], [32], [34], [37], [38], [40], [44]–[46], [53]–[55], [59], [60]). Of the 14 studies, 11 studies contained models with specified language constructs ([28], [37], [40], [44]–[46], [53]–[55], [59], [60]).

Some common technical artefacts observed in these studies included software and software components ([37], [40], [44]–[46], [55]), information systems ([38], [53]–[55], [59]), IT-services ([38], [40], [54], [55]), and technologies and technological devices ([37], [44], [45], [59]).

Product and business service perspective: For this perspective, business services and products were concerned. A product is defined as a good or a tangible commodity that is tradable [61], whereas a service is intangible [61], [62]. Of the included studies, only 4 studies (10.0%) emphasized business services by modeling their relationships with actors and business service life cycle within a DBE ([36], [50], [54], [55]). Of these 4 studies, 3 studies contained models with specified language constructs ([50], [54], [55]).

Business process perspective: The process perspective means a sequence of activities or tasks performed by people or equipment to realize some business goals [63]. This perspective concentrates on business processes among multiple DBE actors. 4 studies (10.0%) integrated the perspective in the models or proposed frameworks ([29], [31], [40], [47]). Of the 4 studies, 3 studies contained models with specified language constructs ([29], [40], [47]).

For instance, in [47] business activities and processes were shown to be mapped with actors in a matrix-based model in a framework of the DBE for complex products.

Negotiation process perspective: As compared to the business process perspective, the negotiation process perspective emphasized only business contract/agreement negotiation processed within DBEs. There were 2 studies (5.0%) which proposed a negotiation and quality evaluation protocol [27] and metamodels for e-business negotiation [35].

Value perspective: The value perspective is represented in models by any value object that is of value to an actor [64]. In total, 7 studies (17.5%) focused on the value perspective by analyzing the value objects, such as money and services, exchanged among DBE actors, and all contained models with specified language constructs ([33], [42], [50], [52], [57], [65], [66]).

Resource perspective: For this perspective, a resource means "an asset owned or controlled by an individual or organization" [67]. 5 studies (12.5%) integrated the resources within DBEs as a perspective in the models ([48], [51], [56], [66]). Of the 5 studies, 4 studies contained models with specified language constructs ([48], [51], [65], [66]).

In [65], the resource perspective was emphasized by modeling a DBE actor's enclosed core resources and global knowledge, manufacturing, and deployment resources.

Decision perspective: 2 studies (5.0%) considered the decisions in DBEs as an important perspective and both contained models with specified language constructs.

The decisions taken in a DBE concern the DBE as a whole and all DBE actors' interactions. This was observed in [43], where decisions, such as joining a DBE, resource and staff allocation, and pricing scheme selection, were elaborated together with interactions among actors within a DBE; and in [60], where decision-making was suggested as a core element of the model in relation to the aggregated emotion state (overall condition) of the whole DBE.

Policy perspective: The policy perspective concerns both policies and regulations. Policies, including external and internal policies, are usually rules that are made by entities to carry out a plan and achieve certain aims. Regulations are made and imposed by public agencies as restrictions with the effect of law [68]. This perspective was shown in 2 studies (5.0%), where both of them contained models with specified language constructs.

Policies, legal regulations, and related concepts were considered significantly in the DBE-specific metamodel in [40], where the authors stated that it covers mandatory, legal, aspirational, and not implementable policies which are guidelines or goals that define the desired state inside a DBE; and in [66], where a legal layer concerning legal regulations, compliance, and obligations was included as part of the modeling framework.

Capability perspective: The capability perspective was aimed to cover a broad view on the concept of capability as a means of capturing context dependent ability and capacity. More information about the diversity of the capability definitions is available in [69]. 3 studies (7.5%) integrated capabilities presenting in DBEs as a perspective while modeling DBEs ([48], [51], [53]) and all of them contained models with specified language constructs.

In [53], the capability perspective was elaborated and placed in the context of a DBE in an example case while investigating how a capability-driven approach can facilitate the use of open data for DBE management.

Goal perspective: A goal can be either a business goal concerning "the business or state of the affairs the individual or organization wishes to achieve" [70] or a system goal meaning "what the target system should achieve" [71]. In [55], [72] (5%), a specific focus was placed on the goal perspective within DBEs as illustrated in the proposed reference model and further developed theoretically. Both of the studies contained models with specified language constructs.

Emotional state perspective: This perspective was suggested in [60] based on human-emotion theories with the aim of describing the "feelings" or conditions of each single actor and the overall status of a DBE. Specified language constructs were defined for models used in this study.

Although multi-perspective modeling has been recommended and adopted in many well-established approaches, such as 4EM [7], Active Knowledge Modeling [73], ArchiMate [74], and MEMO [22], the results concerning different modeling perspectives in the context of DBEs suggested that these perspectives have not yet been well-integrated in existing approaches and some of these important perspectives were neglected (as shown in Figure 3). Despite the common discussion in the included studies on issues about regulating and governing in DBEs, the policy perspective in DBE modeling was observed in only two studies. This shows a lack of support in analyzing policies, rules, regulations, legal and governance issues by means of modeling. Because of the features of decentralization and loosely coupled structure of DBEs, novel viewpoints on how the policy perspective in such multi-actor constellations could be supported by modeling should be prioritized. Another noteworthy perspective is the capability perspective. Considering the development and definition of both *business ecosystems* and *digital business ecosystems*, the notion of capability has been emphasized as a significant element, especially related to the dynamics when ecosystems evolve over time. However, the capability perspective was observed in only three studies.

