Towards Design Principles for Visualizing Business Ecosystems

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Abstract. Business ecosystems have recently gained relevance as a reference frame in which firms entertain diverse relationships to develop, produce, and distribute services and products. Only little research however has looked at how to visualize business ecosystems—although visualizations might provide a helpful instrument for firms to position themselves and manage their interactions within their ecosystem. We report from a systematic mapping study that identified 17 types of visualizations used in the business ecosystem context. On basis of this study, we derive requirements and design principles for Visual Analytic Systems (VAS). We discuss some limitations of current VAS with respect to the question how VAS can support management tasks related to business ecosystems, and we provide an outlook on the role of VAS in supporting business ecosystem governance.

Keywords: Business ecosystem · Visualization · Visual analytic system · Business network · Ecosystem governance · Systematic mapping study

1 Introduction

Business ecosystems have recently gained relevance as a reference frame in which firms entertain diverse relationships to develop, produce, and distribute services and products [11, 24]. The business ecosystem concept captures the complex business environment that comprises institutionalized business partnerships such as supply chains and various types of alliances—and extends these by the fabric of further personal and business ties that might involve various other entities such as public institutions, start-ups or non-profit organizations. This way it builds a reference frame marking the holistic environment of a company. This allows firms to position themselves in the fabric of relationships of current and potential future business partners, which constitutes a prerequisite to form

This paper is an extension of the conference paper entitled "Visualizing Business Ecosystems: Results of a Systematic Mapping Study" by Faber, A., Riemhofer, M., Huth, D., Matthes, F., published in the conference proceedings of ICEIS 2019: Proceedings of the 21st International Conference on Enterprise Information Systems.

J. Filipe et al. (Eds.): ICEIS 2019, LNBIP 378, pp. 299–319, 2020.
https://doi.org/10.1007/978-3-030-40783-4_14

effective business networks with relevant customers, suppliers, competitors, regulatory institutions, innovative start-ups and others more [45, 46]. As entities continuously enter and leave this fabric of relationships, business ecosystems are deemed to exhibit a high dynamic [10, 41, 45].

Various types of business ecosystems have been identified and discussed in literature, including for instance *innovation* ecosystems [1, 12], *platform* ecosystems [52, 55] or *software* ecosystems [43, 57]. These different types of ecosystems build different reference frames to capture the diverse *roles* that firms assume within the ecosystem in focus [27, 39] as well as the structures that capture the relevant *characteristics* and *business objectives* of different contexts as they appear e.g., around marketplaces like alibaba.com [51], or in smart cities [59].

In order to collect, illustrate and analyze these ecosystem characteristics, often visualizations have been used. Visual Analytic Systems (VAS) have been proposed and evaluated to leverage related benefits [17, 40]. VAS allow capturing the needs and demands of diverse user groups through different views and types of visualizations, commonly termed 'layouts'. Visualizations have been shown to deliver insights about the entities and their relations within business ecosystems; and interactive visualizations have been proven to support decision-makers in their ecosystem-related tasks [6, 13, 26]. Considering the effort to collect and analyze the regularly high amounts of data and information required to adequately describe the relationships existing in an ecosystem, visualizations can also help to derive value by spotting anomalies, identifying keystone and niche players, or recognizing change patterns and trends [58].

While some progress has been made in conceptualizing business ecosystems in research, in practice firms still face the challenge *to position themselves* advantageously within their ecosystems [2]. Research on business ecosystems has primarily focused on strategic aspects [2, 31, 32, 53, 61]; yet to a lesser extent on how the assumed ecosystem's potential can be practically leveraged. Remarkably few suggestions have been made by extant research with respect to designing instruments and VAS that *support management tasks* related to business ecosystems, and that contribute to governing business ecosystems.

In this chapter, we embark on two aspects related to the visualization of business ecosystems. First, we report from a systematic mapping study we conducted and that exemplifies *types of visualizations* used in extant business ecosystem literature. Second, we identify requirements for Visual Analytic Systems (VAS), from which we derive a set of design principles for VAS with a view on the advancement of management instruments in the business ecosystem context.

As this chapter is an extended version of a conference article [18], alongside several smaller enhancements its major additions are the formulation of design principles, and a more comprehensive rationale and discussion of the role of VAS in the business ecosystem context.

Section 2 presents related research on business ecosystems and highlights previous work in visualizing ecosystems. Here we also showcase prior literature studies on business ecosystems and particularly, emphasize earlier findings on business ecosystem types to show this concept's value as a reference frame for value creating activities. Section 3 introduces to our systematic mapping study and the process of identifying engineering requirements and design principles. Section 4 presents the spectrum of business ecosystems visualizations along with an overview of requirements and design principles as major findings. Section 5 gives a short summary and interpretation of findings and discusses aspects concerning how VAS can support management tasks related to business ecosystems. We point out some limitations and future requirements on business ecosystem visualization before giving a short conclusion.

