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Collaborative Modeling and Visualizing of Business Ecosystems

Anne Teresa Luisa Faber

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1. Prof. Dr. Florian Matthes
2. Prof. Dr. Helmut Krcmar

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Zusammenfassung

Unternehmen entwickeln, erzeugen und vertreiben ihre Produkte und Dienstleistungen heutzutage in komplexen und zunehmend digitalen Geschäftsökosystemen. Der wachsende Einfluss dieser Geschäftsökosysteme auf den Erfolg und Misserfolg eines Unternehmens wird verstärkt von Unternehmen wahrgenommen. Ein Geschäftsökosystem geht dabei über die klassische Wertschöpfungskette, bestehend aus Zuliefern, Kunden und Konkurrenten am Markt hinaus. Es umfasst neben Geschäftspartnern auf unterschiedlichen Ebenen der Kollaboration auch potentiell interessante Unternehmen und Start-Ups für zukünftige Geschäftsbeziehungen oder öffentliche Einrichtungen, die durch neue Regularien, Gesetze oder Erlasse das Ökosystem beeinflussen können. Um ein umfassendes Bild des Unternehmens und der Interaktion mit seiner Umwelt zu erhalten und informierte ökosystembezogene Entscheidungen zu treffen, ist es für das Unternehmen und verantwortliche Entscheidungsträger notwendig, die Elemente des Geschäftsökosystems und deren Beziehungen zu verstehen. Visualisierungen von Geschäftsökosystemen stellen eine Möglichkeit dar, die Entscheidungsträger im Unternehmen dabei zu unterstützen.

An die Modellierung des sich kontinuierlich verändernden Geschäftsökosystems inklusive Konkurrenten, Geschäftspartnern und Entwicklungen am Markt haben die unterschiedlichen Entscheidungsträger in einem Unternehmen abweichende Anforderungen. Um ein umfassendes Bild des Geschäftsökosystems zu erhalten, ist es deshalb wichtig, die unterschiedlichen Abteilungen und Entscheidungsträger eines Unternehmens in die Modellierung und Visualisierung des Ökosystems mit einzubeziehen und die entsprechenden Bedürfnisse zu erfassen.

Die vorliegende Arbeit adressiert diese Herausforderungen und beginnt mit einer strukturierten Literaturrecherche zur Identifikation von Definitionen und Typen von Geschäftsökosystemen und existierenden Visualisierungswerkzeugen. Im Anschluss beschreiben wir die Relevanz der Ökosystemmodellierung. Die Erkenntnisse basieren auf drei Diskussionsrunden, elf Interviews und einer Online-Befragung, welche die Anforderungen an einen softwaregestützten Geschäftsökosystemmodellierungs- und Visualisierungsansatz in der Praxis beschreiben. Im nächsten Schritt haben wir einen Prozess zur kollaborativen Modellierung und Visualisierung von Geschäftsökosystemen entwickelt. Wir beschreiben die Prozessaktivitäten, notwendigen Rollen und Artefakte. Um diesen Ansatz zu unterstützen, haben wir ein innovatives Tool entwickelt, das den Entscheidungsträgern verschiedene interaktive Visualisierungen zur Verfügung stellt.

Der Beitrag dieser Arbeit ist ein Rahmenwerk, das die kollaborative Modellierung und Visualisierung von Geschäftsökosystemen unterstützt. Der entwickelte Prototyp stellt mehrere interaktive Visualisierungen bereit und interagiert mit einem meta-model-basierten Informationssystem, das die kontinuierliche Anpassung der Daten- und Visualisierungsmodelle erlaubt. Im Rahmen dieser Arbeit beschreiben wir den Einsatz für zwei Anwendungsfälle: die unternehmensinterne Modellierung des Geschäftsökosystems und den öffentlich zugänglichen Einsatz zur Modellierung und Visualisierung eines Ökosystemes, hier am Beispiel von Mobilität.

Durch die prototypische Implementierung ermöglichen wir eine Auswertung in Zusammenarbeit mit verschiedenen Industriepartnern in mehreren Iterationen. Zur firmeninternen Modellierung und Visualisierung unterschiedlicher Ökosysteme wurden der entwickelte Prozess und der zugehörige Prototyp in zwei Industrieprojekten eingesetzt. Zusätzliche haben wir mit Hilfe von öffentlich zugänglichen Datenquellen das Geschäftsökosystem einer Smart Mobility Initiative in Zusammenarbeit mit einer nicht-forschenden öffentlichen Einrichtung modelliert und visualisiert. Darüber hinaus wurden fünf Interviews zur Evaluation und zur Identifikation weiterer Anwendungen des Prototypen durchgeführt.

Abstract

Companies today develop, produce, and distribute their products and services in complex and increasingly digital business ecosystems. The growing influence of these business ecosystems on a company's success and failure is increasingly perceived by companies. A business ecosystem goes beyond the traditional value chain of suppliers, customers, and competitors. In addition to business partners at different levels of collaboration, it also includes potentially interesting companies and start-ups for future business relationships or public institutions that can influence the ecosystem through new regulations, laws or decrees. To gain a comprehensive picture of the company and its interaction with its environment, and to make informed ecosystem-related decisions, it is necessary for the company and responsible stakeholders to understand the elements of the business ecosystem and their relationships. Visualizations of business ecosystems are a way to support these decision makers.

The different decision makers in a company have different requirements for modeling the continuously changing business ecosystem, including competitors, business partners, and market developments. To obtain a comprehensive picture of the business ecosystem, it is therefore important to involve the various departments and decision makers of a company in the modeling of the ecosystem and to identify the corresponding needs and requirements.

This thesis addresses these challenges and begins with a structured literature review to identify definitions and types of business ecosystems and existing visualization tools. We then describe the relevance of ecosystem modeling. Our findings are based on three discussion rounds, eleven interviews, and an online survey, which we use to derive the requirements for a software-based business ecosystem modeling and visualization approach in practice. In the next step, we developed a process to collaborative model and visualize business ecosystems. We describe the process activities, necessary roles, and artifacts created in the process. To support this approach, we have developed an innovative tool that provides stakeholders with various interactive and tailored visualizations.

The contribution of this work is a framework that supports collaborative modeling and visualization of business ecosystems. The developed prototype provides several interactive visualizations and interacts with a meta-model based information system that allows the continuous adaptation of data and view models. In this thesis, we describe two use cases: the firm-internal modeling of the business ecosystem and the publicly accessible tool use for modeling and visualizing an ecosystem, here using the example of mobility.

With the prototypical implementation, we enable an evaluation in cooperation with different industry partners in several iterations. The developed process and the corresponding prototype were used in two industrial projects for the internal modeling and visualizing of different ecosystems. In addition, we modeled and visualized the business ecosystem of a Smart Mobility Initiative in cooperation with a non-researching public institution using publicly accessible data sources. Also, five interviews were conducted to evaluate and identify additional applications of the prototype.

Acknowledgment

I would like to express my special appreciation and thanks to my supervisor Prof. Dr. Florian Matthes. He gave me the opportunity to conduct this research under his supervision and trusted me to manage the TUM Living Lab Connected Mobility research project from day one. I have learned a lot and grown during my time as a research assistant at his chair, and I am immensely grateful for that. I further want to express my sincere gratitude to Prof. Dr. Helmut Krcmar for being my second supervisor.

I would especially like to thank Dr. Sven-Volker Rehm for his support throughout my research endeavor. Our discussions and the feedback received helped me to focus on the relevant aspects of my research and to pour the results in scientific texts.

The presented research was conducted at the chair for Software Engineering for Business Information Systems at the Technical University Munich, which has proven to be an excellent environment. I would like to thank all my colleagues at the chair for their constructive cooperation. My special thanks go to my colleagues Adrian Hernandez Mendez, Daniel Braun, Gloria Bondel, Klym Shumaiev, and Manoj Mahabaleshwar for many fruitful discussions, results achieved together, and your constructive criticism. I would also like to thank my students – Maximilian Riemhofer, Johann Arendt, Marla Narazani, and Sagarika Kathuria – who in one way or the other contributed to the results presented in this thesis.

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Anne Faber

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CHAPTER 1

Introduction and Motivation

The way companies develop, produce, and distribute their services and products is continuously changing as their business conditions are steadily evolving and "successful businesses are those that evolve rapidly and effectively" (Moore, 1993, p.75). This rapid and effective evolution is evoked through the implementation of innovation, in the form of new or changed methods, ideas, services, products or processes. Missing out on disruptive innovations can cause companies to fail (Christensen, 1997). "Disruptive innovations are those that create new markets and categories of customers, not only through the development of new technologies and product categories but also through the creation of new business models or the application of existing technologies in new, more simply designed and user-friendly ways" (DeFillippi et al., 2016, p.2). Companies have to seek ways to keep innovation coming, to integrate and implement it into their daily business.

One way to foster innovation in a company is to involve customers more closely. The digitization has contributed to new possibilities on how to include customers in the development and decision making of how to produce or distribute services or products. Crowd sourcing initiatives and more specifically crowd innovation initiatives are among these possibilities. Through crowd innovation, companies open up there previously internal processes to collect new ideas (Chesbrough, 2003). These ideas can address all steps of a service or product development process. They can target a completely new product or service during the initiation process step, can focus on a specific feature to be designed within the development process steps or can influence the appearance of the packaging in the delivery process steps. The (potential) customer is thereby in contact not only with the distributor of a service or product but also eventually with the supplier or manufacturer.

But not only customers but also competitors and business partners become relevant for the implementation of innovation as "innovative businesses (...) must attract resources of all sorts"

(Moore, 1993, p.75). These resources can come from business partners with whom a long-term business relationship already exists, investors investing in the specific market or business field or public sponsors interesting in fostering development and implementation of innovation. Companies are faced with the challenge to identify the right partners to innovate with, because "increasingly, even large corporations depend on joint business developments, licensing, joint ventures and spin-offs for new product development" (Rehm et al., 2015, p. 87).

All this leads to an opening up of the previous rather linear supply chain, enabling exchange between the different members to search for the optimal partner. In addition to these members of the supply chain, it is essential to perceive and understand actions of competitors or future competitors, partners and future partners, customers and prospective customers but also governmental institutions influencing the service or product market to identify and potentially react to innovation happening in the business environment.

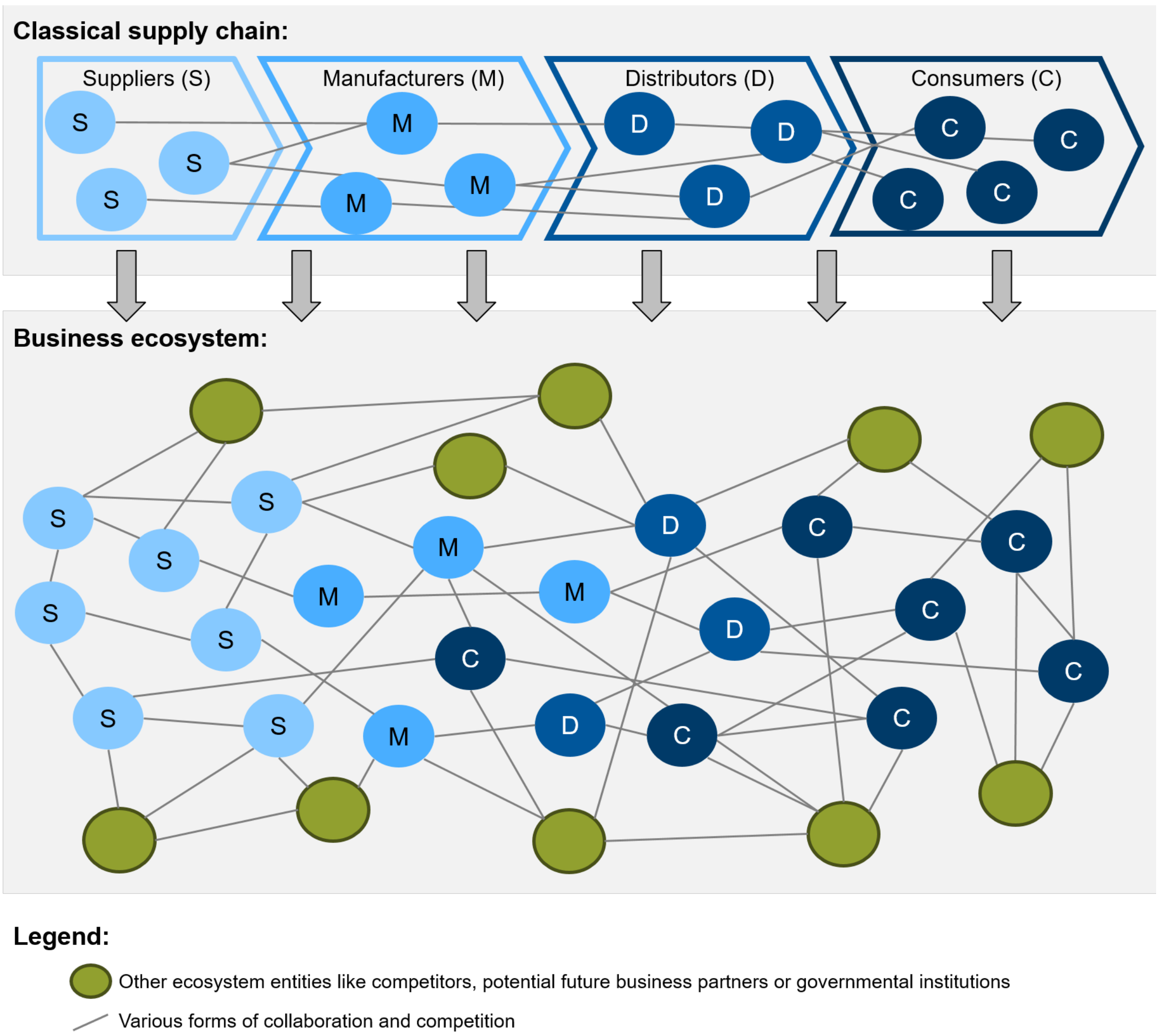


Figure 1.1.: Supply chain broken up towards a business ecosystem

Motivated to support companies and their representatives incorporating and implementing innovation, James F. Moore suggested to view a company “not as a member of a single industry but as part of a business ecosystem that crosses a variety of industries”(Moore, 1996, p.76). Within this business ecosystem companies work cooperatively and competitively to address innovation (Moore, 1993). Thereby, “business ecosystems are formed by large, loosely connected networks of entities” (Iansiti and Levien, 2004a, p.35) with entities such as business partners, competitors, governmental institutions, customers, and influential stakeholders as visualized in Figure 1.1.

To summarize, missing out on the ecosystem perspective especially in recognizing and aligning with the “critical partner” (Adner, 2012) can have significant business implications for the development, production, and distribution of services or products and can lead to business failure.

1.1. Problem description

To not miss out on this ecosystem perspective, companies and their responsible representatives have to define, gather, analyze, and distribute ecosystem information about “partners, competitors, products, and any aspects of the environment needed to support strategic decision-making of an organization” (Basole et al., 2018, p.6:3). We summarize these activities as *business ecosystem analysis*. Due to the changing environment, it is essential for a company to continuously analyze its business ecosystem to be able to react to changes within the ecosystem and adapt its own business strategy.

Business ecosystem analysis poses especially two challenges for companies and stakeholders responsible to make ecosystem-related decisions based on the analysis.

1.1.1. Business ecosystem data

The first challenge is to identify, collect, and handle information about the relevant ecosystem entities that are worth integrating into the analysis. This comprises the availability and amount of information about the identified participants of the business ecosystem and their diverse relations (Park et al., 2016; Basole et al., 2015). Essential information include but is not limited to data about

- business partners, with details on established business relationships, contracts concluded, and key contacts working for highly relevant business partners,
- competitors, for example in the form of sales figures, published information on future strategies or new product developments,
- relevant start-ups, offering innovative services and products including new technologies, which might change the market,
- consumer groups, with their preferences, expectations, and consumer experiences, and
- publicly funded projects, as these can provide insights into future regulations that can affect and influence the market.

Companies and ecosystem stakeholder have to handle this "tsunami of digital data"(Basole et al., 2018, p.6:3), which includes the identification of trustworthy sources, the collection of the information, and finally the processing of it in order to benefit from this data.