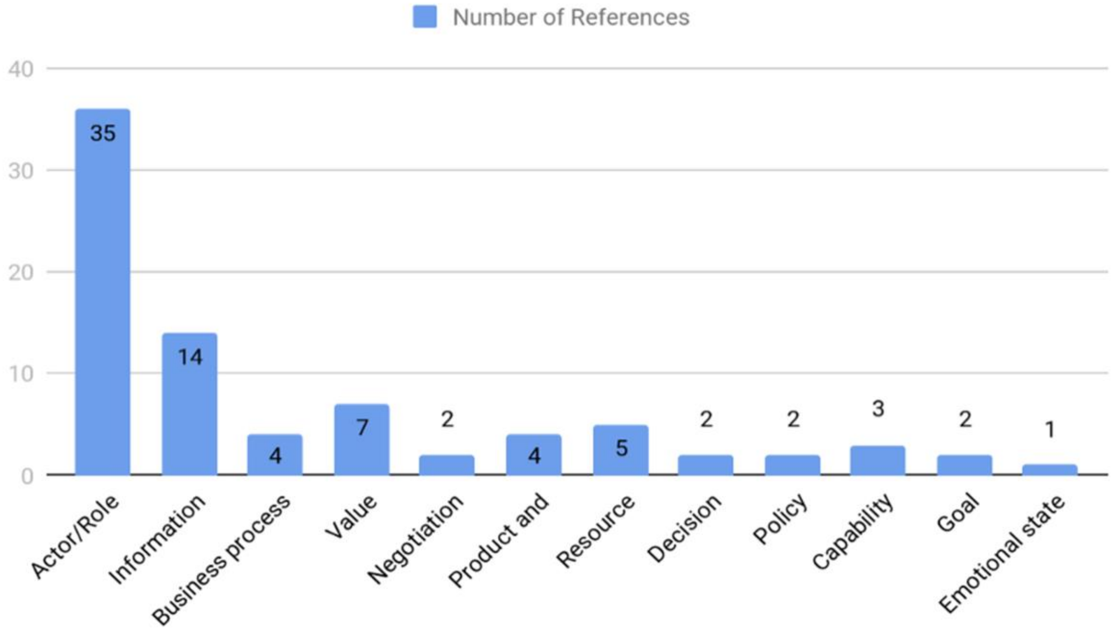

Figure 3. Numbers of studies for each of the DBE modeling perspectives

4.2 Conceptual Modeling Methods of Digital Business Ecosystems

As mentioned previously, this study adopts Karagiannis and Kühn's definition of modeling methods [21] and considers that a modeling method consists of a modeling language, containing a notation and a metamodel (or a language construct), and a modeling procedure.

The following sections present an overview of how conceptual modeling methods and modeling components − languages, notations, metamodels, and procedures, have been applied to the context of DBEs in the included studies. It has shown that several well-established languages have been used for DBEs. However, clear mechanisms of how these languages have been applied to the context of DBEs and how they support the analysis, design, and management of DBEs are not elaborated in the studies. Concerning the language constructs, most studies have included the DBE elements "actor" and "role", which are the two most straightforward elements considering the feature of DBEs as multi-actor constellations. A holistic language construct, taking into account all elements that can be derived from the definition of DBE has not been observed. For the modeling procedures, some similarities are shared among the included studies. The initial phases of the procedures usually concern the scope of a DBE – defining boundaries and identifying involved actors. Then, the parameters concerning actors' interactions, such as relationships, strategies, business goals, and process, are addressed. Towards the final phases of the procedures, analytical activities based on different notions are suggested to be performed.

4.2.1 Conceptual Modeling Language

Based on the definition of a Conceptual Modeling method, this section presents the modeling languages used in the included studies, which are summarized in Table 5.

Table 5. Numbers and types of conceptual modeling languages

Conceptual modeling language	Number of studies	Reference
UML and adapted UML	7	[27], [35], [43], [46], [53], [55], [75]
Enterprise modeling-based	3	[48], [51], [53]
System Modeling Language	1	[50]
BPMN	4	[47], [77], [78], [79]
e^3-value	4	[38], [42], [52], [57]
ArchiMate	2	[33], [59]
Ontology-based	4	[30], [33], [40], [41]
DBE-specific language	2	[80], [81]
Matrix-based	4	[13], [26], [44], [65]
Social network graph	4	[32], [82], [83], [84]
Canvas-based	3	[38], [65], [85]
Unspecified language/model	19	[13], [28], [29], [32], [34], [37], [38], [39], [44], [47], [49], [50], [51], [54], [56], [60], [66], [86], [87]

20 studies used or adapted existing languages. UML was used in several studies [53], [55], [75], such as class diagrams in [35] for defining DBE negotiation protocol and in [43] for a DBE analysis and modeling framework: BEAM. Adapted UML sequence diagrams were used in [27] for representing DBE negotiation protocols and adapted class diagrams were used in [46] for representing different perspectives of a DBE. Enterprise modeling-based languages were shown as 4EM and adapted 4EM models in [51] and [48] and Capability-driven Development method related models in [53]. System Modeling Language (SysML) was suggested in [76] for ecosystem modeling, specifically for smart grid applications based on the Smart Grids Architecture Model framework. BPMN-based models were shown in [47], [77], [78], and [79] for processes which occurred in DBEs. E^3-value modeling was used in [38], [42], [52], and [57] for modeling the different types of actors and value exchanges among them in a DBE. ArchiMate was adapted for use in [59] and was mapped with the V^4 ontology for DBE modeling and analysis in [33].