2 Related Research

2.1 Business Ecosystems

The term business ecosystem was introduced in management literature in the mid-1990s, defining it as a network of companies interacting across adjacent layers of core business, extended business, and business ecosystem [39]. Pointing at the business ecosystem concept's idea as reference frame for the holistic environment of a firm, business ecosystems convey a raison d'être – and undergo a life cycle along several phases [10]. These phases include birth/pioneering, expansion, leadership/authority and self-renewal/death [38, 39].

The first phase denotes the genesis of a core idea or main objective of the ecosystem as its raison d'être, which – as we will illustrate later on – has led to the conception of various types of ecosystems in literature [14]. Towards this objective, firms explore and pioneer in generating innovations, partnerships or technical solutions for existing or new markets. For instance, *innovation* ecosystems often help building consortia that target new technological innovations [3] while *platform* ecosystems center around one platform firm that provides a digital platform as a central hub to which other entities connect [22]. The second phase links to the generation of market structures and evolving competition within and across the ecosystem, which often involves the emergence of network-centric leadership roles by focal firms, or network patterns around digital platforms [53, 54]. The third phase sees the accomplishment of either constant innovation and adaption of the ecosystem's objectives and members, or the failure of adaption, which leads to the dissolution of the ecosystem (as it is conceived in its holistic and goal-oriented nature).

Each developmental phase involves cooperative and competitive challenges [64]. These particularly concern the roles that firms assume within institutionalized business partnerships, as "suppliers, distributors, outsourcing firms, makers of related products or services, technology providers, and a host of other organizations" [27]. These roles are linked by establishing multiple and at times parallel relationships between ecosystem members, which can be flexibly established and dissolved [10]. Firms might also enter or leave the ecosystem, leading to a dynamic rearrangement of partnerships [41].

Different types of relationships emerge from partnership objectives as they are defined in supply chains or various other types of alliances such as technological alliances (for accessing and expanding R&D knowledge), operation-based alliances (for expanding operational/manufacturing capabilities), market-based alliances (for building or complementing market strengths through gaining access to markets or developing market expertise), managerial alliances (for sharing management expertise, e.g. through coaching), or financial alliances (for executing technology acquisition or commercialization strategies) [21]. Beyond such institutionalized business partnerships, the business ecosystem concept also captures the fabric of further personal and business ties that might exist. This fabric involves social relations between entrepreneurs, managers and firm employees, e.g., in expert networks or communities of practice, which together form the overall business environment that is "interconnected through a complex, global network of relationships" [8].

Three meta-characteristics of business ecosystems have been suggested that contribute to a better distinction of the ecosystem concept from clusters or networks – focusing on its emergence along "value-creating activity, such as entrepreneurship or innovation, rather than an industrial sector" [48]. These characteristics are sustainability of resource usage; self-governance, including definition of rules of competition; and evolution via competition and experimentation [48]. This view puts the focus on firms that *actively build business networks* with "resources operating as an interdependent system" [48], allowing to collectively compete against other ecosystems and business networks.

2.2 Visualizing Business Ecosystems

Visualizing the entities and relationships existing in business ecosystems has been proven beneficial for the decision-making of ecosystem stakeholders [7, 13, 26]. Visual Analytic Systems (VAS) have been proposed to enable and support management-tasks related to business ecosystems [15, 40, 44]. They can be used for instance to evaluate a firm's strategic positioning, to identify potential value creation partners, or to recognize newly emerging business opportunities. VAS system architecture generally facilitates user interaction, visual analysis and reporting [40].

VAS use *ecosystem data* in order to provide diverse user groups with different views and types of visualizations (layouts). The availability of data about the ecosystem is an essential requirement for visualizing ecosystems [15, 40]. Apart from data collected from firm-internal sources, ecosystem data generally comprises data sets collected from commercial databases (business and economic data) or from social and business media [6, 8]. Major challenges in collecting ecosystem data concern the high amounts of data and information, the difficulty to distinguish relevant data, the time-consuming nature of manual data search, and the difficulty to find appropriate ways to document information [19].

Various VAS have been developed and described in extant literature. The VAS "dotlink360" supports ecosystem stakeholders in understanding inter-firm relationships in business ecosystems by providing interactive visualizations [5]. It uses six layouts to support visualizing *mobile ecosystems*, involving entities such as mobile network providers, platform providers, or device manufacturers:[1] Scrollable list of entities; composition view (viewing entity detail); temporal view (depicting when relationships were formed and how active an entity is in forming relations); geographical view (location of entities); segment view (chord diagram/network graph); and scatter plot (financial metrics) [5].

[1] We will introduce visuals of the mentioned layouts in our *Findings* section.

In context of Supply Network Management, Park et al. [40] present a VAS that uses five layouts "to highlight different structural aspects", including force-directed, circular, treemap, matrix, and substrate-based layouts.