1.1.2. Integration of different perspectives

The second challenge is to involve different stakeholders and thus perspectives of the business ecosystem in the analysis to get as comprehensive a picture as possible of the ecosystem. Successfully involving these stakeholders and their views means including their specific and diverse requirements in the ecosystem analysis so that they can benefit from the results and make informed decisions. While market analysts are interested in discovering competitive trends, strategies, threats, and opportunities, executives are trying to identify potential strategic partners and customers, and identify innovation white spaces (Basole et al., 2013). When analyzing a company's business ecosystem, these requirements need to be identified and the necessary information gathered and processed in a way that supports ecosystem stakeholders in their ecosystem-specific activities and decisions on a continuous base.

Starting from the analysis of a business ecosystem of a specific market, for example of a certain technology or start-up region, similar challenges arise. In addition, the identification of all relevant actors of the ecosystem is already difficult for a single participating company. While the identification of ecosystem business partners can be supported by internal information systems, the identification and availability of information about other ecosystem entities in the form of indirect business partners, interesting start-ups, and future competitors is more challenging.

Visualizing business ecosystems in form of multiple interactive visualizations have proven to enable business ecosystem stakeholders to take better informed decision (Basole et al., 2016; Huhtamaki and Rubens, 2016; Evans and Basole, 2016). Basole et al. (2015) presented a data-driven approach and Basole et al. (2018) a sophisticated system to visualize business ecosystem data. In addition to these scientific results, there are numerous commercial software vendors that enable – although not primarily – visualization of business ecosystem data.

Nevertheless, these already available tools for modeling and visualizing business ecosystems do not address the above mentioned challenges comprehensively. The requirements of the various ecosystem stakeholders are not included in the modeling process to define how the business ecosystem should be modeled regarding the specific relevant information of the ecosystem entities. In addition, the collaboration of these stakeholders to model the business ecosystem of their interest is not sufficiently supported (see Chapter 4). We address these open issues within this thesis, by proposing and evaluating a *collaborative process* to model business ecosystems. This process is supported through a web-based application visualizing the business ecosystem information using a knowledge management system.

1.2. Research questions

Based on the outlined problem description, we derived research questions operatonalizing and guiding our research. These questions address the challenges we previously identified, allowing a structured approach to achieve the overall objectives. Their answers present our research contributions.

> ***Research question 1:*** What business ecosystem concepts are discussed in the scientific literature?

To build our research on a solid foundation, we analyzed related literature defining business ecosystems, describing roles involved in business ecosystems, stages of business ecosystem evolution, and types of business ecosystems. This foundational work discussed in Chapter 2 gives a clear terminology used in the rest of the thesis.

> ***Research question 2:*** What challenges do practitioners face when completing ecosystem-related tasks?

Through our involvement in a smart city project, we identified challenges practitioners face when analyzing their business ecosystem and taking related decisions. As described by Faber et al. (2017), we developed initial business ecosystem visualizations to evaluate what insights can be gained by following a visual approach (Iyer and Basole, 2016) targeting the specific project business ecosystem (see Section 3.1.2). In addition, we designed an online survey to understand what actions practitioners today already take to model and visualize the business ecosystem of their interest as part of their daily business. We asked how active they are in the different phases of modeling and visualizing their business ecosystem, and where they perceive major challenges within their activities (see Section 3.2). The survey results were published by Faber et al. (2018c).

> ***Research question 3:*** What business ecosystem modeling approaches and visualization tools have been presented in the scientific literature?

We conducted a systematic mapping study as a specific form of a systematic literature review (Kitchenham et al., 2011; Petersen et al., 2008) to identify data-driven business ecosystem modeling approaches with the goal to visualize the ecosystem entities and their relations. As we envision to involve various ecosystem stakeholders in the modeling process, we searched for related approaches in scientific literature. The related work is presented in Chapter 4.

> ***Research question 4:*** What are tool requirements to visualize business ecosystems?

Based on the results of our relevance study (see Chapter 3) and the related work on visualizing business ecosystems (see Chapter 4), we present the concept of our tool-support to collaboratively model and visualize business ecosystems. We collected requirements as discussed by Faber et al. (2019c), which we outline in Chapter 5. In addition, we describe the first version of a web-based application (see Section 5.3) we developed to foster the discussion with ecosystem stakeholders and to collect feedback for the second design cycle as proposed by Hevner et al. (2004).

> ***Research question 5:*** How can business ecosystems be collaboratively modeled considering necessary activities, roles, and artifacts?

As one main contribution, we designed an iterative modeling process which involves various ecosystem stakeholders to contribute with their ecosystem-related requirements and knowledge (see Section 6.1) as described by Faber et al. (2018a,d, 2019b). We describe the respective activities, proposed roles, and artifacts in detail.

> ***Research question 6:*** How can a tool supporting the modeling process be designed?

The tool-support we developed in the second design cycle (Hevner et al., 2004) consists of a web-based application and a meta-model based knowledge management system. Both is describe in Section 6.2. The tool is instantiated in the first iteration of the modeling process and continuously adapted to address changes of the ecosystems and the changing requirements of ecosystem stakeholders.

> ***Research question 7:*** How can a business ecosystem be modeled and visualized using Internet data sources?

As one evaluation method of the design artifact developed, we applied the tool-supported collaborative modeling approach to visualize a smart city mobility business ecosystem using Internet data sources. The extension of the process to identify, assess, and use these data sources is described in Section 7.4 including the created visualizations which eventually can be provided to the public as discussed by Faber et al. (2018d).

1.3. Research design

The scientific work described in this thesis can be classified as design-oriented information system research as it has been described in the memorandum by Österle et al. (2010). Among others, the memorandum provides "rules for rigorous research and security for researchers" (Österle et al., 2010, p.665). The related research results are artifacts in form of constructs – such as concepts, terminologies, language – models, methods, and instances – as implementations of concrete solutions as prototypes or productive information systems. Österle et al. (2010) described the knowledge process as iterations of

1. the analysis, to identify a research topic of relevance for practitioners or scientists and a research plan how to address this topic,
2. a draft of the artifact developed, which differentiated from existing solutions,
3. the evaluation, to proof rigorousness as defined in the research plan, and
4. the diffusion, to spread the gained knowledge within the stakeholder group.

To ensure the differentiation of our research contribution, we conducted a systematic mapping study as described in Section 1.3.1. The created research results – a framework comprising a process to collaboratively model business ecosystems and the instance of a web-based application providing interactive business ecosystem visualizations in form of a prototype – and the followed research approach are discussed in Section 1.3.2.

1.3.1. Systematic mapping study

To analyze existing scientific literature in a structured way, we conducted a systematic mapping study between September and October 2018 as a specific form of a systematic literature review (Kitchenham et al., 2011; Petersen et al., 2008). The detailed results are discussed by Riemhofer (2019).

Overall, the guiding research questions were *Research question 1* and *Research question 3* aiming at the identification of business ecosystem concepts in the literature. We targeted specifically business ecosystem definitions, types, and visualization approaches and tools.

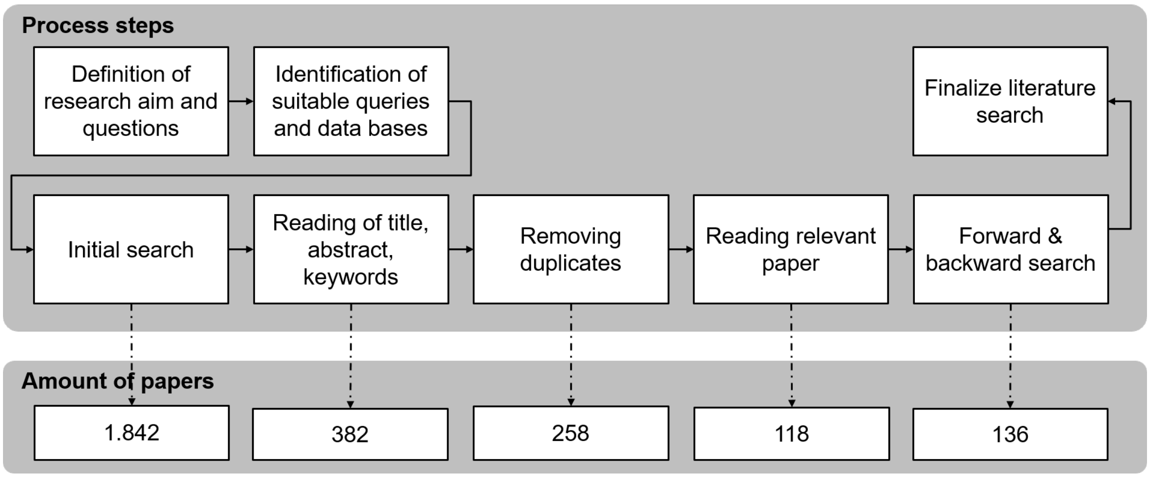


Figure 1.2.: Search process of the systematic mapping study (following Petersen et al. (2008))

The systematic mapping process is visualized in Figure 1.2. In the following, we will describe the conducted steps of searching, selecting, and analyzing existing scientific literature.

Selection of data sources and search strategy

For the selection of suitable databases, we identified research areas where research on business ecosystems is conducted and presented: computer science, information systems, and management theory.

For our mapping study we only used electronic databases. An extensive selection of databases was the first step in fulfilling the research aim of a comprehensive overview of related research. We selected the databases Association for Computing Machinery (ACM), Electrical and Electronics Engineers (IEEE), ScienceDirect, Scopus, SpringerLink, and Web of Science. These databases cover publications of the previously identified research domains.

The search string consisted only of the term *business ecosystem* as described in Table 1.1 and within the initial search only the titles, abstracts, and keywords were analyzed. If at least one of these three contained the term *business ecosystem*, the record was included. This resulted in 1,842 records after the initial search.

Table 1.1.: Search queries of the systematic mapping study to identify relevant business ecosystem literature

Database	Query
ACM	acmdlTitle:(+"business ecosystem") OR record Abstract:(+"business ecosystem") OR keywords.author.keyword: (+"business ecosystem"")
IEEE	((("Document Title":'business ecosystem') OR "Abstract":'business ecosystem') OR "Author Keywords":'business ecosystem')
Science Direct	"business ecosystem" on title, abstract, and keywords
Scopus	TITLE-ABS-KEY("business ecosystem") AND (EXCLUDE(DOCTYPE, "cr") OR EXCLUDE(DOCTYPE, "re") OR EXCLUDE(DOCTYPE, "ed") OR EXCLUDE(DOCTYPE, "le") OR EXCLUDE(DOCTYPE, "no")) AND (LIMIT-TO(LANGUAGE, "English"))
Springer Link	*Find Resources with **all** of the words* **business ecosystem** *where the **title** contains* **business ecosystem**
Web of Science	TITLE: ("business ecosystem") AND TOPIC: ("business ecosystem") AND LANGUAGE:(English) Refined by:[excluding] DOCUMENT TYPES: (EDITORIAL MATERIAL OR CORRECTION) AND [excluding] RESEARCH AREAS: (FOOD SCIENCE TECHNOLOGY OR GEOGRAPHY OR HEALTH CARE SCIENCES SERVICES OR MATHEMATICAL METHODS IN SOCIAL SCIENCES OR MATHEMATICS OR ROBOTICS)

Inclusion and exclusion criteria

In the next process steps, relevant records were entered in the "pool of papers" (Wendler, 2012) and irrelevant records were excluded. After reading the title, abstract, and keywords 382 articles were labeled as relevant. We identified and removed 124 duplicates, leaving 258 relevant records. Records were included in case they were written in English and the scope was related to business ecosystems. We excluded records with a lack of business focus, i.e. interaction of multiple actors crossing industries, but rather describing technical aspects or architectural descriptions of ecosystems. Also, we excluded records with a biological ecosystem in focus. To maintain high-quality standards, results with a "notice of violation" – or "notice of retraction" – note were excluded as well. For the remaining records, a concept matrix (Salipante et al., 1982; Wendler, 2012) was created, consisting of the business ecosystem concepts definition, roles, phases, types, visualizations, applications, and examples as described in Table 1.2.

Table 1.2.: Concept mapping matrix characteristics

Concept	Description and number of identified records
Business ecosystem definitions	Either a new definition of business ecosystem is established, it adds to an existing definition, sums up different definitions or compares existing definitions. 58 papers identified
Business ecosystem roles	The different roles ecosystem actors incorporate are described, a new descriptive metaphor is established for these roles or different roles are compared. 70 papers identified
Business ecosystem 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 papers identified
Business ecosystem types	The paper describes at least one type of business ecosystem or compares multiple types. 42 papers identified
Business ecosystem visualizations	The article contains at least one business ecosystem visualization, describes how a business ecosystem can be visualized, develops or uses a modeling or visualization tool. 43 papers identified
Business ecosystem applications	Applications of the business ecosystem concept both in research and practice. 58 papers identified
Business ecosystem examples	Paper demonstrating a specific example of a business ecosystem in a real world context, e.g., for Walmart or Alibaba. 49 papers identified

Records with at least one hit for these concepts were considered as relevant, leading to 118 records. Last, forward and backward citation search as proposed by Webster and Watson (2002) was applied to these records. This led to the inclusion of 18 additional records.

Overall we analyzed 136 records in our mapping study. All identified records and the respective concept matrix are listed in Appendix A.

Distribution of identified records

Of all 136 papers, books, and book chapters, the earliest was written by James F. Moore in 1993 who pioneered the term business ecosystem. The number of publications is rising continuously. So far, 2018 is the year with the most publications, i.e. 21 records. Only three of the results date back earlier than 2000, all are written by James F. Moore. In Figure 1.3 the distribution of the 136 records per year is depicted.

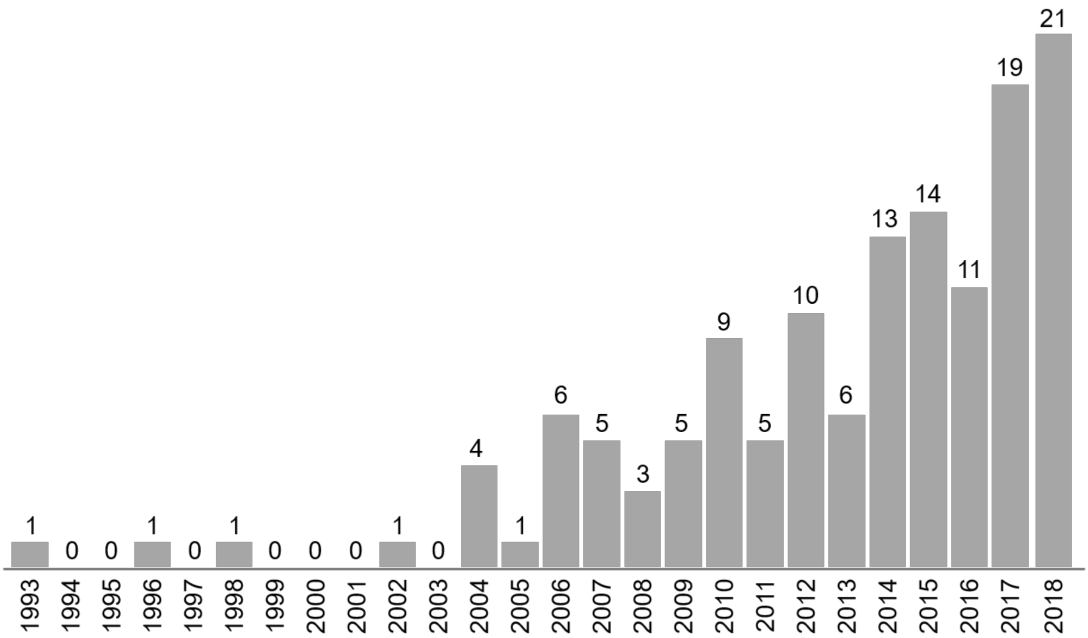


Figure 1.3.: Records per year (adapted from Riemhofer (2019))

In Chapter 2, the results of the systematic mapping study in terms of content related to the foundation of business ecosystems are presented and discussed. This chapter covers the identified definitions, roles, stages, and types of business ecosystems. The records related to the business ecosystem visualizations are presented in detail in Chapter 4, with a focus on visualization tools developed to support business ecosystem analysis.

1.3.2. Design science research

An established methodology in information system research is design science. We followed the design science research methodology as presented by Hevner et al. (2004), which combines two distinct paradigms: behavioral science and design science. We adapted the information systems research framework to our research process described in this thesis (see Figure 1.4).