Ontology-based languages such as OWL and $(OWL)^2$ were used in [30] and [40]. The authors of [41] proposed an ontology-based approach: MAS2DES-Onto, to support the design of DBEs.

Other types of modeling languages were also shown in several studies. Matrix-based models were used in [26] for actors and objectives and actor interactions in the DBE; in [65] for value proposition in IoT DBEs; and in [44] and [13] for DBE actor relationship and interdependence analysis. Social network graphs were used to depict actors in DBEs ([83], [84]), such as in [82], a study with focus on analyzing trust relationship among the actors in the DBE, and in [32], focusing on the design of DBEs for knowledge-intensive business service firms. Canvas-based models were adopted in [65], [38], and [85]. Furthermore, there were a number of other conceptual modeling languages and models used in DBE studies ([28], [29], [32], [34], [37]–[39], [44], [86], [13], [47], [60], [66], [49]–[51], [54], [56], [87]).

A contributor to research on modeling languages of DBEs has been the EU Framework VI Digital Business Ecosystem Project which has, among its other aims, resulted in publications [80] and [81]. Both publications reported results of the development of a DBE-specific Domain Specific Language (called Business Modelling Language, BML). However, a demonstration of the use of the language was not presented explicitly.

4.2.1.1 Language Construct and Metamodel

Metamodels (or language constructs) are one of the two constituents of modeling languages according to the definition of modeling methods. Metamodels are formally defined models. They contain statements about models. These statements define the constructs or express true and desired properties of the constructs in modeling languages [88]. Language constructs consist of modeling language elements but are not as formal as metamodels since the statements of the constructs are not defined in models.

To address the language constructs and metamodels for DBEs, five DBE elements, namely actor, role, capability, relationship, and digital component, were identified as the key concepts based on the definition of DBEs (cf. section 2). Studies with language constructs and/or metamodels were checked against these five DBE elements (see Table 6). With a “defined” language construct, we mean that the DBE modeling elements of the language construct were clearly stated and described in the study, whereas “partially defined” means that the elements, without being clearly described, could be identified in texts or models. In this regard, DBE-specific metamodels were in concern. Some studies utilizing well established languages may have existing metamodels used for general purposes, which was outside the scope of this study.

Among the 47 studies with the use of modeling languages and models, 31 studies (66.0%) have language constructs and/or metamodels. Of these 31 studies, 24 studies (77.4%) have clearly defined the language constructs, whereas 6 studies (19.4%) have only partially defined them. Concerning the five DBE elements, the actor element has been observed in the language constructs of 27 studies (87.1%); the role element in 16 studies (51.6%); the capability element in 7 studies (22.6%); the relationship element in 8 studies (25.8%); and the digital component element in 11 studies (35.5%). Observing the studies published over the past five years as compared to earlier studies, moderate trends show that the capability element has been addressed more but the relationship and digital component elements have decreased in numbers.

In [80], Meta Object Facility (MOF) levels of a DBE-specific Domain Specific Language, called Business Modelling Language (BML), was mentioned without detailed explanation of the language construct and the metamodel. In a related study [81], the MOF levels of BML, of which the M2 level contains the BML metamodel, and the metamodel were further described. In [35], negotiation, information, and protocol metamodels for e-business negotiation processes within DBEs were proposed. In [37], a metamodel was suggested for a healthcare-specific DBE. Ontology-based DBE-specific metamodels were presented in [40] and in [41]. In [43], the author suggested a high-level metamodel of DBE using UML. In [46], a DBE metamodel based on business, software, and innovation viewpoints was shown in adapted UML. In [53], the Capability-Driven Development metamodel and its extension for open data in DBEs were described. In [54], a simple metamodel for DBEs was proposed based on interviews with experts. In [55], metamodels, in the form of reference architecture, for trust-based DBEs were proposed by the authors.

Among these studies, most studies defined the metamodels representing the concepts and model elements for DBEs in order to support modeling activities and the designing of DBEs ([37], [40], [41], [43], [46], [53], [55]), or requirements engineering activities [54]. Three studies focused on developing modeling languages for DBEs and thus defined the MOF levels and/or metamodels as the basis for the languages [35], [80], [81]. Of the 10 studies with metamodels, only one study (10.0%) proposed an extension of an existing metamodel for the open data DBE context based on the Capability-driven Development metamodel as presented in [53].

4.2.1.2 Notation and Visual Presentation

Notations (or visual presentations) as the other constituent of modeling languages concerns graphical symbols representing concepts, relationships, and constraints which can be applied by using the modeling languages.

Among the included studies, visual presentation in the form of models, tables, script-based, and algebra-based notations were used in several studies. However, most studies did not describe or clearly define the notations that they used. In [43] and [27], UML class diagram and adapted UML Sequence Diagrams were used without explaining the notation. Also, adapted UML class diagrams were used in [46] where only the notation used for relationships was defined.