The VAS "ecoxight" was developed in context of visualizing API ecosystems (API…application programming interface) [9]. It draws on data from ProgrammableWeb and Crunchbase[2] and uses five layouts: path view (node-link diagram); category view (chord diagram/network graph); geography view; scatter-net view (scatter plot); and temporal view.

In our own research, we have developed the VAS "Business Ecosystem Explorer (BEEx)" in order to model and visualize "smart city" business ecosystems [15]. BEEx uses a wiki-based approach for collection of ecosystem data and offers collaborative modelling features [20]. It includes five layouts: list; adjacency matrix; force layout; treemap; and chord diagram. In addition, a detail view for each entity is available.

For setting up VAS in practice, diverse stakeholder groups ought to become part of modelling activities [44]. Ecosystem analysts, experts and data scientists together collect ecosystem data and engage in evaluating and interpreting visualizations [14, 18].

Data collection and analysis generally follow four iterative steps [19, 28]: (1) Determining industry structure, i.e., identifying value chain and value propositions; (2) Identifying ecosystem members, i.e., collecting data about organizations and their relevant attributes; (3) Modelling ecosystem elements, i.e., specifying semantics and visual encodings of nodes, edges and dependencies; and (4) Visualize – analyze – interpret, i.e., formulating and refining insights about firms or clusters in key network positions, finding counterintuitive patterns, and identifying eventually missing entities.

2.3 Extant Literature Reviews on Business Ecosystems

As to the increased sensitivity towards the business ecosystem concept, our mapping study is not the first literature review addressing business ecosystems-related research. In Table 1, we briefly summarize four extant literature reviews we have identified. While none of the four reviews directly addresses the issue of visualizing business ecosystems, each of them points towards some requirements for VAS. The studies' insights overall thus provide an impetus to further scrutinize requirements for VAS. In the table, we therefore also point out some basic consequences they have for visualizing business ecosystems. In the following, we discuss how each study informs the positioning of *visualization* in research on business ecosystems.

The study of Mäkinen and Dedehayir [35] looks at ecosystem evolution and strategy. Their focus on the dynamic nature of business ecosystems highlights that the positioning of firms changes over time. As a resulting requirement, VAS need to enable a review of these changes and the influencing factors.

The concept of innovation ecosystems is examined in the study of de Vasconceles Gomes et al. [12]. They identify and discuss six related research streams, which emphasizes that there are diverse "use cases" that should be supported by VAS. As the parameters to describe the use cases overlap, VAS need to provide flexibility for configuring and adapting the model they use for generating visualizations and analytic features.

[2] See https://www.programmableweb.com/; https://www.crunchbase.com/.

Table 1. Extant literature reviews on business ecosystems.

Authors/focus and scope	Study outcomes and → ***Consequences for visualizing business ecosystems***
Mäkinen and Dedehayir [35]: BE evolution and strategy; 68 articles	- Business ecosystem members and their roles - Factors that influence the evolution of business ecosystems - Dynamics of ecosystem change - Strategic considerations of firms positioned in ecosystems → ***The positioning of firms changes over time. VAS need to enable a review of these changes and the influencing factors***
de Vasconceles Gomes et al. [12]: Innovation ecosystems; 193 articles	- Identification of six research streams related to innovation ecosystems: (1) industry platform x innovation ecosystem; (2) innovation ecosystem strategy, strategic management, value creation and business model; (3) innovation management; (4) managing partners; (5) the innovation ecosystem life cycle; (6) innovation ecosystems and new venture creation → ***There are diverse "use cases" that should be supported by VAS. The parameters to describe the use cases overlap. VAS thus need to provide flexibility for model configuration and adaptation***
Järvi and Kortelainen [30]: BE analytic framework; 72 articles	- Identification of three units of analysis: (1) the individual actor (typically a firm); (2) the relationship between the actors; (3) the business ecosystem - *Individual actors* occupy different *positions* in ecosystems, such as a hub or niche position by assuming different *roles* such as customer, delivery channel, seller of complementary products and services, supplier, or policy maker etc. - *Relationships* in the ecosystem comprise (a) interaction, (b) interdependence and (c) substitution as well as (d) focal firm—complementor relationship - *Ecosystem* aspects comprise (a) collective and collaborative value creation, (b) competition between ecosystems, (c) ecosystem clockspeed, i.e., to assess the rate of change of an industry (d) ecosystem life cycle, (e) network structure and (f) transition from supply or value chain management to ecosystem management → ***VAS need to enable a description of business ecosystem on different interconnected levels, and an analysis from different angles (units of analysis). Various data sources might be required to populate models***
Scaringella and Radziwon [49]: Ecosystem types; 104 articles	- Identification of four main types of ecosystems: (1) business ecosystem; (2) innovation ecosystem; (3) entrepreneurial ecosystem; (4) knowledge ecosystem - Definition of *ecosystem invariants*, such as territory, values, stakeholders, to describe similarities, differences, and complementarities of these four ecosystem types - Overview of *existing territorial approach theories*, which differentiate and describe ecosystems based on the spatial agglomeration, e.g., Italian industrial district or regional innovation systems - Proposal of a research framework for future empirical research → ***VAS need to visualize inter-firm connectivity based on various parameters and multiplex relations***
Faber et al. [14]: Ecosystem types; 136 articles	- Identification of 12 business ecosystem types → ***VAS need to enable a synthesis of layouts related to the use case (type of business ecosystem considered) and consequently, a case-specific terminology in models***