On one side of the framework, "the environment defines the problem space" (Hevner et al., 2004, p.79) as the identified business need or "problem" practitioners face drives the design of the artifact. We identified the challenges people face in organizations or as stakeholders of a business ecosystem to collect and process the high amount of business ecosystem-related information to analyze the business ecosystem and make educated ecosystem-related decisions. In discussions with ecosystem stakeholders at the beginning of the scientific process, we identified the problem to determine relevant companies and organizations addressing the same market for future collaborations or as potential business competitors. We conducted an online-survey to identify further challenges not only on a personal but also organizational level.

On the other side, "the knowledge base provides the raw materials from and through which

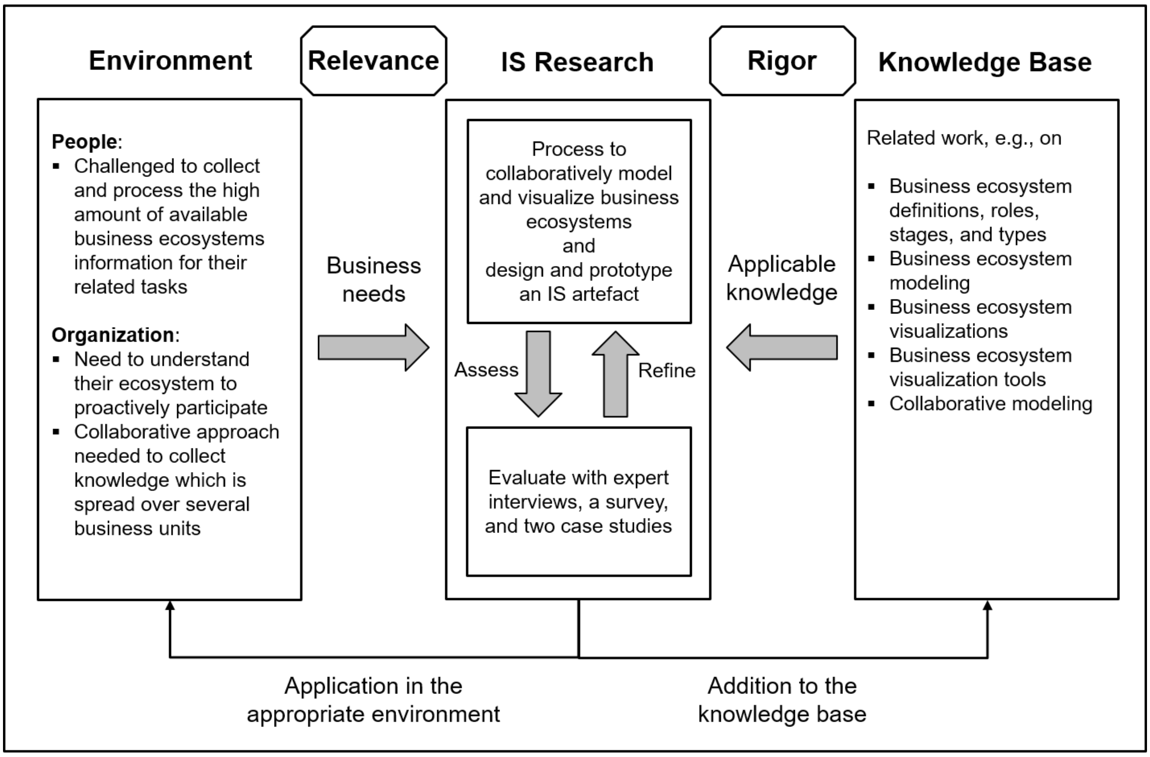


Figure 1.4.: Information systems research framework (Hevner et al., 2004) adapted to the present thesis' contribution

information system research is accomplished" (Hevner et al., 2004, p.79). We have included related work on business ecosystem modeling approaches, business ecosystem visualizations, and visualization tools, which are also referred to as visual decision support systems to identify a clear research gap which we address with this thesis.

In the center of the information system framework are the two processes *building* and *evaluating* of an artifact designed to meet the identified business need (Hevner et al., 2004). We build an instantiation of a web-based application to provide interactive business ecosystem visualizations using a meta-model based knowledge management system. The prototype is instantiated and used as a tool supporting a collaborative modeling process we designed. The second aspect is the evaluation of the design science artifact to rigorously demonstrate the utility, quality, and efficacy of the design artifact (Hevner et al., 2004). We describe our evaluation briefly as one of the seven design principles we followed below and in detail in Chapter 7.

We followed the seven design principles as proposed by Hevner et al. (2004):

Design as an artifact. At the center of design science research is the creation of a purposeful design artifact, which addresses an important organizational problem (Hevner et al., 2004). Thereby, a design artifact can be an instantiation, a construct, a model or a method. In this thesis, the artifact created is a framework which includes a collaborative process and the prototypical implementation of a web-based application we conceptually designed.

The aim of this tool is to support the process to create a model of any business ecosystem by incorporating various ecosystem stakeholders and to provide interactive and tailored visualizations as modeling outcome.

Problem relevance. As "the objective of research in information systems is to acquire knowledge and understanding that enable the development and implementation of technology-based solutions to heretofore unsolved and important business problems" (Hevner et al., 2004, p.84), we regularly exchanged with practitioners of a specific business ecosystem to discuss and propose solutions to their ecosystem-related problems. To broaden our understanding of the state-of-the-practice and especially challenges perceived by stakeholders during their business ecosystem analysis, we conducted an online-survey. Both are in detail discussed in Chapter 3.

Design evaluation. To demonstrate the utility, quality, and efficacy of the design artifact presented in this thesis, we conducted multiple evaluation methods. "Because design is inherently an iterative and incremental activity" (Hevner et al., 2004, p.85), we implemented a preliminary version of the web-based application to collect feedback for the next design phase. Therefore, we conducted eleven interviews in two interview rounds as discussed in Chapter 5. The main design artifact of this thesis was evaluated as described in Chapter 7. Two case studies allowed us to study the artifact in depth in two practical environments and an additional interview series targeted the usefulness of the web-based application. In addition, we simulated the application of the design artifact for a specific business ecosystem using real data.

Research contributions. The main contribution of this thesis is an evaluated framework to collaboratively model and visualize business ecosystems. We designed a process which is applicable to various business foci. Within the process the business ecosystem is collaboratively modeled. We have identified roles used in group modeling and transferred these to ecosystem-related activities during the modeling process. We conceptualized a tool-support for this process which was prototypically implemented by us and thoroughly evaluated.

Research rigor. To ensure the research rigor, we analyzed existing scientific literature addressing business ecosystems. We conducted a systematic mapping study and report about the findings regarding the foundations of business ecosystem research in Chapter 2. The related work on visualizing business ecosystems and especially tools to provide interactive visualizations of business ecosystems is discussed in Chapter 4. The results of the mapping study let to the identification of the research gap we address with this thesis.

Design as a search process. As "design is essentially a search process to discover an effective solution to a problem" (Hevner et al., 2004, p.88), we structured this thesis according to our search process. After the foundation of business ecosystem research, we present first interactions with ecosystem stakeholders to identify their ecosystem-specific challenges in Chapter 3. Early in our research, we applied a visual approach implicating that visualizations are helpful to gain insights of the business ecosystem. This was followed by an online survey we conducted to identify the state-of-the-practice and ecosystem modeling related challenges. Next, the research gap was determined by analyzing related literature addressing the visualizing of business ecosystems and including ecosystem stakeholders in the entire modeling process. We developed an initial prototype, which we evaluated through two interview series. The feedback was used to develop the framework as our design artifact. Finally, we evaluated the framework using multiple evaluation methods.

Communication of research. We communicated our research results both to "technology-oriented as well as management-oriented audiences" (Hevner et al., 2004, p.90). For the technology-oriented audience we chose scientific conferences and journal publications to present our research preliminary and partial results in the various stages of our research process. We targeted conferences with a focus on Information Systems (IS) and discussed the results presented and potential next steps of the design. As management-oriented audience we used our close connection to ecosystem stakeholders of a project ecosystem and industry partners during our design evaluations. A list of the main publications is included in the fourth column of Figure 1.5.

1.4. Outline of this thesis

This thesis is organized in eight chapters describing the research process and the contributions in the form of research results and artifacts, which we designed and evaluated, as visualized in Figure 1.5.

We will briefly describe the contributions of this thesis using the chapter outline.

Chapter 2: Foundation briefly introduces existing scientific literature on business ecosystems. The results of the systematic mapping study are presented regarding business ecosystem definitions, characteristics, roles within business ecosystems, and the stages of business ecosystem evolution. Furthermore, the different types of business ecosystems we identified are presented including a characterization of the relationships between these types.

Chapter 3: Relevance of Business Ecosystem Analysis in Practice describes our interaction with practitioners and business ecosystem stakeholders and the identified challenges of these stakeholders. We describe our involvement in a research project contributing to the establishment of a specific business ecosystem. Preliminary visualizations to better understand a related business ecosystem are discussed. Finally, the results of an online survey we conducted to grasp the state-of-the-practice in German companies of modeling and visualizing business ecosystems are presented.

Chapter 4: Related Work uses the insights gained in the previous chapters and focuses on the related work specifically targeting the visualizing of business ecosystems. Therefore, again the results of the systematic mapping study are used and the relevant records described in more detail. It closes with the presentation of the identified research gap.

Chapter 5: Identification of Tool Requirements summarizes the requirements towards a tool-support targeting the visualization of business ecosystem data. The requirements are based on the concept of the designed prototype, are drawn upon explicitly stated requirements of previously described related work, and the insights we gained through the continuous

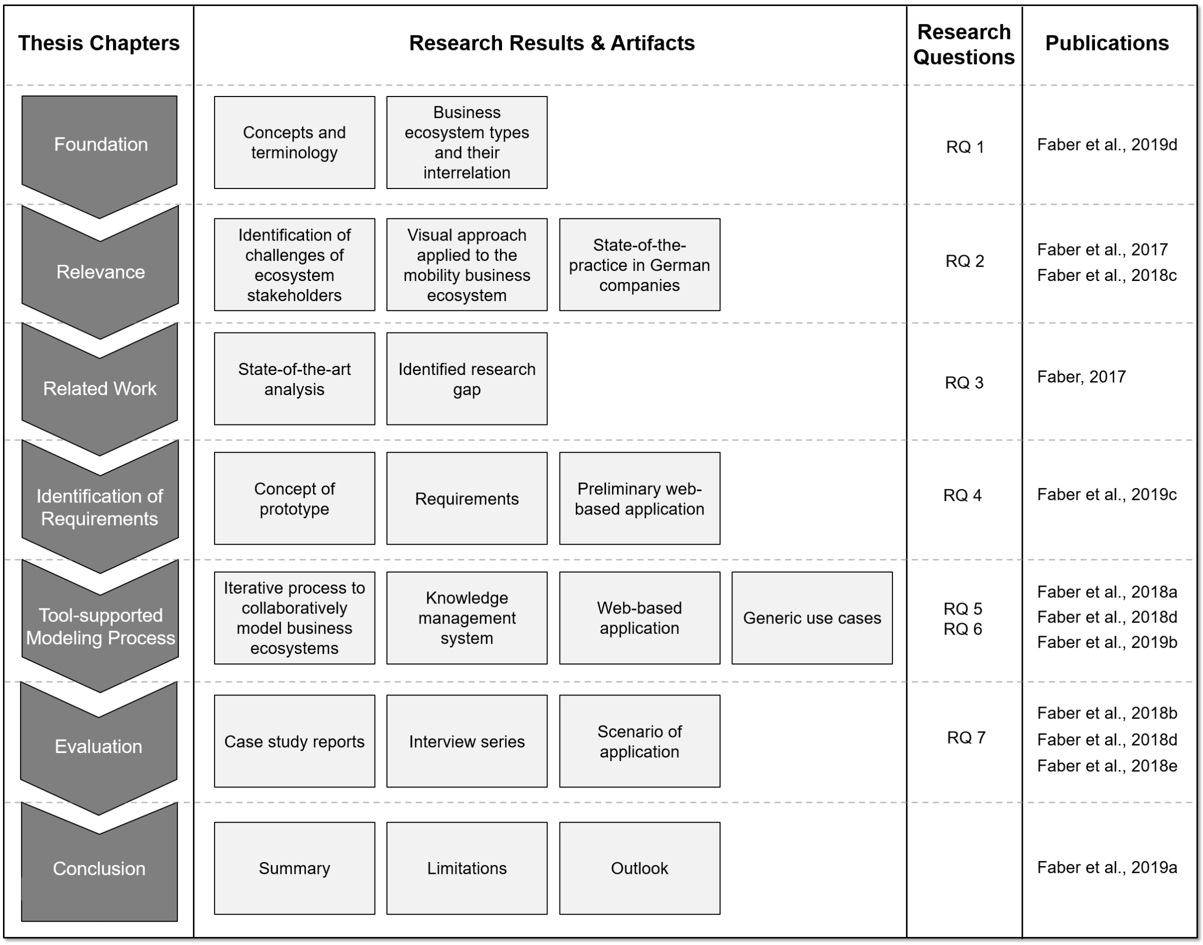


Figure 1.5.: Structure, contributions, and publications of this thesis

interaction with ecosystem practitioners. As the design process is iterative in its nature, this chapter presents the first version of the prototype and the respective evaluation.

Chapter 6: Tool-Supported Business Ecosystem Modeling presents the design of the research artifact in form of a method to collaboratively model business ecosystems and the prototypical implementation of a web-based application to visualize business ecosystems supporting this process. The process activities, involved roles, and artifacts created and used within the process are described. For the instance of the tool-support a knowledge management system was used which provides features necessary to include various ecosystem stakeholders and support the evolution of the business ecosystem model. The system is presented as well as the prototypical implementation of the web-based application. Finally, the chapter closes with a description of two use cases for the application of the developed tool-supported process.

Chapter 7: Evaluation represents the second major contribution of this work: the evaluation of the design artifact. The three evaluation approaches in form of two case studies, an interview series, and a simulation are described.

Chapter 8: Conclusion summarizes on the research contributions presented in this thesis reflecting on the research questions. The limitations of the research approach followed, the results achieved, and the evaluation methods applied are described. Finally, open questions and possible future work are outlined.

CHAPTER 2

Foundation

In order to build this thesis on a clear scientific foundation, we have systematically analyzed literature on business ecosystems. We conducted a systematic mapping study (cf. Section 1.3.1), which provided "an understanding of how the field of business ecosystem research evolved, shedding light on the points of consensus and divergences among scholars and diagnosing whether the intellectual structure within the discourse of a given theme has been properly discussed in the field" (Gomes et al., 2018, p.2). In this chapter, key insights we gained about business ecosystem literature are presented.

In the following, we present scientific work on business ecosystem definitions and characteristics (see Section 2.1), the dimensions of and roles in business ecosystems (see Section 2.2), the evolution stages of business ecosystems (see Section 2.3), and the different types of business ecosystems we identified (see Section 2.4). Based on the description of the business ecosystem types, we discuss the relationship between these ecosystem types as presented by Faber et al. (2019d).

Finally, Section 2.5 is dedicated to a brief summary of the business ecosystem foundations and terminology we use as the baseline for this thesis.

2.1. Business ecosystem definitions and characteristics

In 1993, James F. Moore, at that time the president of GeoPartner Research Inc, pioneered and defined the term business ecosystem in his Harvard Business Review article "Predators and Prey: A New Ecology of Competition" (Moore, 1993):

> *"A business ecosystem [...] crosses a variety of industries. In a business ecosystem, com-*

panies coevolve capabilities around a new innovation: they work cooperatively and competitively to support new products, satisfy costumer needs, and eventually incorporate the next round of innovations." Moore (1993, p.76)

He saw the similarities between natural ecosystems, which sometimes collapse due to too radical changing environmental conditions, and businesses dealing with challenges of innovation. He observed how the changing ecology of business competition affected companies and how these companies were trying to understand and shape the transformation (Moore, 1996). Already in this first definition, the cooperation and competition between companies active in the business ecosystem are mentioned. One aspect, differentiating a business ecosystem from a classical supply chain, which only includes the business partners that collaborate direct or indirect to develop products and services.

Three years later, Moore published the book "The Death of Competition: Leadership and Strategy in the Age of Business Ecosystems"(Moore, 1996) describing the concept and characteristics of business ecosystems in more detail including the necessary changes of management strategies to address this new business phenomenon. In this book, Moore defined business ecosystems more precisely.