Table 6. Application of language constructs, metamodels, and DBE elements

Ref.	Language	Language construct; metamodel (-/✓)	DBE elements (-/✓)				
			Actor	Role	Capability	Relationship	Digital component
[80]	BML	No; MOF levels	-	-	-	-	-
[28]	Other	Partially defined; -	-	-	-	-	✓
[81]	BML	Defined; ✓	✓	-	-	✓	-
[35]	UML	Defined; ✓	✓	✓	-	-	-
[43]	UML	Defined; ✓	✓	✓	-	-	-
[29]	Other	Defined; -	✓	-	✓	-	-
[82]	Social network graphs	Defined; -	✓	-	-	✓	-
[26]	Matrix-based	Defined; -	✓	-	-	✓	-
[44], [45]	Matrix-based	Defined; -	✓	✓	-	-	✓
[46]	Adapted UML	Defined; ✓	✓	✓	-	✓	✓
[37]	Other	Partially defined; ✓	✓	-	-	-	✓
[40]	OWL	Defined; ✓	✓	✓	-	-	✓
[41]	OWL	Defined; ✓	✓	✓	✓	-	✓
[59]	ArchiMate	Defined; -	-	-	-	-	✓
[13]	Matrix-based & other	Defined; -	✓	-	-	✓	-
[65]	Matrix- & canvas-based	Defined; -	✓	-	-	✓	✓
[33]	ArchiMate & V^4 ontology	Defined; -	✓	✓	✓	✓	-
[60]	Other	Defined; -	-	-	-	-	-
[54]	Other	Defined; ✓	✓	✓	-	-	✓
[52]	e^3-value	Defined; -	✓	✓	-	-	-
[47]	BPMN & other	Partially defined; -	✓	✓	-	-	-
[66]	V^2 notation & other?	Defined; -	✓	-	✓	✓	-
[42]	e^3-value	Defined; -	✓	✓	-	-	-
[55]	UML	Defined; ✓	✓	✓	-	-	✓
[53]	Enterprise modeling-based	Defined; ✓	✓	-	✓	-	-
[57]	e^3-value	Partially defined; -	✓	✓	-	-	-
[48]	4EM	Partially defined; -	✓	✓	✓	-	-
[51]	4EM	Partially defined; -	✓		✓	-	
[87]	Other	Defined; -	✓	-	-	-	-
[50]	Other	Defined; -	✓	✓	-	-	-

-, not shown or cannot be observed in the study; ✓, shown or can be observed in the study.

There were few studies that explained the notations used. Notation for ArchiMate used in [33] was clearly defined with mapping of the V^4 ontology and partially defined in [59]. In [42] and [57], the notations used for e^3-value was explained in the text. A simple modeling was developed for interdependence among actors in the DBE in [13] where the notation was illustrated and defined. In [66], the notation for the four different layers of the Service Analysis and Engineering Framework was illustrated and described in the text. The notation for models applying Capability-driven Development to open data and ecosystems was illustrated and defined in [53].

4.2.2 Conceptual Modeling Procedure

As mention previously, a modeling procedure in combination with a modeling language forms a modeling method according to Karagiannis and Kühn's definition [21]. Modeling procedures describe steps and guidelines for applying the language using the modeling method to create valid models. In this section, we consider only the conceptual modeling procedure, whereas additional procedures and recommendations concerning high level processes and various aspects of DBE management are summarized in the Discussion section.

The conceptual modeling procedures presented in the studies were categorized into those pertaining to general guidelines (3 studies; 21.4% of 14 papers) and the others referring to step-by-step processes denoting prescriptive guidelines (11 studies; 78.6%). Among the 11 studies with prescriptive guidelines, some similarities in the steps were observed. For the initial phases of the procedures, different terms were used, such as boundaries, scope, social agents, roles, species, actors, or partners, which essentially concerned the scope of a DBE and addressed the defining of the scope and the identifying of involved actors. After mapping out the scope, boundaries and actors, the middle phases of these procedures emphasized the different parameters concerning actors' interactions, such as relationships, strategies, business goals, and processes. Towards the final phases of the procedures, analytical activities based on different notions, such as value analysis, control point analysis, interdependence analysis, factor and change analysis, and behavior analysis, were suggested to be performed.

4.2.2.1 General Guidelines

In [46], four general steps for modeling DBE based on STRategic Ecosystem Analysis Method (STREAM) were described. These steps were: (1) gather information; (2) identify entity and relationship types; (3) capture actual entities and relationships; and (4) conduct analysis to answer ecosystem-related questions.

In [40], the authors emphasized the choice of modeling strategies and approaches to DBE modeling depending on the purpose of modeling, the level of detail, the use case, and the scope of DBE. Top-down approach, bottom-up approach, and policy-based modeling were named.

In [33], practices for DBE analysis, such as profitability analysis, and resource selection analysis were, suggested.

4.2.2.2 Prescriptive Guidelines

In [89], [90], and [91], a methodology for designing a DBE was proposed with five phases: (1) define roles of different digital species; (2) define digital species collaboration; (3) make digital species intelligent; (4) protect digital ecosystem by implementing security requirements; and (5) enable, improve, and construct individual digital species.

In [26], multi-actor ecosystem analysis using the MACTOR (Matrix of Alliances and Conflicts: Tactics, Objectives and Recommendations) method was demonstrated with four steps: (1) identify actors; (2) identify business and strategic objectives; (3) position actors in relation to strategic issues; and (4) formulate actors' interaction matrix.

In [44] and [45], the Methodology of Business Ecosystem Network Analysis (MOBENA) was proposed for analyzing DBE with four phases: (1) ecosystem perimeter, elements and relationships (actors and technologies identification); (2) ecosystem model representation and data validation; (3) ecosystem analysis (Business Ecosystem Value Analysis and Business Ecosystem Control Point Analysis); and (4) ecosystem evolution.