An analytic framework is formulated by Järvi and Kortelainen [30]. The authors identify individual actors (firms), actor relationships and the business ecosystem overall as central units of analysis. This affords that VAS need to enable a description of business ecosystems on different interconnected levels, and an analysis from different angles (i.e., units of analysis). In addition, it accentuates the fact that various data sources are often required to populate models.

Scaringella and Radziwon [49] identify four major types of business ecosystems. Their findings suggest that VAS need to visualize inter-firm connectivity based on various parameters and multiplex relations.

Our own research [14] brings forward twelve types of business ecosystems, and describes their diverse objectives and underlying structures—which all however might overlap in a given use case. We draw from this the particular requirement that VAS need to enable a synthesis of layouts related to the use case (i.e., the type of business ecosystem considered) and consequently, must allow for a case-specific terminology in models.

In a cross-study perspective, we can constitute that while extant studies consider determining factors of business ecosystems and their analytical value and the like, the tie-in to the *management tasks* appearing in practice – and that afford a visual representation of the ecosystem in focus – stills lacks consideration.

2.4 Ecosystems as Reference Frame for Value Creating Activities

As extant literature on business ecosystems showcases, each identified *type of ecosystem* features distinct constitutive characteristics and relationships that express its overall nature and raison-d'être. In previous research, we have identified and characterized several types of business ecosystems [14]. We identified 12 ecosystem types, which we describe in Table 2. As to our analysis, two perspectives define the central *type of linkage* that drives the conceptualization of business ecosystems (BE); organizational perspective and value perspective. The organizational perspective considers ecosystems as *stakeholder-driven* entities, comprising *Entrepreneurial BE* and *Family Spin-off BE* as well as (to some extent) *Software BE*. The value perspective reflects the *value-driven* nature of ecosystems, i.e., actuated by ideas as well as innovations of products, services and value assets. The most prominent ones in literature involve *Platform BE*, *Digital BE* and *Innovation BE*.

The diversity of conceptions that have been formulated in order to characterize business ecosystem types suggests that there is a multiplicity and plurality evident in the relationships that substantiate *what we conceive* and study as business ecosystem. In other words, business ecosystems are conceived as *reference frame for various forms of value creating activities and relationships*, whereby the exact conception is delimited to the distinct perspective taken. This notion of a pluralistic nature of the business ecosystem concept as we can observe it empirically motivates our study of ways to visualize the intricate relationships and instantiations involved. On another take, the insight that the pluralistic nature of business ecosystems leads to the *de-facto instantiation of various types of ecosystems* – as networks of organizations, services, resources and the like – points us to scrutinize also the *nature of these networks* that eventually lead to synergetic value creation. (We will touch upon this aspect in the *Discussion* section).

Table 2. Business ecosystem types (based on [14]).

Business ecosystem (BE) type	Definition and selected references
Entrepreneurial BE	An *Entrepreneurial BE* consists of start-up related organizations, such as entrepreneurs, investors or end-users, who collaborate to form a new start-up [48]
Family Spin-off BE	A *Family Spin-off BE* is created in case a spin-off of a family company splits up from the parent company [34]
Platform BE	A *Platform BE* incorporates a platform as the "keystone entity" [22], i.e., a central hub to which other entities connect
Innovation BE	An *Innovation BE* forms around an innovation [12, 56], which occurs when the market demands change or new technologies disrupt the markets [3]
Software BE	A *Software BE* is "a set of businesses functioning as a unit and interacting with a shared market for software and services, together with the relationships among them" [29]
Knowledge BE	A *Knowledge BE* is located around a university, focusing on knowledge generation and is usually geographically localized with close proximity [49]
Digital BE	A *Digital BE* (a term coined by the European Union) essentially is a *Platform BE*
Mobility BE	A *Mobility BE* is a subtype of the *Innovation BE* and includes, e.g., ride sharing, connected cars, and driver-less transportation [48]
IoT BE	An *IoT BE* "is comprised of the community of interacting companies and individuals along with their socio-economic environment, where the companies are competing and cooperating by utilizing a common set of core assets related to the interconnection of the physical world of things with the virtual world of Internet" [37]
Internet BE	An *Internet BE* is the ecosystem around the Internet as the core asset of innovations [4]
Mobile Internet BE	A *Mobile Internet BE* is a subtype of the *Internet BE* [4]
Customer-centric BE	A *Customer-centric BE* focuses on customers in a keystone position, who are involved in the idea generation and product/service development [22, 23]

3 Method

Our research aimed at understanding how, and to what extent, visualizations and VAS are currently being used in the business ecosystems context. To this end, we conducted a study of extant academic literature [33, 42]. More precisely, we undertook a systematic mapping study as proposed by Wendler [63], as we aimed at a general overview that (a) determines the coverage of visualizations/VAS in the field, (b) helps building a classification scheme for visualizations, (c) shows overall occurrences of layouts, and that allows us to (d) combine our results to draw conclusions on the further development of VAS to support design of management instruments in the ecosystem context. After an initial literature study, for the latter aspect (d), in a second step we interpreted our analysis in order to derive requirements for VAS design. These requirements are then categorized to form design principles [50], which we offer to research and practice.