"Business Ecosystem. An economic community supported by a foundation of interacting organizations and individuals – the organism of the business world. This economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders. Over time, they coevolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies. Those companies holding leadership roles may change over time, but the function of ecosystem leader is valued by the community because it enables members to move toward shared visions to align their investments, and to find mutually supportive roles." Moore (1996, p.26)

Compared to his first definition, now not only organizations but also individuals are part of the economic community of a business ecosystem. In this definition, Moore described the "ecosystem member organisms" – using the metaphor of biological ecosystems – such as suppliers, lead producers, competitors, and other stakeholders.

To emphasize how much broader the business ecosystem is compared to the core business and even the extended enterprise, he visualized "a more or less typical business ecosystem" (Moore, 1996, p.27) as depicted in Figure 2.1.

In this illustration, the "other stakeholders", as referred to in the definition, are described as investors or trade associations but also governmental agencies and quasi-governmental regulatory organizations. The business ecosystem also includes "direct competitors, along with companies that might be able to compete" (Moore, 1996, p.27). All members located in the center have a high stake in the value creation, which decreases the further away the members are from the core business.

The book addressed strategic managers by giving advice on which questions to ask when analyzing their company's business ecosystem, such as "Who are the leaders (of the business ecosystem)? [...] What are the most important threats to this business ecosystem, now and in future?"

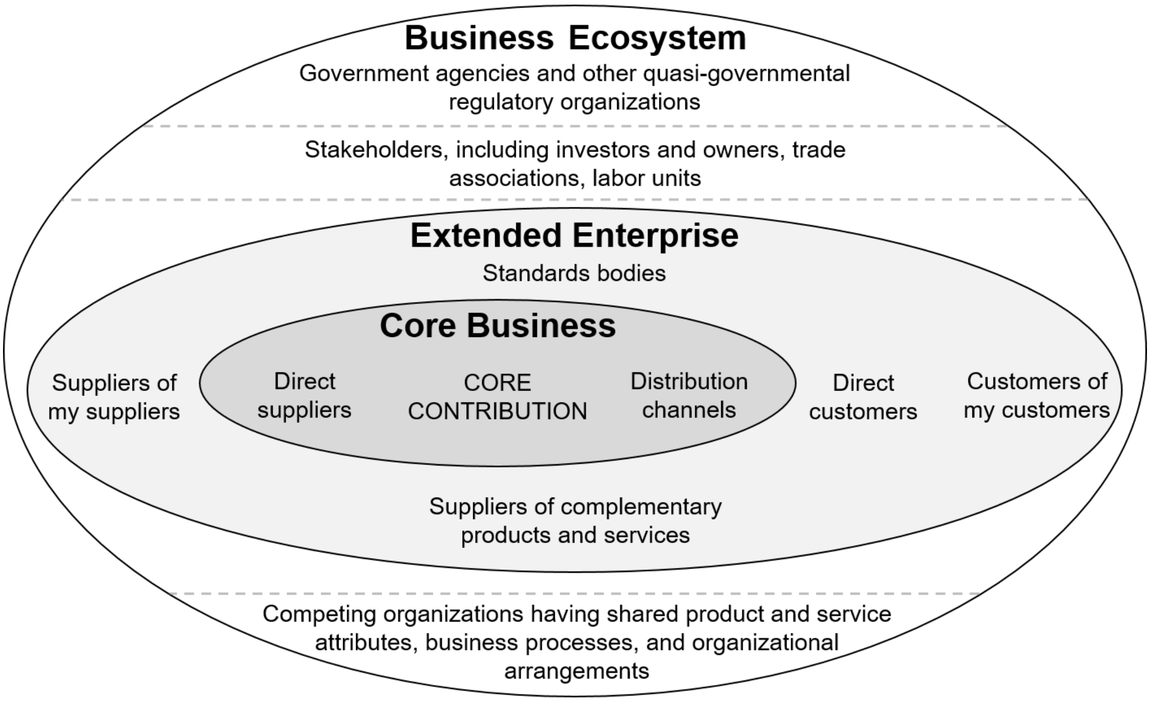


Figure 2.1.: A business ecosystem in relation to the core business and extended business (Moore, 1996, p.27)

(Moore, 1996, p.44). The advice given in the book is intended to enable executives to "become ultrasophisticated at developing business models for their respective communities" (Moore, 1996, p.57). Thereby, "the goal is not to become an industry leader, but to be a destroyer of old industries and creator of new ones" (Moore, 1996, p.55).

After Moore's publications, Marco Iansiti and Roy Levien were the first to pick up the business ecosystem topic in 2001. They analyzed and described the particular challenges and opportunities of business ecosystems. Similar to Moore, they also used the metaphor of natural ecosystems in biology for their definition as "this analogy operates at many levels: firms, business units, technologies, and products all exhibit networks of interdependencies and ecosystem-like dynamics" (Iansiti and Levien, 2004a, p.35).

> *"Like biological ecosystems, business ecosystems are formed by large, loosely connected networks of entities. Like species in biological system, firms interact with each other in complex ways, and the health and performance of each firm is dependent on the health and performance of the whole. Firms and species are therefore simultaneously influenced by their internal capabilities and by the complex interactions with the rest of the ecosystem."*
> Iansiti and Levien (2004a, p.35)

The authors defined three success factors for a business ecosystem adapted from biology:

1. *productivity*, which measures whether and how effectively an ecosystem can turn resources and the core value into economically measurable success,

2. *robustness*, which describes how predictable an ecosystem is regarding sudden changes or transformations, and
3. *niche creation*, which stands for the ability to create variations, innovation, and new business models.

In addition, Iansiti and Levien (2004b) emphasized the influence of the ecosystem health on the health of each firm within the ecosystem. They used the examples of AOL and Yahoo as companies which financially weakened members of their business ecosystem with their aggressive deals, taking "an action without understanding the impact on [...] the ecosystem as a whole" (Iansiti and Levien, 2004b, p.10).

After the publications of Moore, and Iansiti and Levien, research on business ecosystems was published more frequently in the scientific literature (see Figure 1.3). All general definitions of business ecosystems, i.e. definitions not describing a specific business ecosystem type, we identified through the systematic mapping study are listed in Appendix B. In the following, we present characteristics and definitions of business ecosystems, which, in our opinion, contribute to a sound knowledge of how the related research evolved.

Peltoniemi and Vuori analyzed the already existing definitions of business ecosystem concluding with their definition that includes four "relevant complexity concepts"(Peltoniemi and Vuori, 2004, p.10).

> *"A business ecosystem (is) a dynamic structure which consists of an interconnected population of organizations. These organizations can be small firms, large corporations, universities, research centers, public sector organizations, and other parties which influence the system. [...] Business ecosystem develops through self-organization, emergence and coevolution, which help it to acquire adaptability. In a business ecosystem there is both competition and cooperation present simultaneously."* Peltoniemi and Vuori (2004, p.13)

The authors describe these four relevant concepts of business ecosystems:

1. *self-organization*, as participants of a business ecosystem are gathered voluntarily and without external or internal leader,
2. *emergence*, as the result of interactions between different ecosystem units is something, which no one of those units could produce by oneself; a business ecosystem is always more than the sum of its part,
3. *co-evolution*, which appears within business ecosystems, as the evolution of one company affects the evolution of other companies; also, strategic changes of one company can strongly affect other companies in its ecosystem, and
4. *adaptability*, the whole ecosystem adapts to changed conditions by emergence, co-evolution, and self-organization.

Thereby, the first concept, *self-organization*, contradicts to the definition of Moore (1996) and also the roles discussed by Iansiti and Levien (2002) as they described central companies holding leadership or keystone players (cf. Section 2.2). Peltoniemi and Vuori might only refer to the influence of governments at this point, as they outlined "there may be some control and incentives set by government, but in general companies are free to create the kind of structures they prefer" (Peltoniemi and Vuori, 2004, p.10).

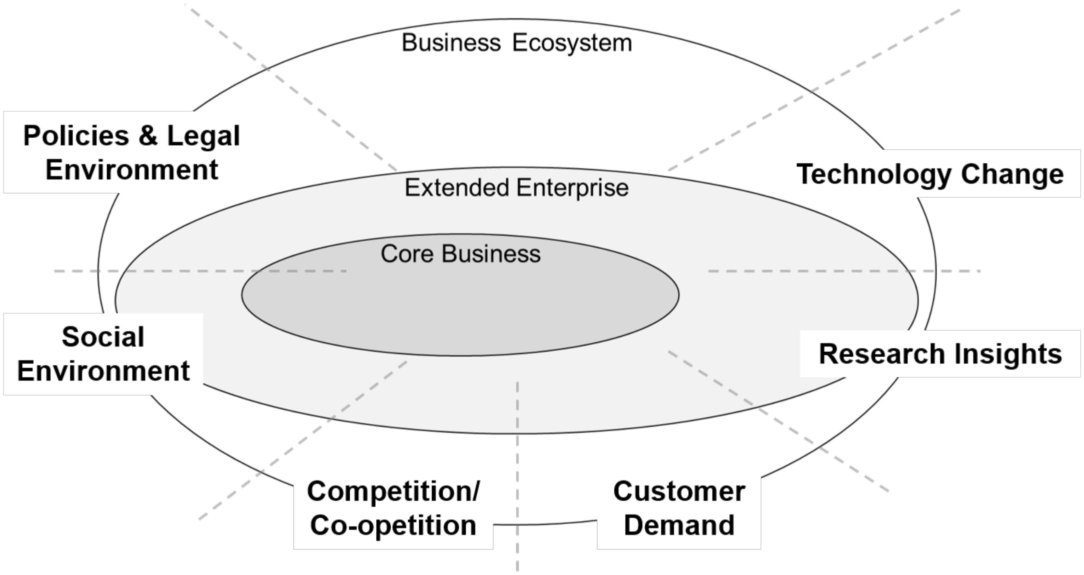


Figure 2.2.: Sub-ecosystems within the business ecosystem (Heikkilä and Kuivaniemi, 2012, p.22)

Heikkilä and Kuivaniemi specified Moore's framework by introducing six ecosystem sub-sectors, as visualized in Figure 2.2. Each sub-sector represents an important aspect of the whole business ecosystem. Dividing the business ecosystem into these sub-sectors helps to overcome the challenge of recognizing "who are the next actors or areas that should be contacted and involved in collaboration" (Heikkilä and Kuivaniemi, 2012, p.22):

1. *technological change*, to identify the potential (information) technologies for the business and to contact the respective suppliers,
2. *research insights*, to include research and development (R&D) and research projects related to the topic of the business,
3. *customer demand*, to involve customers through customer co-creation which helps to identify trends and changing demands,
4. *competition/co-opetition*, to try competitors into co-opetitors, as competitors might have some specific knowledge or capabilities relevant for the business,
5. *social environment*, to collaborate with various kinds of associations and societies which helps to keep track of social change, such as changing work practices, processes, culture, and social mood, and
6. *policies and legal environment*, to be aware of legal aspects, such as work regulations or privacy laws, influencing for the pursued business model.

In 2010, Zhang and Fan analyzed the current state and research trends on business ecosystems. According to the authors, the evolution of business ecosystems is driven by internal and external factors (Zhang and Fan, 2010). While the internal factors are the interactions between individuals, including collaboration and competition, the three external factors are:

1. the competition with other ecosystems,
2. the economic, social, political as well as the legal environment, and
3. the natural environment that supplies the material resources for business ecosystem's survival.

They provide a business ecosystem definition as well:

> *"Business ecosystem is an open, dynamic and selforganizing system based on the interactions of entities that evolve over time."* Zhang and Fan (2010, p.3)

This definition includes the three characteristics of openness, which enables new entities to enter and leave the ecosystem, dynamic, through the changes of interaction and constellation of the ecosystem entities, and self-organization, similar to the concept of Peltoniemi and Vuori (2004).

In 2015, Basole et al. (2015) developed a data-driven approach to provide ecosystem stakeholders with interactive visualizations. They focused especially on the complex network of relations between ecosystem entities:

> *"Business ecosystems consist of a heterogeneous and continuously evolving set of individuals and firms that are interconnected through a complex, global network of relationships. These firms come from a variety of market segments, each providing unique value propositions."* Basole et al. (2015, p.1)

The work of Rahul C. Basole and his colleagues is discussed in more detail in Chapter 4.

Adner (2017) presented a "clear definition" of an ecosystem to name explicitly "its implications, its boundaries, and its relationship with alternative perspectives" (Adner, 2017, p.2), namely the ecosystem-as-structure perspective:

> *"[The ecosystem is defined by] the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize."* Adner (2017, p.2)

He identified two distinct views on business ecosystem theory, namely "ecosystem-as-affiliation, which sees ecosystems as communities of associated actors defined by their networks and platform affiliations; and [...] ecosystem-as-structure, which views ecosystems as configurations of activity defined by a value proposition" (Adner, 2017, p.2).

The first view targets an industry or a company network similar to the biological metaphor of an ecosystem, as Moore (1993, 1996) proposed it. The focus is on ecosystem entities breaking down traditional industry boundaries (Moore, 1996; Mäkinen and Dedehayir, 2012; Fragidis et al., 2007a). The entities cooperate and compete at the same time (Heikkilä and Kuivaniemi, 2012), leading to constant innovation of all organizations within the ecosystem (Moore, 1993). This concept is followed when analyzing organizations' ecosystems, such as WalMart (Moore, 1996; Iansiti and Richards, 2006), Amazon (Isckia, 2009), Alibaba (Tan et al., 2009), Walt Disney (Lyu et al., 2013), or Cisco (Li, 2009). Some depicted a static contemporary situation of a business ecosystem, while others looked at the development discussing success (Isckia, 2009) and failure (Tellier, 2017) of the respective business ecosystem.

The second view, ecosystem-as-structure, for which Adner "suggest[s] a new set of questions for strategy research" (Adner, 2017, p.2), focuses on a value proposition or innovation which is in the center of the business ecosystem (Isckia, 2009). After identifying this value proposition or innovation, the companies relevant to offer the value proposition or contribute to the innovation are collected (Adner, 2017). The business ecosystem consists of a set of organizations from different industries, but in the core of the business ecosystem is a value rather than a company. Examples from literature are Taobao.com (Li et al., 2018; Zhang and Wang, 2018; Rong et al., 2018c), Alipay (Guo and Bouwman, 2016) or the health and life science business ecosystem in San Diego (Majava et al., 2016).

Recently, Sako (2018) defined three meta-characteristics of business ecosystems:

1. *sustainability*, which implies that the ecosystem can thrive without outside influence or assistance,
2. *self-governance*, which implies the ecosystem is not dependent on an outside force, nor is it controlled by a single dominant actor within the ecosystem, and
3. *evolution*, the business ecosystem ability to evolve through competition and experimentation.

He also provided a definition addressing a better distinction of the ecosystem concept from clusters or networks.

> *"A business ecosystem is a collection of business and other actors with resources operating as an interdependent system. Business ecosystems differ from clusters in sustainability, self-governance, and capacity to evolve over time."* Sako (2018, p.21)

Thereby, business ecosystems can be "thin on the meta-characteristics" (Sako, 2018, p.21) as platform-based ecosystem such as Apple or Google on self-governance and evolution due to the dominant role of the platform in this kind of ecosystem; or "more complete in their meta-characteristics" (Sako, 2018, p.21) as for example the startup or mobility ecosystem.

Overall, all definition can be considered rather similar often referring to the original definition as provided by Moore (1993, 1996) or Iansiti and Levien (2004a,b). Summarizing the definitions, the core elements of a business ecosystem are a loosely connected network of actors from various industries, which can play different roles within the ecosystem (see Section 2.2), and depend on each other for the ecosystem to survive (Peltoniemi and Vuori, 2004; Peltoniemi, 2006; Fragidis et al., 2007a; Shang and Shi, 2012; Rong and Shi, 2014). The metaphor of biology is often picked up again to emphasize the roles ecosystem entities occupy or the evolution of the ecosystem. Both are described in the following.

2.2. Business ecosystem dimensions and roles

Moore (1996) mentioned the roles of customers, organizations, stakeholders, and the government; the value of and the value flows within the ecosystem, products and processes; and constructs, namely markets and society. He identified "seven dimensions of competitive advantage" (Moore, 1996, p.63):

1. *customers*,
2. *markets*,
3. *products*,
4. *processes*,
5. *organizations*,
6. *stakeholders*, and
7. *government and society.*

All influence each other respectively and not only the core business around which the business ecosystem spans. Customers and society define the demand of a market and thus the value. The government sets rules, creates incentives, and might even shape the demand as well. Organizations create products through processes and stakeholders influence single organizations or the government through lobbying. However, entities within the business ecosystem rarely change roles. An organization, a stakeholder, or the government can be customers, but all other dimensions – markets, society, products, and processes – do not change.