In [13], three stages were demonstrated for modeling partner interdependence with the proposed DBE interdependence modeling methodology. These stages were: (1) DBE partner identification; (2) DBE interdependence type and substance articulation; and (3) DBE interdependence representation.

In [76], the authors proposed a framework for DBE modeling consisting of nine stages divided into three parts. Part I – business ecosystem architecture development to (1) identify boundaries of ecosystem; (2) identify actors and their roles; (3) identify value propositions and business models; and (4) identify interaction among actors. Part II – factor analysis includes investigation of (5) factors and their impact on actors, roles, and interaction in ecosystem and (6) potential changes in the ecosystem. Part III – ecosystem simulation and reconfiguration for (7) ecosystem simulation to identify ecosystem reaction towards the potential changes; (8) ecosystem reconfiguration due to changes; and (9) business model reconfiguration. The methodology of business ecosystem architecture development proposed in a related study [50] was dedicated to the part I of the authors previous work [76], where a fifth stage – verification of business ecosystem architecture design was added to complement the original four stages.

In [47], a methodology for the development of the DBE model was suggested with five steps: (1) scenario analysis of products under consideration; (2) formulation of objectives, business goals, and requirements; (3) modeling of ecosystem structure; (4) designing and analyzing of underlying ecosystem architecture; and (5) prototypically implementing and evaluating ecosystem architecture.

In [31], the authors presented a behavior analysis framework, for analyzing the behavior of multi-agents in DBEs, with three stages: (1) DBE scope analysis (elicit social agents and observe how partners use digital agents within a DBE); (2) business process analysis; and (3) behavior articulation.

4.3 Modeling Tool

Modeling tools for DBEs are scarcely addressed in the included studies. In [59], an open modeling tool within the Open Models Initiative Laboratory (OmiLAB) supporting DBE design and management was envisioned. In [50], a web-based tool, namely Ecosystem Map Generator, was briefly mentioned without further elaboration on the construction and demonstration of the tool. It was said to facilitate some stages of the methodology of business ecosystem architecture development proposed in the same study, including identification of actors and roles, interaction among them, value propositions, and business models.

Tools for visualizing the relationships among actors and roles within DBEs, including the Business Ecosystem Explorer (BEEx) ([92]–[98]) and the ecoxight ([99], [100]), were proposed, but these tools are not intended to support modeling as their primary focus. A number of tools for simulation of DBEs have been developed, e.g., for simulating the network of interactions, providing metric measurements, and identifying potential partners ([101]–[103]), and management of partnerships within DBE [104].

4.4 Other Purposes

Among the included studies, several had other topics as the main research concern, which, therefore, were beyond the scope of this study. Despite being out of this scope, these studies addressed modeling in some way. Thus, they were considered eligible during the full-text reviewing process (c.f. the reasons of exclusion for full-text articles in section 3.2) and relevant as their contributions intersect with modeling of DBEs. These contributions are listed in the following:

- Two research groups presented visualization tools for representing actors and relationships within DBEs, namely, Business Ecosystem Explorer (BEEx) ([92], [94], [96]–[98]) and ecoxight ([99], [100]). The BEEx tool allows users to visualize DBEs' actors and their relationships based on various data input and presented in four different layouts – force-directed layout, tree map layout, chord diagram layout, and matrix layout. The ecoxight tool visualizes actors and relationships within DBEs as nodes and edges and provides four different views on its interactive interface – path view, category view, geography view, and as a ScatterNet (scatterplot).

- An agile approach of modeling and visualizing DBEs conducting through collective means was presented together with the BEEx tool and demonstrated in cases [93]–[97]. We also identified tools for some management tasks related to DBEs. More specifically, a tool for finding right partners [104], performance indicators for assessing collaborative benefits [105]–[110], an architectural framework for DBE interoperability [111], architectural options for managing usage control of data within DBEs [112], and a method supporting strategic analysis for understanding companies' roles and functions in DBEs [113], [114] were suggested. Also, two studies concerned working procedures for modeling, designing, and implementing technical structures of DBEs [115], [116].
- Simulations of DBEs were conducted [117]–[121] with different intentions, such as displaying measurements based on simulated interactions within DBEs [102], simulating and identifying suitable business partners within DBEs [101], [102], and simulating and evaluating the influence of performance indicators within DBEs [106]–[110].
- Requirements analysis of DBEs was discussed, specifically in the context of open data [122]. Also, to facilitate defining new user requirements and functionalities for cloud integration of DBEs, a digital business ecosystem integration framework was proposed [123].
- The lifecycle of DBEs was addressed in three studies, including a narrative of the idea of DBE development over time [124]. Analysis of how DBEs form around hub firms in their emerging stages was conducted in [125]. From the perspective of open innovation, how SMEs conduct open innovation through collaboration in DBEs and how this affect the development of DBEs, were investigated [126].
- Two studies focused on the comparison among different DBEs. Similarities of digital transformation among five DBEs were presented in [127]. Based on corporate capital relations, DBEs in different industries and domains were compared and analyzed in [83].
- An economic viewpoint was taken in [128] to investigate how to evaluate values obtained by DBEs actors based on proposed economic models.
- Surrounding conditions and factors of DBEs were taken into account in two studies. [129] explored how different structures of DBEs affect companies' performances under different situations (negative and positive shocks). The authors of [130] suggested explanations of which ecosystem designs are beneficial under which conditions through a qualitative approach.