Two research questions guided our inquiry of literature: What visualizations and VAS are reported in literature to illustrate business ecosystems and the overall business ecosystem concept (RQ1)? And, which requirements for VAS have been formulated (RQ2)? The rational of RQ1 is to identify visualization types, such as network or chord diagrams, used within business ecosystem research. RQ2 aims at synthesizing existing VAS requirements to provide visualizations that primarily target the *dynamic* changes of business ecosystem entities and their relations.

3.1 Systematic Mapping Study

A systematic mapping study generally "aims at reviewing a relatively broad topic by identifying, analyzing, and structuring the goals, methods, and contents of conducted primary studies. Therefore, the state-of-the-art research, research gaps, or matured sub-areas can be identified and explicated" [63, p. 1318]. To accomplish this objective, during our mapping study, we followed eight process steps as visualized in Fig. 1. The following paragraphs describe how we conducted our process steps of searching, selecting, and analyzing.

Selection of Data Sources and Search Strategy. For the selection of suitable databases, we identified computer science, information systems, and management theory as relevant domains to our study focus of VAS and business ecosystems. We limited our search on electronic databases and in a first step selected the databases Association for Computing Machinery (ACM), Electrical and Electronics Engineers (IEEE), ScienceDirect, Scopus, SpringerLink, and Web of Science, as these databases cover publications of the previously identified research domains to a reasonable extent.

We conducted our search in September and October 2018, using the search string "business ecosystem" and consequently analyzed (within the initial search) only titles, abstracts, and keywords of the identified records. If at least one of these three contained the term 'business ecosystem,' we considered the record as relevant; resulting in overall 1,842 records after the initial search.

Inclusion and Exclusion Criteria. In the next process steps, we included relevant articles to the "pool of papers" [63] and excluded irrelevant papers. Irrelevant papers comprise those with a lack of business focus, i.e., not describing interactions of multiple business actors, but that rather described technical aspects or architectural descriptions of business, or biological ecosystems. Records were included in case they were written in English and the scope was related to business ecosystems. In case a record was labeled with a "notice of violation" or "notice of retraction" note, the according record was excluded as well, in order to maintain quality standards of analyzed literature. After reading title, abstract, and keywords, we labeled 382 articles as relevant; from which 124

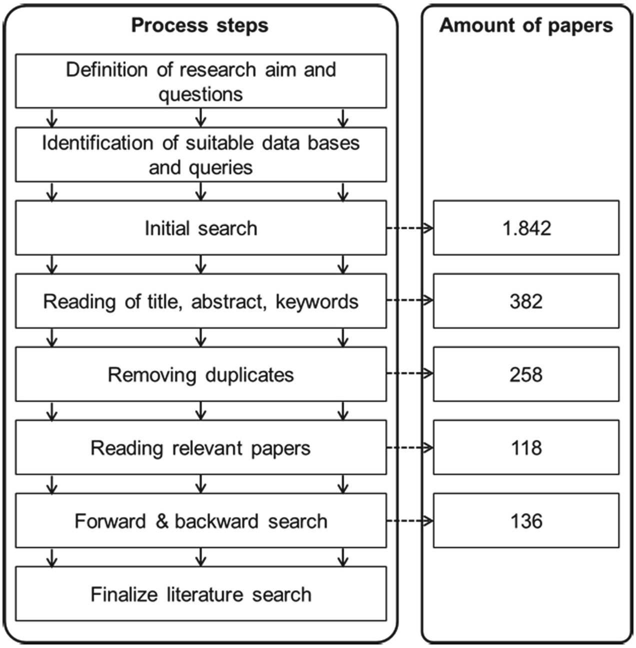


Fig. 1. Search process following Wendler [63].

duplicates were removed, leaving 258 relevant papers. For these remaining papers, we created a *content mapping matrix*, which consisted of the business ecosystem characteristics *definition, roles, phases, types, visualizations, applications,* and *examples*. Table 3 below provides a short characterization of each analytic characteristic.

Applying the content mapping matrix led to 118 relevant records, i.e., records discussing at least one of the seven characteristics. In a final process step, we applied forward and backward citation search on these records as described by Webster and Watson [62], through which we identified 18 additional records. Overall, we analyzed 136 papers in our systematic mapping study. While we made use of this data to undertake other interpretations (e.g., [14]), here we will only present results related to business ecosystem visualizations and VAS.