The *customer* role was emphasized often in following business ecosystem literature (Fragidis et al., 2007a,b; Hou et al., 2010; Joo and Marakhimov, 2018), as customers greatly shape the demand of the product or service of the core business. Customers – or end users (Giesecke, 2014) – get more and more involved in the value creation and potentially become co-creators. Fragidis et al. (2007a) even proposed a customer-centric business ecosystem as specific business ecosystem type (see Section 2.4).

Iansiti and Levien (2002, 2004a) defined four roles of actors in business ecosystems considering their relevance and influence within the ecosystem:

1. *keystones*, an entity with a central position within the business ecosystem, which guides other entities and campaigns for the overall ecosystem health,
2. *niche players*, these entities are not in the center of the business ecosystem, but are still important for the value creation,
3. *dominators*, organizations that use vertical or horizontal integration to gain control over the whole ecosystem, and
4. *hub landlords*, similar to the keystones, except that hub landlords try to extract as much value from the ecosystem as possible without supporting it.

A healthy business ecosystem comprises only of keystones and niche players (Iansiti and Levien,

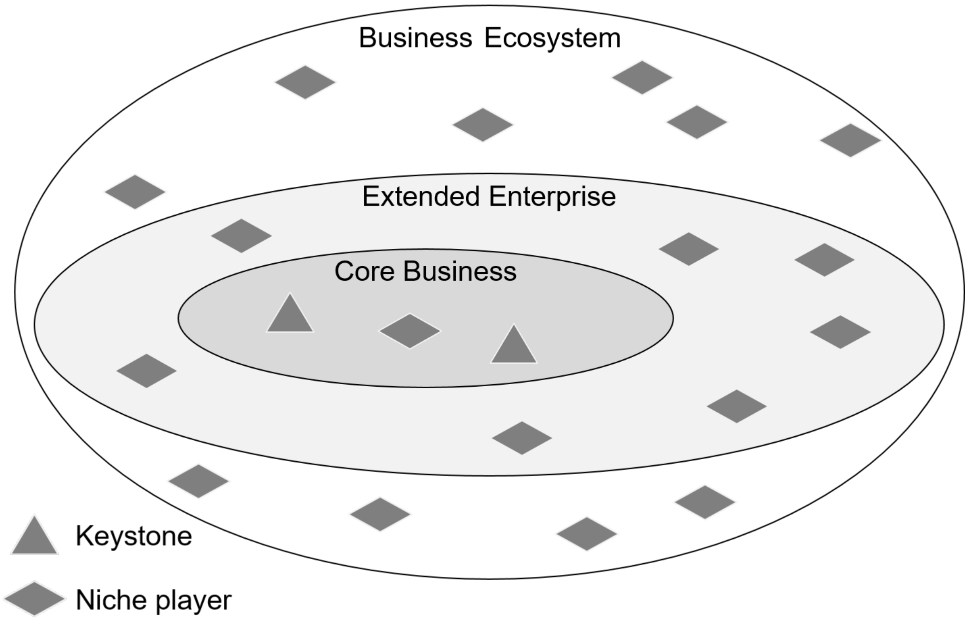


Figure 2.3.: Moore's framework with the Iansiti and Levien's roles (adapted from Riemhofer (2019))

2004a). As depicted in Figure 2.3, the core business includes the keystones and some important niche players, while most of the niche players are located in the two outer circles, the extended enterprise and business ecosystem. A dominator strategy is not necessarily unhealthy for a business ecosystem (Iansiti and Levien, 2004a) but as soon as a keystone organization pursues the dominator strategy and takes over its respective business ecosystem, the ecosystem might not be loosely coupled any more. The dominator directly controls all resources and values. A hub landlord endangers the overall ecosystem health as it extracts the value from the ecosystem.

Other terms, such as *leaders* and *followers* (Sun et al., 2018), have been used in literature to describe keystones and niche players. Kim et al. (2010) added a fifth role to the 'keystone - niche' concept: *the flagship* as depicted in Figure 2.4. A flagship is not the central hub of an ecosystem, but it still inhabits an important hub location and thus connects more niche players to the central keystone. Due to their centrality and importance within their business ecosystems, flagships are located in one of the inner circles of Moore's framework.

Describing the electric mobility business ecosystem, Giesecke (2014) used other behavioral descriptions for the roles within a business ecosystem:

1. *aggregators and providers*, which are the keystones of the business ecosystem as they aggregate the assets from the input providers and enablers to create and provide the core value of the business ecosystem,

2. *input providers*, which are comparable to niche players as they influence the production of the value by providing inputs such as material, energy, information or funding that change during the production process,

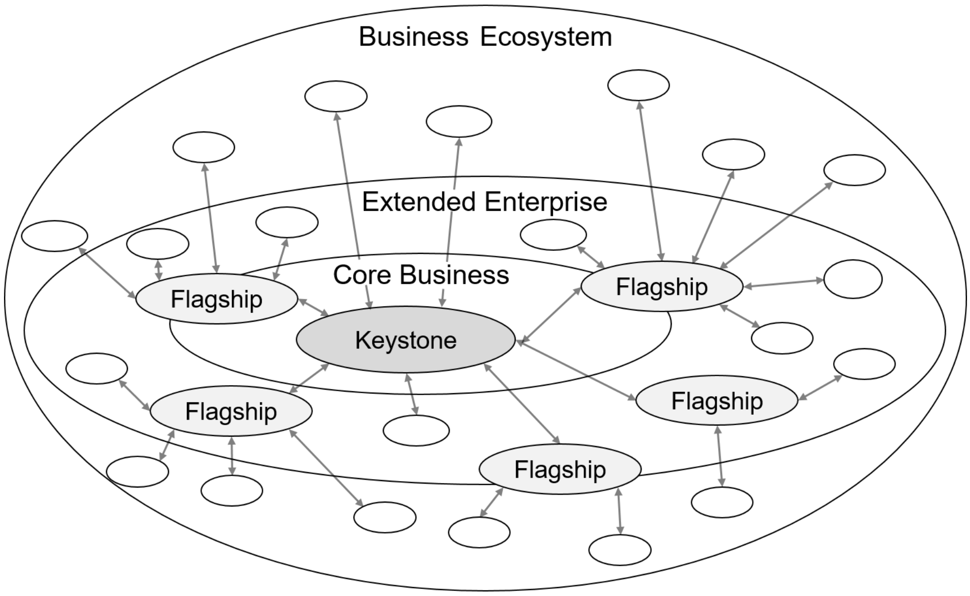


Figure 2.4.: A conceptual business ecosystem with business ecosystem entities acting as flagships (adapted from Kim et al. (2010))

3. *enablers*, who are also some kind of niche players that provide tangible or intangible assets and differ from input providers as their assets, such as software products or process analyses, can change in the production process,
4. *governors*, influencing the ecosystem by setting the rule frame (in terms of, e.g., standards or policies), and
5. *end users*, who consume the core value of the ecosystem.

Moore's seven dimensions not only include the actors but social constructs that set the stage for a business ecosystem (Moore, 1996). Analyzing the relevance of the ecosystem actors, all role definitions include some form of an ecosystem leader (Sun et al., 2018), either the keystone, dominator, or hub-landlord (Iansiti and Levien, 2004a), or the aggregators and provider (Giesecke, 2014). Other organizations within a business ecosystem take up different roles around these leaders but are still essential for their respective business ecosystem. The role of the customers, or end users, is explicitly stretched as they shape the demand and cause the business ecosystem to innovate.

2.3. Business ecosystem stages

Using the metaphor from biology again, Moore described the evolution of business ecosystems as "a series of four roughly sequential stages" (Moore, 1996, p.69):

Stage I: Pioneering an ecosystem. A viable new business ecosystem is searched for in which capabilities can be linked to create core offers on which to build. It is relevant for the further development of the business ecosystem that the value generated is much superior to the status quo. It is a phase which includes brainstorming and idea development.

Stage II: Expansion of an ecosystem. Starting from a core set of strategic relationships and invests, the community broadens its scope to establish a critical mass. A successful paradigm must be made more reliable and replicable.

Stage III: Authority in an established ecosystem. The community architecture becomes stable, and competition for leadership and profits within the business ecosystem gets brutal. New entities might enter the business ecosystem, and competition turns inward as well as outward.

Stage IV: Renewal or death. Either - or phase. Continuing innovation must take place for the community to thrive and new ideas must be incorporated. Otherwise the ecosystem becomes obsolete and dies.

The four stages are visualized in Figure 2.5. Each evolutionary stage comprises cooperative and competitive challenges in order to maintain a healthy ecosystem along each phase.

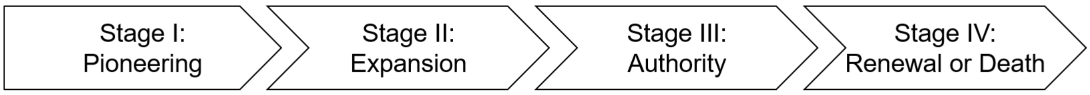


Figure 2.5.: The four evolutionary stages of a business ecosystem (Moore, 1996)

In their book "Business Ecosystems: Constructs, Configurations, and the Nurturing Process", Rong and Shi (2014) describe five phases of business ecosystem evolution learning from three cases – ARM Limited, Intel Corporation, and MediaTek Inc. – and a following cross-cases analysis:

Phase 1: Emerging. A new solution is proposed. Together with partners, the supply chain is initiated for the new market.

Phase 2: Diversifying. The supply chain tries to adapt to market uncertainties by diversifying the solution. The network of cooperating ecosystem entities is very flexible.

Phase 3: Converging. The market specializes in the selected solution to offer. The partners' networks become integrated and focused on those specialized markets.

Phase 4: Consolidating. The ecosystem tries to create the dominant design and might last for a long time. The network of collaborating ecosystem entities is stable and forms a close alliance for mass production of that dominant design.

Phase 5: Renewing. Niche markets are emerging, and the original market might be replaced by the emerging market. Ecosystem entities re-enter, the partners' network reorganizes itself to address changes, and the previous phases repeat.

The five phases are similar to the stages proposed by Moore (1996). The second stage was split by Rong and Shi (2014) into two phases: diversifying and converging. The final phase, renewing,

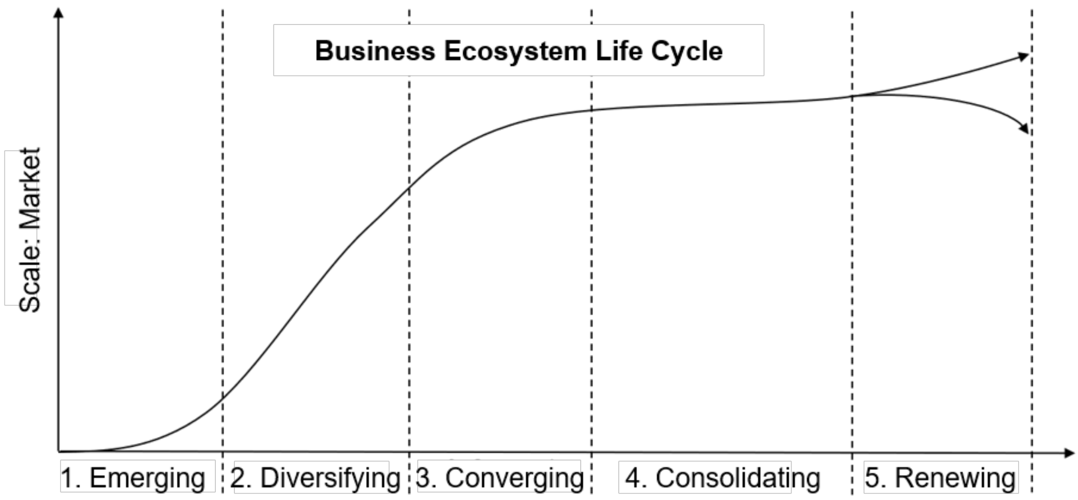


Figure 2.6.: The business ecosystem life cycle as presented by Rong and Shi (2014, p.140)

is equal to Moore's phase four, as the failure in niche creation leads to recession and, finally, the death of the ecosystem. The market scale of each phase is depicted in Figure 2.6.

Zhang and Wang (2018) analyzed institutional and strategic works of Alibaba in building the Taobao e-commerce ecosystem, and slightly adapted Moore's four stages of business ecosystem evolution. They consolidated the stages two and three into *expansion and leadership*. As they analyzed the specific and successful case of Alibaba and Taobao, their third and final phase includes only the *self-renewal*.

2.4. Business ecosystem types

Finally, we describe the various types of business ecosystems discussed and analyzed in the scientific literature. We explain the similarities and differences between ten identified types and set them in relation to each other.

Platform business ecosystem. A platform business ecosystem incorporates a platform as the keystone entity of the business ecosystem, a central hub to which other entities connect. A platform is created by the keystone organization(s) and offers solutions that can be leveraged by other members of the ecosystem (Iansiti and Levien, 2004b). An example of such a platform business ecosystem is Apple's App Store, through which Apple and third-party developers sell software applications (Apps) that users of Apple devices can download. Every App extends the functionality of Apple's devices, thus increasing its value (Basole and Karla, 2011).

A business ecosystem and a platform business ecosystem only differ in the core value: while a product or service provided by one or more keystones is the heart of a business ecosystem as defined by Moore (1996) and others, the platform is the center of the platform business ecosystem. As for Apple, the App Store is the core value rather than the iPhone, because the phone would lack value without third-party Apps.

Innovation ecosystem. Even though some scholars use the term innovation ecosystem synonymous to the term business ecosystem (Gawer and Cusumano, 2014; Overholm, 2015), we distinguish between these two concepts (following Scaringella and Radziwon (2018)).

Adner and Kapoor (2010) were among the first to describe an innovation ecosystem. Starting from a value chain, they included the core innovator as well as the upstream suppliers and the downstream buyers and complementors. This definition fits the 'keystone - niche' concept introduced by Iansiti and Levien (2004b). However, it does not include other entities relevant for business ecosystems, such as the government or research bodies. Both were added by Bodde and Taiber (2014), who further defined criteria for building innovation ecosystems:

1. there are many new, rapidly developing, and distinct technologies in the market,
2. these technologies create the most value when combined, and
3. organizations new to the field enter the ecosystem.

Contrary to traditional business ecosystems, which are based on the exploitation of resources and cost-reduction to create values to its customers, an innovation ecosystem is neither distributed around an existing product or service, but rather an innovation (Gomes et al., 2018; Valkokari, 2015). Innovation actions occur when the market demands change or new technologies disrupt the markets (Annanperä et al., 2015). Even though innovation is an essential aspect of business ecosystems, it is not the base of it.

Examples for innovation ecosystems are the ecosystem that formed around the smartphone when it was invented, with Apple claiming a keystone spot at an early stage. A more current example is Tesla (Bodde and Taiber, 2014).

Software ecosystem. Jansen et al. defined a software ecosystem as "a set of businesses functioning as a unit and interacting with a shared market for software and services, together with the relationships among them. These relationships are frequently underpinned by a common technological platform or market and operate through the exchange of information, resources and artifacts" (Jansen et al., 2009, p.187f).

The software ecosystem is another subtype of business ecosystems (van den Berk et al., 2010; Hyrynsalmi et al., 2015) and is an adaption of a business ecosystem to the software industry, where the center can be either one or more software vendors (Popp, 2010), a software platform or a programming language (Jansen et al., 2009).

Knowledge ecosystem. A knowledge ecosystem differs from a business ecosystem in three ways (Clarysse et al., 2014):

1. the ecosystem's focus activities,
2. the players' connectivity, and
3. the keystone player.

According to Scaringella and Radziwon (2018), this type of ecosystem is located around a university, focusing on knowledge generation and is usually geographically localized with proximity. As key stakeholders, they identify large firms with established R&D departments, small and medium enterprises (SME), and start-ups.

Digital business ecosystem. The European Union initiated the digital business ecosystem approach to strengthen the competitiveness of SMEs in the European Union. Initially, it was designed to supply SMEs with free software tools to help them grow and develop (Stanley and Briscoe, 2010). The digital business ecosystem essentially is a platform ecosystem, which is described in detail by Corallo (2007).