5 Discussion

Recalling the characteristics of DBEs, namely, digital environment, heterogeneity, symbiosis, co-evolution, and self-organization and -optimization (c.f. Section 2), we observed that the included studies in this review have not directly addressed these characteristics in relation to presenting their research outcomes. However, some of the proposed outcomes reflected these characteristics by conceptually capturing related information in DBEs.

The characteristic of heterogeneity has been reflected in the most studies since it denotes the actors within DBEs. This is corresponding to our results suggesting that analysis of DBEs' actors has been the major focus of DBE modeling among the included studies. Despite the significant emphasis on actors, the characteristic of symbiosis focusing on the relationships among actors has not been addressed to the same extent. Two studies, nonetheless, provide solid basis for capturing the conceptual information related to the relationships among the different actors in DBEs by investigating the interdependency [13] and dynamics and motivations [66]. Concerning the digital environment, several studies emphasize the digital components and artifacts in their models or language constructs ([40], [46], [55], [59]), which establishes research foundation for further work on fully supporting the characteristic of digital environment, in terms of creating innovations and enhancing performance by means of shared platforms or technical infrastructures, with modeling methods. Few studies have taken into account the conceptual information for the characteristics of co-evolution and self-organization related to the collective transformation in actors' capabilities and roles and the adaptation to changing contexts. This corresponds to our results showing that the capabilities and decisions in DBEs have not been represented sufficiently in the proposed models and methods. The insufficiency also reflects that the dynamics and ever-changing aspects of DBEs are difficult to address. The attempts in investigating how collaborative decisions can be based on overall conditions of DBEs [60] and how capabilities can be designed to support dynamic contexts and resilience in DBEs [51], [53] can be used as starting points in improving realizations of the two characteristics in further research.

In the following sections, the research questions are discussed in relation to the results of this study. The importance of the studies focusing on other related research topics in the context of DBEs are also discussed.

5.1 RQ1: Methods for Analysis, Design, and Management

Concerning the research question 1, our results suggested that few studies presented a holistic and comprehensive conceptual modeling method for DBEs. That is, methods consisting of modeling languages, including notations and metamodels (or language constructs), and guidelines or procedures for modeling DBEs were identified in 8 (8.5%) of the 94 included studies.

Of the 47 studies with the use of modeling languages and models, 19 (40.4%) did not specify the modeling languages and models that were used. Several known languages, such as UML, BPMN, 4EM, and ArchiMate were used or adapted to be used in DBE studies. Ontology-based languages and matrix-based models were also seen in the included studies. Proposal for a new DBE-specific modeling language was reported in 2 studies. Based on the definition of DBE (cf. section 2), five key DBE elements, namely actor, role, capability, relationship, and digital component, were identified to screen if the language constructs and metamodels of DBE modeling in the included studies had captured the essence of DBEs. The element "actor" was addressed in the most studies, followed by "role" and "digital component". However, none of the studies covered all DBE elements in their language constructs or metamodels. In particular, the element "capability" was included in 7 studies, which is relatively lower as compared to the other elements. We argue that this indicates that modeling of DBEs remains at an initial level since "actor" and "role" are long-established concepts and can be regarded as fundamentals. In contrast, "capability", being a relatively new concept in modeling, pertains to advanced aspects, i.e., explication of functionalities and their delivery in DBE contexts. Considering the original ideas of DBE [3] and business ecosystem [2], the co-evolution of capabilities among actors is essential within an ecosystem. Hence, further improvement in capturing and documenting capabilities of DBEs is a suggestion derived from our results.

Both general and prescriptive guidelines concerning DBE modeling procedures were suggested in 14 (14.9%) of the 94 included studies. A novel contribution of general guidelines was a top-down policy-based DBE modeling approach proposed in [40]. The authors argued that this approach could offer an effective guidance in DBE modeling from the objectives to concrete implementation since this general top-down procedure started the modeling from DBEs' policies where the DBEs' entities were then constrained by these policies such as legal, or aspirational [40]. Based on the results, most of the prescriptive guidelines have "defining the scopes and boundaries of DBEs"; "identifying actors, roles, or digital components"; and "capturing interactions or relationships" as some of the major steps. We also observed that some of these prescriptive guidelines were presented without demonstrating corresponding outcomes of the steps. These major steps reflect our aforementioned observations about the results of the DBE elements "actor", "role", "digital component", and "relationship/connection" being addressed by moderate to high amount of included studies in their modeling language constructs or metamodels. However, none of the included studies have integrated modeling procedures for DBEs with other methods, procedures, or tools of other IS development and management areas, such as Enterprise Architecture frameworks (e.g., TOGAF, FEA, etc.), SAFe, SCRUM, and DevOps. We argue that the integration could address some of the challenges of assessing and planning the societal impact of information systems, supporting business driven information system integration, as well as supporting governance of large and distributed information system architectures that aid digital businesses. Other procedures, such as a high-level agile process for ecosystem modeling [94]–[97], DBE lifecycle and establishment phases [27], [39], [115], and a DBE model design process [38], were proposed in the outlined studies. Despite the fact that the studies kept a high level of abstraction in the proposal for DBE lifecycle and design procedures, as such they contribute to the overall body of knowledge of development and application of DBEs.