3.2 Conceptualizing Design Principles

Beyond our efforts to map the field of visualizations and VAS, we intended to draw conclusions on the design of VAS and their use in the ecosystem context. To this end, we carried out an interpretation of the resulting articles, looking at their suggestions for handling visual information, which permitted us to formulate *engineering requirements* for VAS. A consequent categorization of these requirements allowed us to synthesize *design principles* for VAS design. Design Principles are the principal beliefs, philosophies or guidelines that should be interpreted "to enable practitioners and researchers to create further (application software) …in different organizational setting and environments" [36, 50, 60].

Table 3. Mapping matrix and analytic characteristics used in our mapping study.

Business ecosystem characteristic	Description of characteristic	Number of identified records
Definition	Either a new definition of business ecosystem is established, it adds to an existing definition, sums up different definitions, or com- pares existing definitions	58
Roles	The different roles ecosystem actors incorporate are described, a new descriptive metaphor is established for these roles or different roles are compared	70
Phases	The paper establishes a business ecosystem life cycle, describes at least one state of a business ecosystem, or it compares different life cycle models	29
Types	The paper describes at least one type of business ecosystem or compares multiple types	42
Visualization	The article contains at least one business ecosystem visualization, describes how a business ecosystem can be visualized, develops or uses a modelling or visualization tool	43
Application	Applications of the business ecosystem concept both in research and practice	58
Example	Paper demonstrating a specific example of a business ecosystem in a real-world context, e.g., for Walmart or Alibaba	49

While we identified design principles by studying the existing literature, we also got inspired through our own research (e.g., [25]). Our design principles' validity thus relates to—and is limited by—the cross-case cogency of these references.

We formulate our design principles in a way to delineate the boundary conditions, elements and processes that facilitate application and valuable use of a VAS. For each design principle (DP) we thus formulate those aspects that—to our interpretation—*facilitate* valuable use, i.e. using terms such as 'enable', 'ensure', 'support', 'provide', and the like.

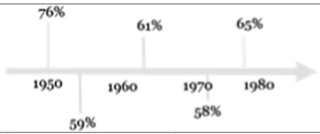
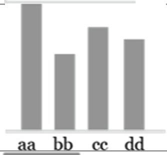
4 Findings

4.1 The Present Spectrum of Business Ecosystems Visualizations

In our mapping study we identified 43 records that include business ecosystem visualizations. Either they use visualizations to describe a business ecosystem, or they discuss how a business ecosystem *can* be visualized. All of these records include at least one visual to depict an actual, simplified, or sample business ecosystem.

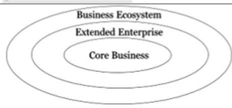
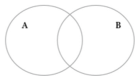
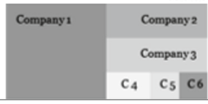
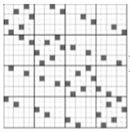
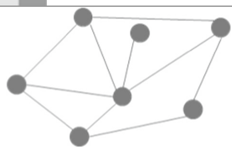
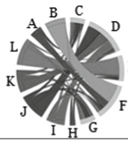
In Table 4 we provide an overview of the types of business ecosystem visualizations we identified in our literature study. We group them by their underlying explanatory objective, e.g., whether they are used to showcase geographical dispersion (A. Geographical Map), hierarchies (G.), temporal changes (B.) and others more. Table 4 also indicates the occurrence of instances counted per category. Not surprisingly, with 56 mentions, layouts that explain connections (H.), both static and as flow diagram, comprising matrix, node network, chord diagram and directed network layouts, were the largest group reported. Groupings and hierarchies (G.) constitute the second largest group of

Table 4. Types of business ecosystem visualizations identified in our literature study (adapted from [18]).

Explanatory objective*	Layout type*	Exemplary layout
A. Geographical Map (2)	*A1* Connection Map (1) *A2* Dot Map (1)	A1  A2 
B. Progression (time) (4)	*B1* Timeline (4)	B1 
C. Correlation (5)	*C1* Bubble chart (2) *C2* Scatter plot (3)	C1  C2 
D. Ranking (5)	*D1* Bar chart (5)	D1 
E. Listing (7)	*E1* List (7)	E1 

(*continued*)

Table 4. (*continued*)

Explanatory objective*	Layout type*	Exemplary layout
F. Progression (any value) (8)	*F1* Line chart (8)	F1 
G. Grouping (parts and wholes; hierarchies) (15)	*G1* Moore Framework (4) *G2* Venn diagram (2) *G3* Hyperbolic tree (1) *G4* Sunburst diagram (3) *G5* Tree map (5)	G1  G2  G3  G4  G5 
H. Connection (Static) and Flow (56)	*H1* Matrix (7) *H2* Node network (28) *H3* Chord diagram (4) *H4* Directed network (17)	H1  H2  H3  H4 

*The numbers in brackets indicate the instances counted per category.

layouts with 15 mentions. This indicates that the navigation within the networked relationships (presumably across different types of network-like structures) as well as the hierarchical, top-down (and vice versa) exploration of these networked structures takes significant space in the analytical use of visualizations.