Mobility business ecosystem. As the concept of smart cities gained popularity and (smart) mobility ecosystem being one aspect of it, mobility ecosystems were described applying the business ecosystem concept. The mobility business ecosystem includes innovative mobility services such as ride sharing, connected cars, and driver-less transportation (Sako, 2018). In addition, the actors are OEMs and their suppliers, public transportation, existing organizations without prior experience in the field, and research and regulatory bodies (Faber et al., 2018a). The mobility business ecosystem can be seen as a subtype of innovation ecosystems.

IoT business ecosystem. Another business ecosystem type was created with the emergence of the Internet of Things (IoT). Mazhelis et al. defined the respective IoT business ecosystem as "a special type of business ecosystem which 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 the Internet. These assets may be in the form of hardware and software products, platforms or standards that focus on the connected devices, on the connectivity thereof, on the application services built on top of this connectivity, or on the supporting services needed for the provisioning, assurance, and billing of the application services" (Mazhelis et al., 2012, p.5). They further specified the behavior-wise roles of an IoT ecosystem, including regulatory and legislative bodies such as governments, and adopted the 'keystone - niche' concept introduced by Iansiti and Levien (2004a).

In 2017, Papert and Pflaum (2017) developed guidelines for developing an IoT business ecosystem:

1. define the IoT service, which will be the core of the business ecosystem,
2. determine own value contributions,
3. identify necessary complementors for the value creation,
4. initiate the business ecosystem, build and foster relations with other organizations necessary for the value creation and delivery,
5. negotiate compensation for valuable contributions, and
6. realize the desired IoT service.

Entrepreneurial Ecosystem. This ecosystem type is described in the literature with the name entrepreneurial or start-up business ecosystem. Scaringella and Radziwon (2018) described it as

1. the government's role is to nurture and sustain entrepreneurship; and
2. the ecosystem is purposely built around an entrepreneur or entrepreneurial teams.

Other, already existing enterprises and organizations, such as universities, are involved in the ecosystem as well.

Sako (2018) characterized it as an ecosystem consisting of start-up related organizations, such as entrepreneurs, investors or end users, who collaborate to form a new start-up.

Internet business ecosystem. The Internet business ecosystem is the ecosystem around the Internet as the core value (Bai and Guo, 2017). It is a specific type of platform business ecosystem.

Mobile Internet business ecosystem. The mobile Internet business ecosystem is a subtype of the Internet ecosystem (Bai and Guo, 2017). It itself is a subtype as well, essentially describing platform ecosystems such as Google's Android or Apple's iOS (Gueguen and Isckia, 2011). Sometimes being called mobile OS business ecosystem (Yang et al., 2018), a mobile business ecosystem sets the respective platform in its center and develops around it.

Customer-centric business ecosystem. Fragidis et al. (2007a,b) extended the platform ecosystem by adding customers in a keystone position connected to the platform in the center. The customers are involved in the idea generation and product/service development.

In addition to its extension of the platform ecosystem concept, it is a type of knowledge and innovation ecosystem by including customers in the generation and sharing of ideas and their knowledge.

Family spin-off business ecosystem. A family spin-off business ecosystem as described by Lozano (2017) is happening in case the spin-off splits up from the family company. The ecosystem consists of five major components:

1. *the family*, providing and committing financial assets,
2. *the family business*, providing financial aid and knowledge,
3. *the project committee*, a decision body inside the family business assessing the spin-off and deciding on the level of support it will retrieve,
4. *the environment*, guiding and supporting the spin-off, and
5. *the spin-off enterprise* as the center of the family spin-off business ecosystem.

Overall, the most often vividly discussed type of ecosystem in the literature is the innovation ecosystem with thirteen papers dealing with this type. This is analogous to the result of the literature review by Scaringella and Radziwon (2018). Gomes et al. (2018) analyzed literature with the focus on innovation ecosystem and when it established apart from the business ecosystem research. Platform ecosystems are the focus of eight papers we identified. Software and mobile business ecosystem were both presented in six papers.

2.4.1. The relation between business ecosystem types

According to the description of each business ecosystem type, we mapped the types and their relation to each other in Figure 2.7. In a first step, we identified two perspectives in which a business ecosystem and thus ecosystem type can be looked at.

One is an organizational perspective. It has the enterprise – or multiple enterprises such as the entrepreneurial group or the family spin-offs – in focus. The business ecosystem is the collection of all other entities in relation to this enterprise.

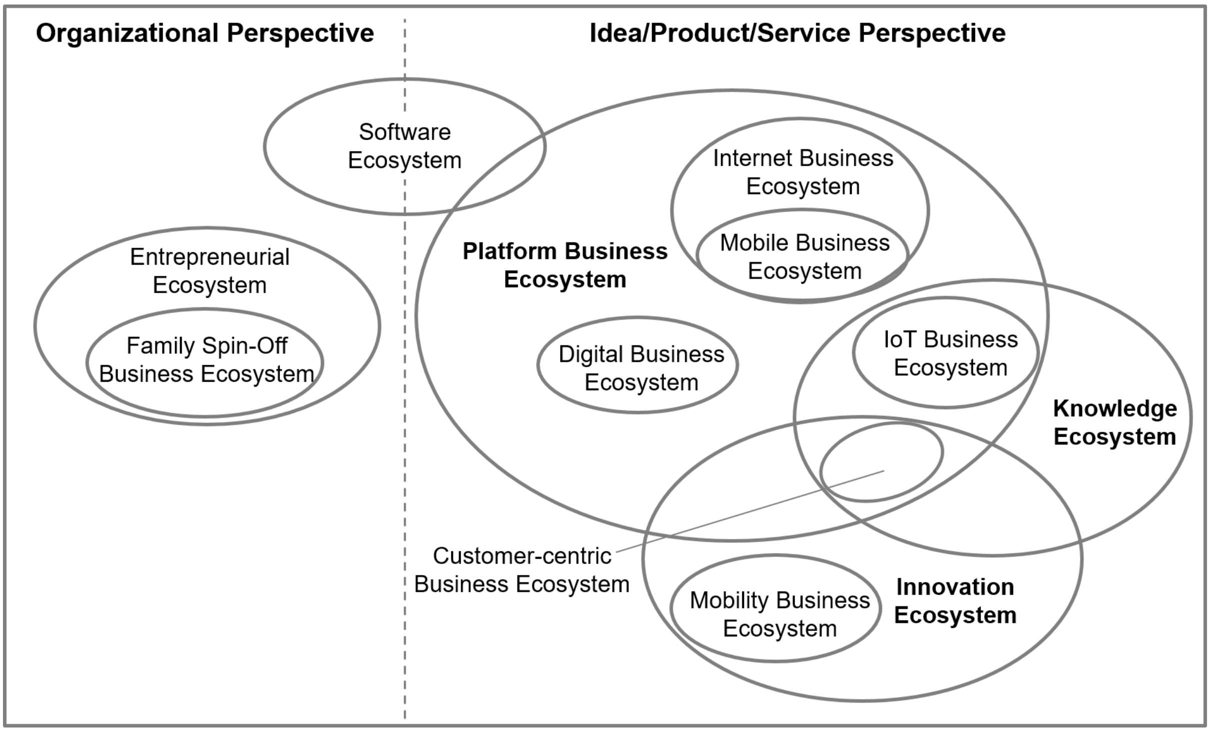


Figure 2.7.: Relation between identified business ecosystem types in scientific literature (Faber et al., 2019d)

The other perspective is the idea, product or service perspective. This perspective has a value creation – in the form of an idea, a product or service – in the center of the business ecosystem similar to the ecosystem-as-structure concept by Adner (2017). Three in the scientific literature often discussed business ecosystem types are the platform business ecosystem, the knowledge ecosystem, and the innovation ecosystem. Subtypes of the first mentioned ecosystem type are Internet business ecosystem with the mobile Internet business ecosystem as a further subtype and the digital business ecosystem. As within an IoT business ecosystem both the platform used to connect multiple devices to share data generated can be in focus but also the data and knowledge created with this data as such, this subtype is positioned in the intersection of knowledge and platform business ecosystem. As the mobility business ecosystem addresses innovation within the innovation connected to applying technologies for urban mobility, this is a subtype of the innovation ecosystem. The customer-centric business ecosystems include the customer as the main contributor to a platform. They contribute to the knowledge generated and the associated innovation.

The type software ecosystem is located between both categories. The center of the software ecosystem can either be one or more software vendors (Popp, 2010) – categorizing it in the organizational perspective or a software platform or programming language (Jansen et al., 2009) – for which the product or service is in the center.

2.5. Summary and terminology for this thesis

When introducing and pioneering the concept of business ecosystems, Moore emphasized its relevance for companies as companies need to have an understanding of their ecosystem for the company's success in dealing with innovation as "managers can't afford to ignore the birth of new ecosystems or the competition among those that already exist" (Moore, 1993, p.76).

A business ecosystem is a loosely connected network of entities from various industries; these entities can play different roles within the ecosystem and depend on each other for their survival. These entities are companies, governmental institutions, customers, and individuals all influencing the ecosystem and their interaction can be the various forms of collaboration and competition.

For the reminder of this thesis, we refer to the business ecosystem member organisms as defined by Moore (1996) as *ecosystem entities* which includes all mentioned forms of entities. However, if only *ecosystem organization* is referred to then merely organizations, firms, companies or enterprises are intended. We do not differentiate between *organizations, firms, enterprises*, and *companies* and use all four terms synonymously for a legally incorporated entity with the purpose of conducting business, including non-profit organizations as well.

The relevance of business ecosystems as described in the literature will be discussed from the perspective of practitioners in the following chapter.

CHAPTER 3

Relevance of Business Ecosystem Analysis in Practice

Complementing the previously describe relevance of business ecosystems as discussed in the scientific literature, this chapter is dedicated to the practitioners' perspective. Through a close interaction with ecosystem stakeholders, we collected their perception of the relevance of business ecosystem analysis in practice.

We therefore focus first on a mobility business ecosystem. Section 3.1 illustrates the concept of smart cities and the related mobility business ecosystem in more detail as published by Faber et al. (2018d). The project environment of a three-year project addressing smart city and smart mobility is briefly described as it provided the starting point of the research described in this thesis. This project environment was used to conduct discussion rounds with ecosystem stakeholders to understand the relevance and challenges perceived by these stakeholders (Section 3.1.1). Besides the results of the discussion rounds, we demonstrate a preliminary attempt to visualize the mobility business ecosystem in Section 3.1.2 published by Faber et al. (2017).

Section 3.2 presents the results of an online-survey as published by Faber et al. (2018c). The survey aims to understand what actions practitioners already take to model and visualize their business ecosystems and which challenges practitioners perceive.

3.1. Smart cities and related mobility business ecosystems

The digital transformation and its accompanying changes have long reached cities including their outskirts and rural satellites, and are expected to provoke massive changes to cities. Actively integrating prospective advancements of this transformation into city infrastructures can enable cities to become what is commonly termed smart cities (Snow et al., 2016; Meier and Portmann, 2016). Smart cities are a recent vision in urban development policy of novel technology-based infrastructures to improve all facets of urban life (Mone, 2015). The concept of smart cities is often considered as a possible solution to challenges cities are confronted with, such as urbanization, migration, pollution, as well as changes in the demographic structure of societies, and climate change, which parallel the societal task to develop sustainable and humane technologies (Hollands, 2008, 2015; Marrone and Hammerle, 2018).

Due to its promise and potential, the concept of smart cities has increasingly gained attention of policy makers, citizens, researchers, and entrepreneurs (Albino et al., 2015). In 2018, the European Commission defined a smart city as “a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business” (European Commission, 2018). Technology can be considered as a potential enabler of smart cities (Khatoun and Zeadally, 2016). The facets of a smart city are diverse as digital technologies are used to include citizens in governmental processes and decisions (“smart governance”), to measure air quality or noise level (“smart environment”) or to enhance digital services in vehicles, traffic systems, and infrastructure (“smart mobility”) (Mitchell et al., 2010), to name just a few. Besides smart governance smart mobility is often recognized as the most common indicator of smart cities (Chourabi et al., 2012).

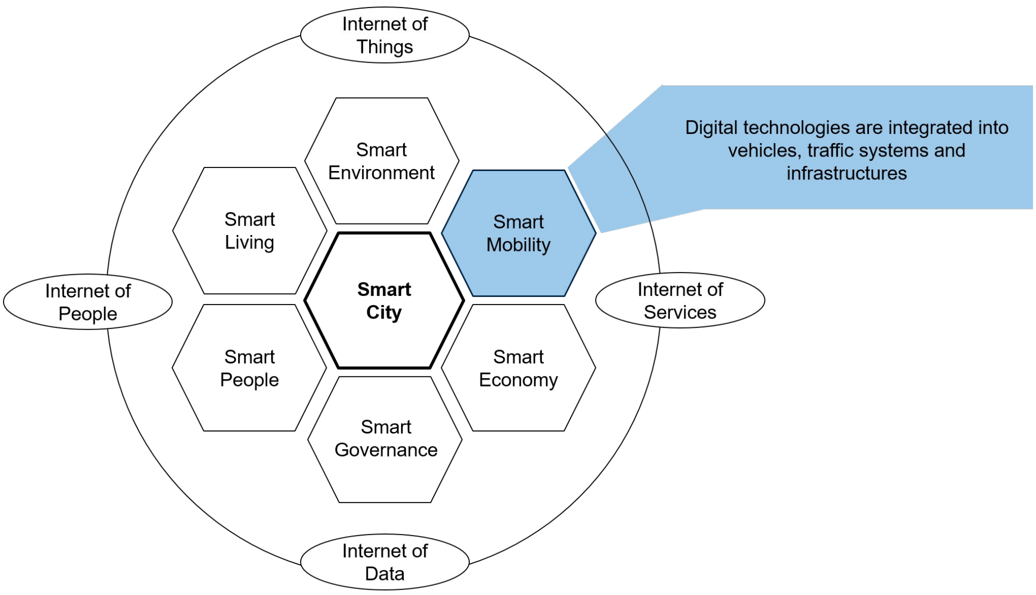


Figure 3.1.: Smart City Model with the focus on Smart Mobility based on Khatoun and Zeadally (2016)

A digital infrastructure for transportation or mobility is one proposed feature of smart mobility that supports work and leisure travel and alleviates the challenges of an urban commute. Digital mobility infrastructures in smart cities are envisioned to integrate technologies such as cyber-physical systems, embedded systems, smart objects, and smart traffic control that intend to create ‘intelligent’, ‘ubiquitous’ or ‘smart’ environments including for instance location-based services. The design, integration, and implementation of a digital mobility infrastructure require coordination between entities from industries such as logistics and automotive but also governmental institutions. Hence, beyond the infrastructure, a business ecosystem of multiple firms, organizations, and stakeholders can be envisioned, all collaborating to enable or improve urban mobility (Rehm et al., 2017).

Understanding the evolution of such mobility business ecosystems is instrumental for developing public policies, taking strategic decisions about business and technology partnerships, or identifying gaps in the services provided to citizens and businesses as service customers (Basole et al., 2012b). Hence, the proactive management of the business ecosystem is gaining relevance for firms, as well as city authorities (Basole et al., 2012b). Particularly, for attaining a competitive edge, firms have to adapt their competencies and identify complementary business partners and services relative to their specific position in the ecosystem (Rehm and Goel, 2017).

Established mobility actors, such as automotive OEMs, their parts supplier, and public transportation agencies, are challenged especially by technology companies using their advantage of applying new technologies - such as augmented reality or artificial intelligence - to urban mobility. Tech giants such as Google and Apple are entering the mobility ecosystem by developing self-driving cars and pushing autonomous driving (Etherington and Kolodny, 2016; Taylor, 2016) exhibiting disruptive innovative characteristics. New actors enter and transform the existing mobility markets that are geographically focused on specific metropolitan areas. As a result, new mobility business ecosystems are currently emerging. With new technologies being used and applied, mobility related legislation has to be discussed and possibly adapted, with cities, their governments, and public institutions as actors of these ecosystems.

Besides commercial mobility providers such as the automotive OEMs and public transportation providers, also cities, their governments and public institutions are under pressure to address these challenges and to understand the emerging structures within mobility ecosystems to make informed decisions (Khatoun and Zeadally, 2016). One initiative to address these changes was the TUM Living Lab Connected Mobility project located in the Munich area. In the following, we will refer to this specific mobility business ecosystem.