As suggested by the results, only one of the included studies envisioned a modeling tool (OmiLAB) aimed to support DBE design and management [59]. Consequently, more tools for supporting DBE modeling methods need to be developed, including by extension of existing tools, for instance, by extending tools used for Enterprise Architecture Management or information system analysis and design with functionalities targeting the specifics of DBE design and management.

5.2 RQ2: Modeling Purpose

Concerning the research question 2, the results suggested that analysis and design of DBEs were the main DBE modeling purposes. In particular, most of the included studies focused on the actor/role perspective while modeling DBEs for analysis and design purposes. This is considered reasonable since the multi-actor constellation is a key feature of DBEs and the complex actors' interconnection within DBEs was observed as a main challenge of DBE analysis and management in a recent review study [5]. Our results also suggested that, the product and business service, decision, policy, capability, and goal perspectives were taken into account by few studies. These numbers are much lower as compared to the actor/role and the information system architecture and component perspectives. We argue again that this indicates the current state of knowledge for modeling DBEs since the existing approaches do not support the capturing of comprehensive knowledge of DBE's multiple perspectives. Essential and clearly identifiable perspectives for initiating a DBE, such as the actor and IS architecture and component perspectives are researched more, while other perspectives, equally important, e.g., the policy perspective dealing with goals, rules, and legal regulations among the interconnected actors within a DBE, are currently unaddressed.

Regarding the modeling perspective, the following is concluded. Ecosystem is highly complex; thus, a multi-perspective approach to modeling and analysis needs to be adopted. In Enterprise Modeling, a common view is that "all perspectives are equally important because they allow building a holistic view on a problem situation, solutions, and the enterprise as a whole" (c.f., for instance, [23]). Considering the complexity and the multitude of characteristics of a DBE, a holistic view of a DBE could be established by modeling and integrating the different perspectives. This can be a way to explicate the complexity as well as to make sure that certain aspects of the DBE, e.g., the diversity of the actors involved, do not overshadow the adherence to commonly set business rules and goals of the ecosystem. However, our overall observations concerning the DBE language constructs and metamodels, modeling procedures, and modeling perspectives suggest that the current scientific research supporting the ability of modeling the multi-constellations of DBEs, is insufficient. Moreover, the existing EM methods do not provide explicit support for DBE modeling. They need to be extended for the purpose of capturing the aspects relevant to DBEs and to be able to deal with the expected complexity.

Resilience is a long-term sustainability goal of every DBE. Among the means of supporting DBE resilience is the establishment of a more holistic approach to design and management that integrates several modeling perspectives on the ecosystem. When we consider a DBE and its characteristics, especially the heterogeneity and symbiosis, the means used for addressing resilience in such environments should be different from those used in a single and a single type of company. Some of the aspects of resilience in an ecosystem includes diversity, efficiency, adaptability, and cohesion [131]. Take adaptability and cohesion as examples, as a part of adaptability, making adjustments in an environment populated by highly diverse and interdependent actors becomes more intricate as compared to addressing adaptations in a single-actor environment. A way to improve this is to model and expose the means of adaptation, such as capabilities, based on the collective viewpoints of a DBE's actors [51]. As for cohesion, it means to strengthen partnerships and align multiple actors' visions and goals within a DBE. To have the means to model and resolve conflicts among actors' goals and policies at different levels will support this aspect of resilience. Hence, modeling the various perspectives of a DBE will contribute to a more holistic view on the environment and, in turn, the management of the many aspects of resilience in DBEs. Considering the current results and practices, the challenges lie in not only how to find the balance between reasonably detailed but still adequately holistic picture of a DBE, but also the lack of a systematic methodological support in managing DBE resilience.

The increasing need for automation in digital business is another issue related to DBEs, especially in the context of Industry 4.0, at the core of which is interconnected devices, systems, and services provided in a networked fashion. Manually conducting digital business, e.g., handcrafting relationships with all suppliers on a case-by-case basis and attempting to monitor their performances, has a negative impact on efficiency, thereby decreasing the competitiveness of a business. Recall the Digital Vaccine DBE example, to ensure accurate and individual-centric preventive care is offered to users, it is important to continuously monitor the qualification of new care providers entering the ecosystem. Due to a large number of providers, the automation of their onboarding process would lead to a more efficient operation of the DBE and contribute to achieving the essence of digital business. However, we have analyzed the included studies in this review and observed that none of them directly address the linkage of conceptual modeling and automation in DBEs. We concluded that there has been insufficient research done for the automation within DBEs. More research needs to be devoted to how conceptual modeling will support the capturing of knowledge and the designing of IS that facilitates the issue of automation in the context of DBEs.

5.3 Importance of Studies with Related DBE Topics

Some of the included studies report research findings of importance in relation to aspects which can support the establishment of modeling methods for DBEs. These aspects are considered relevant in terms of providing insights in how DBEs and their lifecycles develop over time; how to generate more practical usages of DBE modeling methods, especially in different domains and industry practitioners' viewpoints; and how specific issues in the context of DBEs can be managed. Altogether, these studies suggest a diverse overview of the significant scientific facts and issues related to DBEs that need to be taken into consideration when discussing and developing the Conceptual Modeling methods used for the DBE contexts.