4.2 Requirements and Design Principles for Visualizing Business Ecosystems

Extending on our discussion reported in Faber et al. [18], in the following section we give an overview of how we synthesized requirements and design principles for VAS in the business ecosystem context. Table 5 summarizes our suggested four design principles and 18 requirements. Our synthesis bases on three major pillars; first, the requirements *explicitly proposed* in articles included in our literature study, particularly from Basole et al. [5], Park et al. [40], Hernandez-Mendez et al. [25], Reschenhofer [47] and Basole et al. [9]; second, our interpretation of further articles from the study; and third, our insights basing on previous research conducted in close cooperation with business partners as users of VAS in contexts of urban mobility, passenger vehicle innovation, and publishing business ecosystems [19].

Table 5. Requirements and design principles for VAS in the business ecosystem context (based on [18]).

Requirements for VAS ordered by Design Principles (DP)	Reference sources
DP 1: Facilitate navigation for analysis of business ecosystems	
- Top-down and bottom-up hierarchical examination of BEs; providing flexible navigation across higher-level overviews and individual details	[5]
- Supporting definition of a case-specific terminology displayed in the GUI in order to facilitate user-specific wording	[5]
- Preferring visual interaction to prompt/query-based user interfaces; providing filters to customize queries	[9, 40]
- Providing configurability for ease-of-use in GUI and model/query design	[9]
- Enable navigation through different layouts	[19, 40]
DP2: Enable flexibility in data and model adaptation	
- Defining multiple attributes for each relation	[19, 47]
- Enabling run-time modification of BE model and visualizations (layouts)	[25, 47]
- Providing role-based GUIs for different stakeholder roles	[25]
- Using web-based technologies, such as JavaScript libraries for building user interfaces	[25]
- Support integration (e.g., through APIs) of different data sources	[19]
DP3: Enable visualizations of BE models and data	
- Capturing and displaying inter-firm connectivity and composition (BE model)	[5]
- Providing multiple layouts to enable comparative perspectives on similar data and contexts	[5, 9]
- Allowing for synthesized layouts that capture higher-level summaries and link to case details	[5]
- Providing interactive features (clicking, dragging, hovering, filtering) for analysis	[19]
DP4: Provide features for analytical use	
- Supporting semi- and non-structured underlying BE data	[25]
- Capturing and displaying temporality of inter-firm connectivity and composition	[5, 9]
- Defining and displaying multiplex relations between entities	[9]
- Enable binding of data and view model, i.e., data and view model should be linked to ensure elements of the data model are visualized at any time	[19, 40]

From our interpretation, we see four groups of requirements emerging as themes that eventually lead to the formulation of four design principles (DPs). These concern requirements towards, the use of VAS to navigate BE visualizations (DP1); the adaptability of the ecosystem data and the VAS model used to create layouts (DP2); the interactive VAS features linked with the layouts (DP3); and VAS features for analytical use (DP4).

Design Principle 1 expresses the need to "*Facilitate navigation for analysis of business ecosystems*". It captures requirements that concern navigating the complex relationship structures in order to reach a decent impression of the business ecosystem in focus. This involves also the possibility to define case-specific terminology, and to enable visual interactions with the models.

Design Principle 2, "*Enable flexibility in data and model adaptation*" concerns the ecosystem data and how the VAS uses this data to form models. Here, features such as run-time modification of BE model and visualizations, or the option to include different data sources are originating from the necessity to integrate a generally abundant amount of ecosystem data along an intensive and iterative agile modelling process [15].

Design Principle 3 calls for VAS features that "*Enable visualizations of BE models and data*". This involves requirements on interactive VAS features linked with the layouts, e.g., provision of multiple layouts that offer interactive features for analysis like clicking, dragging, hovering, or filtering.

Design Principle 4 is to "*Provide features for analytical use*". Both, manual visual analysis as well as automated analysis can potentially be supported by VAS, e.g., automated sensitivity analysis (as reported in [40]). Here, attention must be given to the handling of temporality, or the definition of multiplex relationships between entities.

5 Discussion

5.1 Summary of Findings of the Systematic Mapping Study

Our mapping study covered databases that contain articles holding perspectives from engineering, management and information systems. As we find layouts reappear across these fields, we believe that the found set of layouts (Table 4) provides a decent overview of the current state of play regarding VAS for business ecosystems. We also observe that the requirements for visualizing and analyzing entity distributions, relationships and their networked structures, resurface across different studies and use cases (Table 5).