The TUM Living Lab Connected Mobility project

The TUM Living Lab Connected Mobility[1] (TUM LLCM) project was initiated in 2015. The project aimed at supporting the digital transformation in the area of smart mobility and smart cities and was funded by the Bavarian Ministry of Economic Affairs and Media, Energy and Technology (StMWi) through the Center Digitisation.Bavaria, an initiative of the Bavarian State Government. The project started in August 2015 and ended in December 2018.

One project aim was a technical contribution to the development of an open, provider independent digital mobility platform offering mobility services to users and serving as a basis for developers to include their own mobility services as stand alone services or on top of existing services. As one feature, this digital mobility platform should offer users different modes of transportation to get from point A to point B according to the user's preferences and needs.

[1] `http://tum-llcm.de/en/`

The provided mobility services should include indoor navigation as well as eco-sensitive traveling recommendations, to name just a few.

A further project objective was to contribute to the establishment of a mobility ecosystem through networking activities between already established and currently arising mobility providers, service providers, developers, and users on a personal, organizational, and technical level. Munich, the regional focus of the project, with a population of more than 2.5 million in its urban area and more than 5.5 million in its metropolitan region has a mobility business ecosystem embracing more than 3.000 firms in the automotive, traffic, and logistics sectors residing in the urban area and more than 18.000 firms in the metropolitan region.

The project intended to support ecosystem stakeholders who are already – or were about to become – engaged in a smart city mobility initiative with informative insights about the related ecosystem. A preassumption of the research team was that all participating stakeholder groups – governmental institutions, mobility initiatives, start-ups or established corporate organizations and the like – were eager to discuss, contribute to, and use the obtained project results and to influence the evolution of the business ecosystem by establishing an ongoing dialogue between them.

Besides discussion rounds, which are described in more detail in Section 3.1.1, the project organized three conferences to present and discuss achieved results with fellow researchers, but especially with representatives of the mobility ecosystem.

Due to the fruitful project environment, we engaged with mobility business ecosystem stakeholders to analyze their understanding and perceived relevance and challenges associated to the business ecosystem analysis. We maintained a high interaction with all project members, partners, and ecosystem stakeholders.

3.1.1. Perception of stakeholders towards the mobility business ecosystem

As from an outside perspective, the mobility ecosystem is changing in a fast pace, it is of interest how participants of this ecosystem perceive the relevance to analyze the ecosystem. We used the project environment and conducted three discussion rounds with representatives of an automotive manufacturer, a management consultancy active in the automotive sector, and a German conglomerate company also active in the automotive sector. We conducted these discussion rounds between January and May 2016. The discussion rounds all lasted 90 minutes debating mobility business ecosystems in general and in relation to an open, provider-independent mobility platform. Two of the three discussion rounds were held in German, the remaining one in English. The first discussion round happened with two representatives of the management consultancy and two researchers, the second discussion round with two representatives of the automotive manufacturer and one representative of the conglomerate company and two researchers. The last discussion round happened together with the entire project team and the same representatives as the previous one plus one additional representative of the conglomerate company. All discussion points were documented during the sessions, which were all held either at the university premises (first and last discussion round) or the automotive manufacturer premises. Analyzing the three discussion rounds, we observed the following facets related to the perceived changes of the mobility business ecosystem by the discussion participants:

Relevance of innovative mobility solutions. Observing the changes in urban mobility and the corresponding new ecosystem actors are relevant for established mobility actors. This aspect was picked up during the discussion rounds as automobile manufacturers invest in new forms of digitization with new actors, leading to a rearrangement of their ecosystem.

Innovative technology companies which enter the mobility ecosystem offering new mobility solutions influence the mobility ecosystem. Established mobility players seem to acknowledge the associated possibilities companies new in the mobility ecosystem may provide.

Identification of ecosystem entities. Considering these new ecosystem actors as a relevant influence factor of the changing mobility ecosystem, leads to the necessity to identify them. For the established mobility provider it is relevant to identify which entities and stakeholders are already active in the ecosystem and which are missing.

Within this context, possible new business opportunities were discussed. Collaboration with or investment in these new actors are interesting opportunities to address and participate in changes of the mobility ecosystem. To address the most promising or most suitable partner, all possible have to be identified.

Visualizing ecosystem information. Within the discussion rounds, the aspect of visualizing information about the ecosystem were picked up. Especially for the development of a platform, participating and potential interesting contributors should be made visible – also publicly accessible.

How such a visualization could look like was not further elaborated.

Relevance of the ecosystem for success of platform. As the technical contribution to the development of an open, provider-independent digital mobility platform offering mobility services to users and developers was one project aim, the ecosystem of such a platform was also discussed. The relevance of the ecosystem of users, developers and mobility providers was emphasized as the platform ecosystem is a central aspect for the successful development of the digital platform.

The collected insights represent merely individual opinions of the discussion participants but the results indicate ecosystem related challenges stakeholders face. As already outlined in the discussion rounds, we identified visualization as a possible support for ecosystem stakeholders to better understand the ecosystem with its entities and their activities.

3.1.2. Visualizing the mobility business ecosystem

In a first attempt to use ecosystem visualizations to foster the understanding of the mobility ecosystem, we applied the visual approach as proposed by Iyer and Basole (2016). This approach consists of the four steps

1. determine the industry structure,

2. identify companies and their attributes,
3. finalize semantics for nodes and dependencies, and
4. visualize, analyze, and interpret.

We followed these steps to create a visualization of the German mobility business ecosystem with a focus on the Munich and Bavarian region as presented by Faber et al. (2017). Our aim was to better understand which companies are already active in offering user-centered mobility services, such as car-sharing, ride-sharing, or bike sharing. Leading to insights about how the established mobility ecosystem stakeholders – such as automotive OEMs, part suppliers, and public transportation providers – address the changes in urban mobility demands.

In the following, we describe our results in applying the above process to the mobility ecosystem in focus.

Determine industry structure

The first step of the visual approach to understand ecosystems is analyzing the industry structure, in this case the connected mobility industry. Therefore, we analyzed industry and trade publications and newspaper articles in 2016 addressing the connected mobility, e.g., Rossbach et al. (2013); Bosch GmbH (2013); Mathes et al. (2015); Mosquet et al. (2014), to identify and determine the new value chain of connected mobility. The resulting, exemplary industry stack is listed in Table 3.1.

Table 3.1.: Identified connected mobility stack following Iyer and Basole's (2016) visual approach

Organization category	**Examples**
Automotive OEMs	BMW, Volkswagen, Mercedes
Parts suppliers	Robert Bosch, Dräxlmaier, Continental, Denso
Technology companies	thinkstep AG, Panoratio, Starship Technologies, Siemens
Platform & connectivity providers	Deutsche Telekom, Vodaphone, Google, RideCell
New competitors of affected industries	Allianz, RWE, Sixt
Public institutions	City of Munich, SWM (Munich City Utilities operating inner city city public transportation), StMWi (Bavarian Ministry of Economic Affairs, Regional Development and Energy)

Additional to the classic mobility ecosystem players – the automotive OEMS, their parts suppliers, car rental agencies, and public institutions offering public transportation – 'new' industry groups gain relevance.

Mobility services address the user's wish for mobility as a service, which is "a mobility distribution model in which all users major transport needs are met over one interface and are offered by mobility operators"(MAAS–Alliance, 2018). Mobility services are gaining more and more importance, especially in cities, and might even be the future of OEM's business, replacing the automotive production and sales (Botsman, 2015). Using mobility services to get from point A to point B, consumers have the option to choose several means of transportation. Especially popular and widely discussed became transportation network companies (TNCs) as mobility services, such as Uber[2] available also in Germany, Lyft[3] available in United States or Gett[4] in the United Kingdom, which connect private drivers using their own cars to passengers searching for a lift.

An addition to the classic mobility stack are *technology companies*, which vary from companies focusing on advanced driver assistance systems, machine learning to enable autonomous driving (Cornet et al., 2017), artificial intelligence to cyber security (Nayak, 2016), all addressing the digitized advancements of mobility. These companies influence urban mobility by adding completely new services, e.g., the Starship delivery robot[5], or by supplying automotive OEMs with software and hardware, e.g., thinkstep data analysis software[6].

Companies offering the transmission of data and providing access to mobility services are bundled in the group *platform and connectivity providers*. By connecting users to mobility services, they play an important role in enabling digitized mobility by providing real time location information of the next bus, train or Uber car.

New competitors of affected industry recognize the advancements in connection with digitized mobility. An obvious example are insurance companies, offering insurance rates depending on driving habits or user's general mobility footprint. Other industries are energy providers, addressing the charging challenge in connection with e-mobility, or insurance companies, offering insurance policies based on driving behaviour.

The last group of entities, we identified for the connected mobility ecosystem in focus, covers *public institutions* including public transportation companies in the classic mobility ecosystem. These companies have to adapt to the digitized service landscape for example by proving online travel planning and ticketing. However, of even greater importance are public institutions responsible for legal and tax regulations. They have the power and ability to influence the mobility ecosystem by enabling business models or forestalling them. Especially in the context of privacy of mobility data and the liability in context with autonomous driving, new regulations are necessary (Collingwood, 2017), which will form the connected mobility ecosystem.

The proposed stack and the according separation of these group of mobility ecosystem entities is not strict, as entities might fit into more than one group. As the ecosystem continuously evolves, also the identified groups need to be revised and adapted when necessary.

[2]`https://www.uber.com`
[3]`https://www.lyft.com/`
[4]`https://gett.com/uk/`
[5]`https://www.starship.xyz/`
[6]`http://www.gabi-software.com/international/databases/`

Identify companies and attributes

In the second step, to understand the connected mobility ecosystem companies and their attributes have to be collected for all identified industry groups of the connected mobility stack (see Table 3.1). Besides the identification of the relevant ecosystem entities, their relations within the ecosystem are important. For the mobility ecosystem the type of relationship varies from investments or acquisitions, partnership or cooperations, personnel move (Webb and Whiteaker, 2016) to negotiation and failed talks.

Following Iyer and Basole's (2016) visual approach, which they applied to the IoT ecosystem, we evaluated industry publications, news portals, and websites, and company websites to collect relevant entities of the ecosystem and their relations. We started to collect data of established German OEMs and their suppliers network. By analyzing their web presences and published reports, the relations between OEMs and supplier were identified. Additional to these classic mobility ecosystem entities and relations, mobility services already provided by OEMs were documented, including the associated relation. This was followed by the data collection of public transportation providers.

In a next step – to gather data about 'new' ecosystem entities and their relations – publicly accessible data sources were identified and evaluated. The variety of these databases is huge, ranging from national databases, e.g. Gründerszene[7] or Bayern- International[8], to international ones, e.g. Crunchbase[9] or AngelList[10].

Targeting information especially about technology companies, we used Crunchbase[11]. This platform provides business information about private and public enterprises focusing on investments and funding information, but also merger and acquisitions. Crunchbase provides a limited but free of charge access to these business information. Companies are tagged with attributes describing their field of action, for example, "Transportation" or "Mobile". By searching for German automotive OEMs, we identified relevant funding and acquisitions.

Conducting the above-described steps, an overall sum of 97 connected mobility ecosystem entities and 192 associated relations were collected and documented.

Visual model language

As network visualizations are the main used visualization types for business ecosystems, we decided to use a node network. The ecosystem entities, i.e. the ecosystem entities are visualized as nodes and their relations as links between nodes.

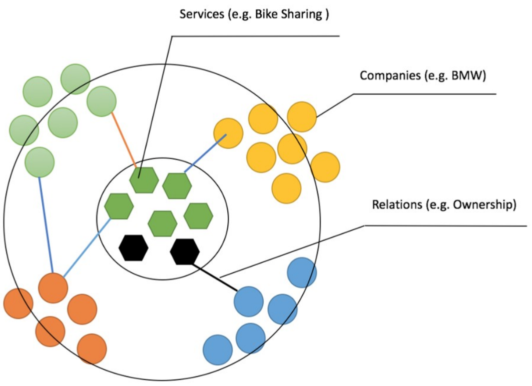
We visualized the collected information in a modified ego network visualization[12] where the

[7]http://www.gruenderszene.de/
[8]http://www.bayern-international.de/en/
[9]https://www.crunchbase.com
[10]https://angel.co/
[11]https://www.crunchbase.com/
[12]http://www.analytictech.com/networks/egonet.htm

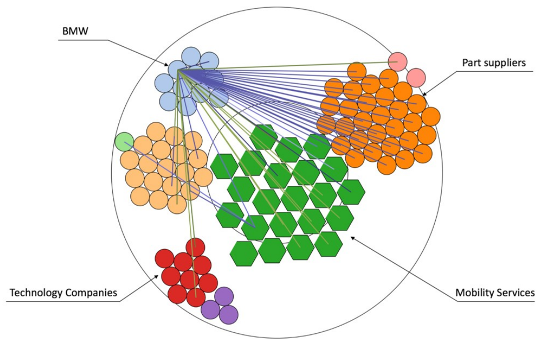
focus is on the mobility services provided in the ecosystem. A sample of such a modified ego network is visualized in Figure 3.2a explaining all visual specifications.

The data we collected is visualized in Figure 3.2b. The center of the visualization contains the mobility services represented with hexagons as nodes. All other entities are displayed as circles, grouped into categories of the connected mobility ecosystem stack. Finally, each category and type of relation between entities is mapped to a different color.

Due to the high amount of entities and relations, we visualized one company and its relations. We chose the BMW group due to its size and relevance for the Munich and German industrial landscape.



(a) Proposed ego network visualization explaining the visual representations



(b) Applied ego network visualization to the Crunchbase data collected and filtered for BMW

Figure 3.2.: Visualizing the German mobility business ecosystem using a modified ego network (Faber et al., 2017)

Interpretation

With the provided visualization, we aimed at an easy identification of companies collaborating to provide different mobility solutions. As the ego node of the network visualization we chose mobility services. In addition, entities can be identified with no links and possibly no contribution to the visualized mobility services. The presented visualization might help stakeholders of the connected mobility in addressing the trend from products towards (mobility) services (Bosch, 2016).

For the specific visualization in Figure 3.2b, it indicates that the BMW group is already active in providing mobility services due to the number of relations between BMW and mobility services. It shows the strong integration with German automotive part suppliers and already established technology companies enriching the mobility ecosystem. By filtering for other companies, the same understanding of involvement in the connected mobility ecosystem can be gained.

The results of the discussions and the initial visualization present ecosystem stakeholders' challenges related to the changing mobility ecosystem and how an ecosystem visualization can be used to contribute to a better understanding of the ecosystem.

The previous described results targeted a specific ecosystem: the mobility business ecosystem with a regional focus of Munich and Germany. In a next step towards a broader understanding about the perception of business ecosystem in practice, we conducted an online survey.

3.2. State-of-the-practice in analyzing enterprises' business ecosystems

To complement the previously described perceptions of company stakeholders actively participating in a disruptive business ecosystem and their challenges, this section focuses on a state-of-the-practice in German companies modeling and visualizing a business ecosystem of their interest. The aim of the survey was to understand what actions practitioners today already take to model and visualize their business ecosystem in enterprises' daily business, how active they are in the different phases of modeling and visualizing their business ecosystem, and where they perceive major challenges within their activities. This includes how the work is distributed within the enterprise, how data is collected, which sources are used, how data is documented and reported upon using various available tools, and what business ecosystem visualizations are already in place in case the collected data is visualized. In addition, we try to identify where stakeholders conceive challenges which can be addressed in future work.

We designed the online survey in 2017 addressing companies mainly in Germany to broader our understanding of requirements towards business ecosystem modeling and visualization in practice (Faber et al., 2018c). The survey with its explorative characteristics provides the basis for more conclusive research as it can support to determine the research design, sampling methodology, and data collection method (Singh, 2007).

3.2.1. Survey design

As the analysis of business ecosystems is a data intense process (Basole et al., 2015), we structured our survey according to the associated activities *data collection*, *data documentation*, and *data processing and reporting* (see Figure 3.3). We refer to data here as business ecosystem data. Our theoretical foundation is based on related literature addressing business ecosystem analysis (see Chapter 2) and our activities visualizing the mobility business ecosystem (see Section 3.1.1).

In addition to these three data focused process steps, we also added a question about perceived challenges of modeling business ecosystems by ecosystem stakeholders and reasons for inactivity, in case the participant answered accordingly.