The lifecycle and development of DBEs illustrated in [124], [125], and [126] lay a scientific foundation for the different stages of DBE development which sould be supported by the modeling methods. When designing and deploying DBEs with the use of modeling methods, the simulation studies [101], [102], [106]–[110] can serve as a basis in understanding how different parameters related to the context of DBEs will behave on how to further improve the modeling methods in order to obtain information concerning these parameters. The external conditions and factors contributing to the changing nature of DBEs are investigated in [129] and [130], which can be used as starting points for understanding how DBEs behave in dynamic contexts and, in turn, assist the scientific development in modeling methods addressing the DBE characteristics of co-evolution and self-organization.

Studies reporting practical cases of managing specific issues in the DBE contexts can enrich the aspect of the feasibility of DBE modeling methods. They also provide insight in what the practical needs for the modeling methods are from the viewpoints of different domains and industry practitioners. Visualization tools and the agile approach of illustrating DBEs' actors and their relationships [93]–[97], [99], [100] are demonstrated in several cases. This helps the industry practitioners to understand the actors and relationship network structures. Also, the reported findings are useful for scientific researchers as the important layers in these visualization tools can be analyzed and, in turn, can be used as practical knowledge in improving the support of the two characteristics of heterogeneity and symbiosis in DBE modeling methods. Specific issues, such as finding appropriate partners within DBEs [104], managing data usage control [112], and analyzing strategic roles and functions of companies in DBEs [113], [114], are addressed and reported in several studies as discussed in Section 4.4. These studies also suggest more practical scenarios of tackling specific issues in the context of DBEs that can be taken into account when designing modeling methods for DBEs and enrich the usage situations and activities that these modeling methods support. To complement the specific issues in the DBE contexts, the functioning DBEs in different domains are compared and reported in two studies ([83], [127]). The study findings serve as an overview by providing comparisons regarding the industrial and economic aspects on how the DBEs are operating in different clusters and what the economic figures of the DBEs imply based on the categorizations of different domains and industries in the current business landscape. This overview assists further scientific research in developing modeling methods of DBEs that are domain-specific by enhancing the understanding of the specificities in the diverse domains and industries.

5.4 Study Limitations

A limitation of this study concerns the search terms used occasionally and informally as synonyms of "digital business ecosystem". As mentioned above, this study followed the phases of evolution of ICT adoption described in [12] and thus omitted search terms related to non-ecosystem driven networked organizations (e.g., value chain, value constellation, value web). Nevertheless, some other terms (e.g., platforms or platform ecosystems), which we consider as synonyms of digital business ecosystems as they correspond to our understanding of the concept of DBE to a sufficient extent, have not been included since they have emerged as relatively new trends after the commencement of this study.

Despite the limitation being a concern for the validity of this study, we have conducted a comprehensive search with an elaborated search strategy in the major bibliographic databases as well as forward and backward searches of reference lists from the included studies in order to retrieve all relevant records. Details on the search strategy and the process of study retrieval are documented in Section 3 and illustrated in **Error! Reference source not found.**. The inclusion or exclusion criteria used for the study selection have been clearly defined a priori as presented in Section 3.2. As mentioned previously, quality assessment with defined quality criteria for each of the included studies has not been performed in this literature review. This is because of the lack of establishment of hierarchy of evidence and the variation of study design in Computer Science and the IS field. The fact that the quality assessment has not been performed could be considered a limitation and affects the internal validity of this literature review [132]. Concerning the external validity [133], detailed descriptions of the study context of each included study could inform readers about the aspects of generalizability, applicability, and feasibility. However, most of the included studies in this literature review have not reported well-elaborated information about their study contexts. This, in turn, leads to a threat against the external validity, in terms of how and to what extent these findings in the included studies and the synthesized outcome presented in this literature review could apply to other or wider study contexts of DBEs.

6 Conclusions

This systematic literature review provides an overview of the current scientific knowledge concerning the support of Conceptual Modeling for the DBE lifecycle. Regarding the five characteristics of DBEs, heterogeneity related to DBEs' actors has been reflected in the most studies. This is in line with the findings of this study suggesting that the language constructs and metamodels, modeling procedures, and modeling perspectives are all taking the focus on modeling of DBEs' actors. The characteristics of symbiosis and digital environment have been addressed in scientific studies providing solid basis in their research outcomes. However, improvements are still required in order for the modeling methods to fully support these two characteristics. Despite the need of improvement, a moderate trend shows that the relationship and digital component elements in language constructs or metamodels are considered less in the studies published over the past five years as compared to earlier studies. Another moderate trend observed when comparing the included studies chronologically suggest that there are more studies addressing the capability element in language constructs or metamodels in the past five years. If this trend persists, it will facilitate the development of modeling methods addressing the characteristics of co-evolution and self-organization related to the dynamics and changing nature of DBEs, which are scientifically immature in its current state. The analysis on the modeling purposes and the related multiple perspectives shows also, for instances, that the decision and the capability perspectives have been overlooked. Based on the analysis and the findings of this literature review, essential modeling perspectives, elements in modeling language constructs, and common modeling procedures related to the modeling of DBEs have been highlighted, which can support practitioners and researchers in identifying the significant concepts and steps while applying existing modeling methods to the context of DBE as well as in developing new modeling methods and tools for DBEs.

Because of the scarcity of existing Conceptual Modeling methods and tools for DBE design and management, future research should focus on the development of such methods and supporting tools. There is an urgent need for a systematic approach guiding the integration of the multiple perspectives for modeling DBEs and thus aiming at supporting a holistic view on DBEs. These efforts are essential in order to facilitate the transformation from single to multi-role and ecosystem-oriented business models, as well as for the support of resilience and automation aspects in this context.

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