Among the 17 layouts identified, *network-type visualizations* such as node network layout or directed network layout that emphasize connections as static, transitive or indicating flow, are the most frequently applied visualizations. In addition, the prevalent use of layouts like hyperbolic tree, which accentuate *how* a business ecosystem is conceptualized as hierarchy or in groupings – and *how entities are distributed* within this pattern of relationships (e.g., sunburst diagram) – indicates that VAS are indeed used as instruments that help identifying, navigating and refining relationship structures as *tailored for a given task.*

These impressions have been reinforced by our collection and interpretation of engineering requirements for VAS as they are discussed by us and other authors. We identify 18 requirements on VAS [18], which can be grouped into four design principles. From a high-level perspective, these principles span aspects of usability (DP1), adaptivity (DP2), interactivity (DP3), and analytical readiness (DP4), pointing at the roles of VAS as analytic tool, as data management system, and as management instrument for diverse stakeholders. These findings all speak to the base assumption that each instantiation of a business ecosystem visualization must involve and explicate a *unique set of characteristics* constitutive for both, the ecosystem as it is conceived, and the management task for which the VAS has been set up.

5.2 Making Business Ecosystem Visualizations Actionable: The Missing Design Principle

Particularly striking about business ecosystems' literature is the fact that it mirrors quite a variety of "types of ecosystem" and resulting from that, a diversity of relationships and characteristics that constitute a specific ecosystem conception. This circumstance is particularly important for our exploration of VAS for business ecosystems. The task of a VAS will ultimately be, to help identifying, modelling and analyzing the particular constitutive characteristics as well as those predominant relationships and interrelations that are material to fulfil a task related to managing an organization's positioning in the ecosystem, or related to overall ecosystem governance.

However, the tie-in between ecosystem visualization and the management tasks has not yet been made. Primary management tasks related to business ecosystems include the positioning of a firm in its specific ecosystem environment, and the configuration of effective business networks from the reference frame that the ecosystem conception provides. Both of these tasks base on an *exploration and understanding of the ecosystem's formation rationale*, or raison d'être. VAS in this vein need to help explicating factors that drive the evolution of the ecosystem, and that support the formation of effective business networks along value creation processes or strategies.

This latter aspect provides for a missing Design Principle, which refers to the task of building, i.e., designing and implementing, the infrastructures of business networks, or "*Facilitating business infrastructuring*". This design principle involves supporting the process along which ecosystem stakeholders turn the *potential* that the ecosystem conception entails, into *effective* business networks.

For forming business networks, firstly, ecosystem stakeholders navigate the ecosystem with help of strategic analyses to identify promising new partnerships or business opportunities. Secondly, business network members ally to design, implement and coordinate their relationships on basis of an actionable infrastructure. Such infrastructures serve as the network's shared asset and allow for establishing performative constellations of value creating activities (as shown in [46]).

For VAS to become a material instrument in the related management tasks, will require to extend the current conception of VAS towards (a) synthesizing network configurations on basis of predefined or learned relationship patterns, as well as (b) orchestrating the set of potential and effectively arranged relationships within defined value creation processes. This latter point is also a prerequisite for the use of VAS as instrument in business ecosystem governance, because it expedites the role of VAS as mediator between platforms and their stakeholders (as exemplified in [44]).

5.3 Limitations and Future Requirements on Business Ecosystem Visualization

In this sense, the set of layouts identified in the mapping study should not be understood as a converging set of visualizations. On the contrary, we believe that in the future more sophisticated layouts will be developed that make use of larger sets of data – as well as of data changing as dynamically as do business ecosystems and their conceptions.

As to our interpretation of the set of design principles and requirements, in particular DP4 will presumably see considerable extension in future applications as it is the basis for an automated analysis of ecosystem data. Given the size and complexity of ecosystems, features for automated data gathering or machine learning-based systems that are able to identify and present data relevant to a specific user of a VAS might bring about a significant extension of applicability and usability of VAS as strategic tool for management tasks related to business ecosystems.

In addition, regarding the handling of ecosystem data, sustainable approaches for collecting ecosystem data and modelling are required. In context of smart city ecosystems for instance, the instantiation of an 'ecosystem editorial office' has been suggested that supervises data collection alongside crowd-based approaches that allow leveraging domain experts as well as citizens [16, 44]. However, how ecosystem analysis can be institutionalized has not been studied so far.

6 Conclusion

VAS for visualizing business ecosystems today provide a sound set of layouts to capture relevant network structures and relationships, as our systematic mapping study shows. The insights reported from extant studies suggest a comprehensive set of engineering requirements for VAS, which can be grouped into four design principles. Together they respond to the dynamic nature of the business ecosystem context including the criticality of handling ecosystem data, navigating and interacting with visualizations, and adapting VAS models and layouts for different stakeholders as VAS users. However, the tie-in to critical management tasks related to business ecosystems has not yet been made. More efforts are required in research and practice to enhance VAS towards management instruments, which facilitate business infrastructuring in order to turn the potential that the ecosystem conception entails into effective business networks.

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