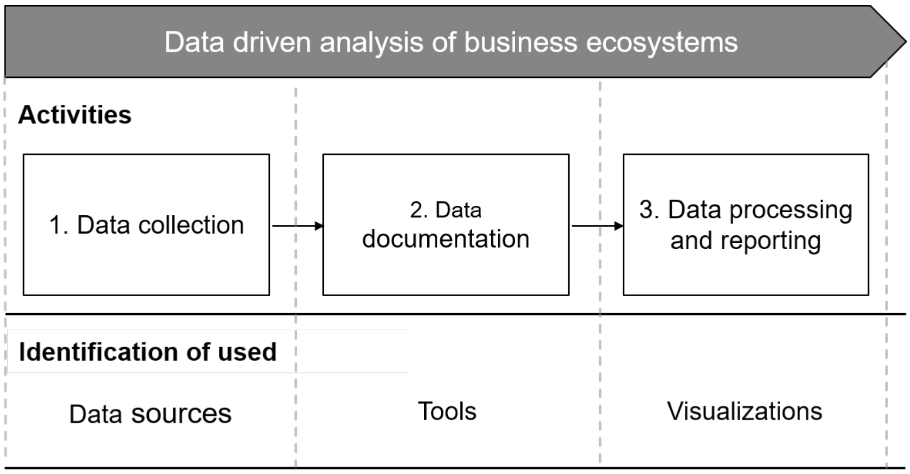


Figure 3.3.: High-level understanding of the business ecosystem analysis process as a data intensive process

Data collection method

After designing the questionnaire following Fowler (1995), we performed a pre-test consisting of its completion by three non-related researchers. The questionnaire was adapted according to the received feedback of inconsistency in naming, order of questions, and spelling mistakes. The final version of the questionnaire was published as an online survey available between beginnings of July to end of August 2017. In total, we contacted 51 companies from various fields of business activity via email and published an open call for participation using the social media platform LinkedIn[13]. We chose enterprises which previously worked with the research instiution and had a strong background in Enterprise Architecture Management, as this is one focus of the institution. All contacts were approached twice via email. Within the emails, we briefly explained the concept of business ecosystems and the relevance for enterprises due to technological innovations. This was followed by an invitation to participate in the survey using a provided link. For this survey, we used the survey software questback[14] allowing the participants to complete the survey in an internet browser window. All survey questions are included in Appendix C. The completion time of the questionnaire was estimated with 15 to 20 minutes.

The online questionnaire consisted of seven sections, starting with questions covering the participants' and their enterprises' details and if the enterprise is active in analyzing their business ecosystem (section one and two of the questionnaire), followed by the participants' role and the division of labor (section three). The fourth section addressed the business ecosystem related data collection, followed by the process step of data documentation and processing (section five),

[13]`https://linkedin.com/`
[14]`https://www.questback.com`

the perceived challenges within the analysis process (in section six) and finally the reasons why companies are not active in analyzing their business ecosystems (section seven).

After the question if companies are active in analyzing their business ecosystem in the second part of the questionnaire, the questionnaire was split into two paths. One path following for participants and enterprises active in the business ecosystem analysis (covering the section four to six with an overall of 21 questions) and one for the others (only comprising of section seven asking for the reasons of inactivity with an overall of 8 questions). This allowed skipping questions not fitting to a certain group of participants.

The only mandatory question for participants to answer within the questionnaire was if the company is active in analyzing its business ecosystem in section two, whereby the remaining other questions could be omitted by the participants. The available alternatives to answer questions were predefined by the researches and generated using existing literature, the researchers' own experience and insights gained through the discussions with stakeholders. Whenever a question allowed multiple answers this was explicitly stated, for questions with exclusive options the used tool provided a suitable feature only allowing one answer to be given. Wherever feasible the answer option *other* allowed the participants to enter additional information as free text. The answer option are highlighted in the following using italic. For each question addressing business ecosystems, the definition of business ecosystem was displayed in the header of each questionnaire page: *The term business ecosystem describes the holistic environment of a company covering current and potential future business partners, customers, suppliers, competitors, regulatory institutions, and innovative start-ups.*

Description of responses and participants

Upon survey closure, we received 52 completed surveys of overall 86 times the survey was opened and 61 times started but not finished. The answers of the different questionnaire sections are described in detail in the according section below.

Participants were working for companies active in a broad variety of business areas. 13 times *Information Technology (IT) Providers* was selected as business field, 9 times *Automotive Manufacturer* and 5 times *Public Institution.* Multiple participants of one company were allowed to participate in the survey. Eight survey participants categorized their company size as *1 – 100 employees*, five answered with *101 – 1.000 employees*, 16 with *1.001 – 30.000 employees*, and finally, 23 with *more than 30.000 employees.* Most of the participants described their job as *Enterprise Architect* with 18 responses or *Innovation Manager* with 11 responses. Out of these, 25% worked as *external consultant*, i.e., 12 survey participants.

3.2.2. Survey data analysis

In this section, the analysis of the survey responses is described. We follow the structure of the business ecosystem data analysis process as depicted in Figure 3.3.

After asking participants regarding their work background, the survey included the only mandatory question, if the company is *active in analyzing its business ecosystem*, which was answered by with yes by 46 participants (88%).

Data collection

Aiming to understand the participants' roles within the analysis process, and how the work is divided within the company, we ask three questions. When asked for their responsibilities within the business ecosystem analysis, multiple answers were possible. 27% answered with *data and information collection*; 19% each with *information processing* or *using (processed) information for strategic decisions*; *answering to higher management level* were chosen by 17%; *responsibilities not clearly defined* 13%, and 5% answered with *other*. The business ecosystem related tasks are performed *full-time* by 42%, *part-time* 12% work on a *daily basis*, 24% on a *weekly basis* and 10% on a *monthly basis*. The final single-answer question of this section addressed the potential existing teamwork within the enterprise and no participant answered that she is *working alone, no other responsible colleague known*. 56% stated they work *collaboratively in a team and the responsibilities are clearly defined*, 32% selected *not alone, but work is rather uncoordinated between me and other colleagues*, and 12% chose *other* as answer.

This indicates that enterprises realize the importance of analyzing their business ecosystem as they already invest manpower with more than 40% of the participants working full time in this area and more than half working collaboratively in a team.

The fourth section of the questionnaire entailed questions about the data collection process, the information gathered and the sources used. It comprised of seven questions, which could all be answered by the participants choosing multiple answers. 81% of the participants answered that they collect the information *actively, by searching for relevant information*, compared to 38% *collecting only by chance, i.e., passively*. When asked for time related development of the market as part of the analysis, 92% responded with *current development of the market and existing business relations*, 76% with *future development of the market and business relations within the next five years*, and 30% with *future development of the market and business relations exceeding the next 5 years*. As an increasing amount of information is now available in digital format, we asked participants which format of data is used, which was replied by 92% with *digital information, e.g., news feeds*, and 32% with *printed information, such as brochures*. The next two questions aimed at the data sources in use when collecting business ecosystem data, visualized in Figure 3.4 and Figure 3.5.

The main data sources in use are *internal company information sources* and *online search engines* (both 76%), followed by *international news portals* (60%) and *national online news portals* (55%). Online search engines were included in the available answers to understand if participants start with concrete data bases, news portals, etc. or by searching for information through whichever source listed as a suitable online search engine result.

When asked to name three sources according to their order of usage, *internal sources* were stated most as first source (nine participants) and *online search engines* as second or third source (four participants or rather two participants). Often used are also *multi client market research studies*,

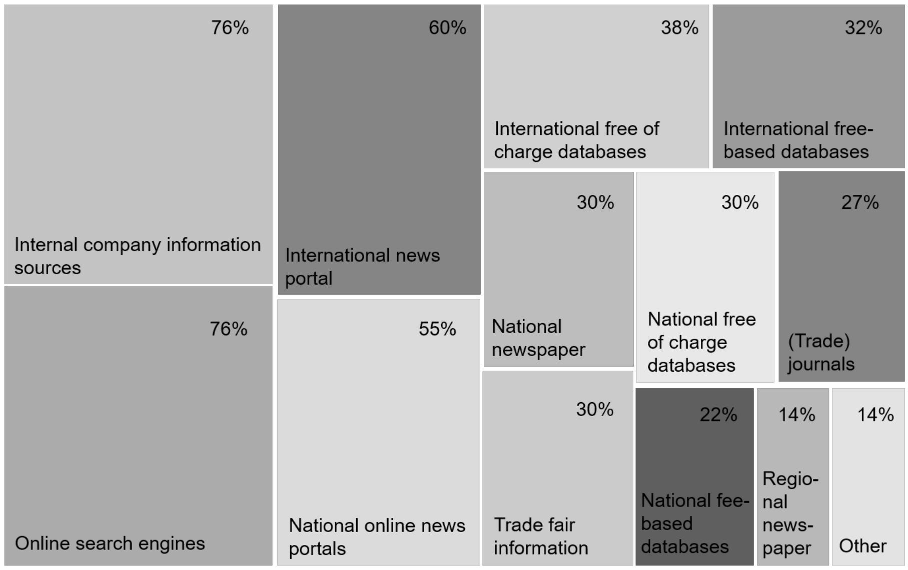


Figure 3.4.: Sources used for information gathering within the business ecosystem analysis (Faber et al., 2018c)

e.g., published by Gartner, stated by three participants as first source, and by one as second and third source in each case.

Using these data sources, the next questions addressed the information collected. Within the business ecosystem analysis, 81% of the participants are interested in information about *competitors*, 84% in *business partners*, 62% in *start-ups*, 59% in *suppliers*, 43% in *public regulatory institutions*, 22% in *public research institutions*, and 11% stated *other*. Besides the classic competitor analysis, enterprises also analyze their direct and indirect environment. As companies of the business ecosystem can be described using various attributes, we asked for company related information interesting for stakeholders analyzing the business ecosystem. 81% answered with *Business Model*, 76% with *Business Area*, and 70% with *Strategic Decision*. All possible answer options and the corresponding number of answers are displayed in Figure 3.6.

Data documentation

When asked how the participants document the collected information, 16% answered *with pen, paper and non-electronical document storage*, 73% selected *as digital documents in a (shared) file system*, 38% *transfer the information into a standard tool*, 16% *into a dedicated commercial tool*, and 14% *into a custom-developed tool providing business ecosystem related features*, 8% chose *other*. Within this questions the participants were able to state the tool in used in a free text field for the different answer options. The *standard tools* in use appear to be Microsoft Office

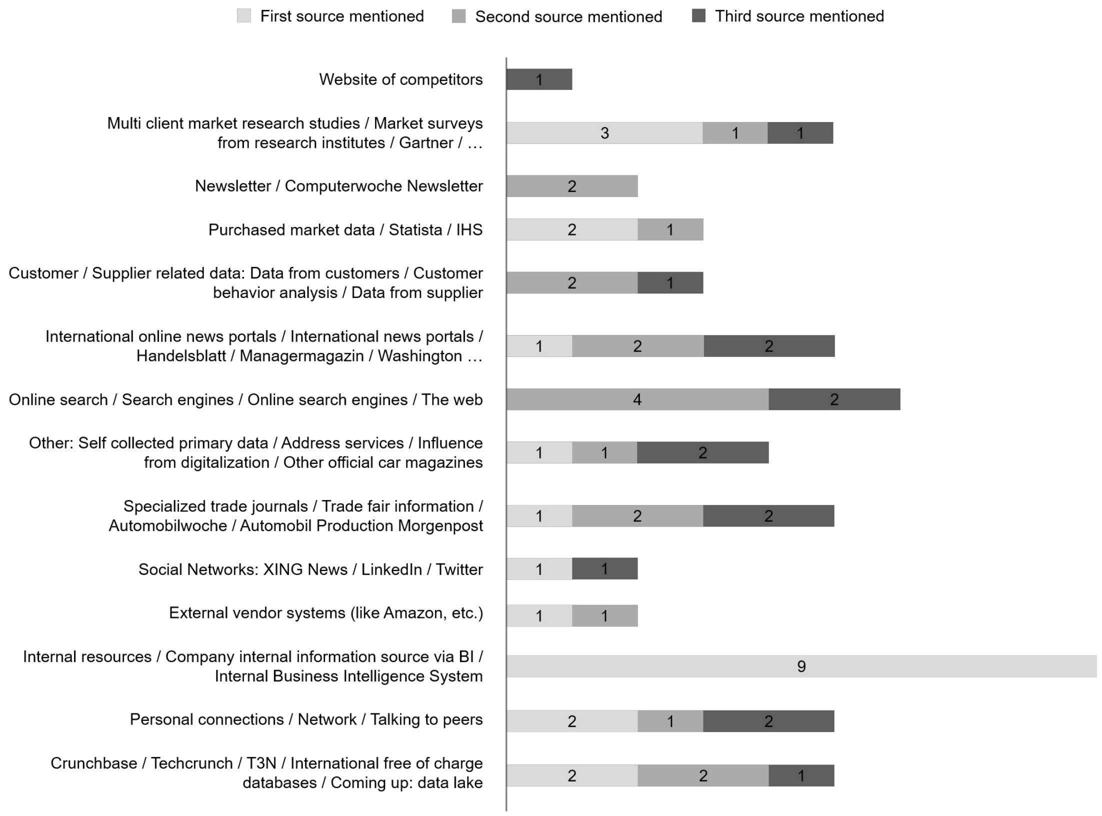


Figure 3.5.: Main sources for the business ecosystem analysis (Faber et al., 2018c)

software such as Word, Excel, PowerPoint, OneNote, but also Google Drive; as commercial tools SugarCRM[15] and SAM[16]; and as custom-developed tools Tableau[17], Qlik[18], and PoolParty[19].

Data processing and reporting

The next questions targeted at the reporting of the collected and processed business ecosystem information whereby 51% of the participants *notify colleagues ad hoc whenever information is available*, 41% *notify colleagues according to an agreed reporting schedule*, 51% *provide access to information, but perform no active notification*, 11% *carry out no reporting or sharing of information*, and 8% selected *other.* Based on this, the results of the processed business ecosystem analysis information are an *updated and accessible database* (30%), *a list of current/potential future competitors, business partners and innovative start-ups* (43%), *(economic) figures/perfor-*

[15] https://www.sugarcrm.com
[16] https://www.sam.ai/
[17] https://www.tableau.com
[18] http://www.qlik.com
[19] https://www.poolparty.biz/analytics-visualization/

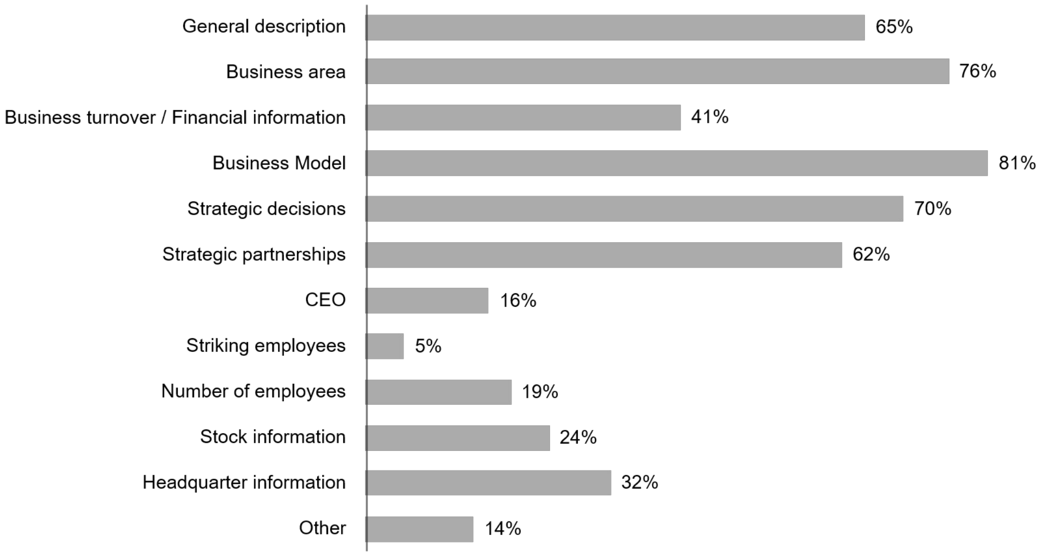


Figure 3.6.: Company-related information for business ecosystem analysis of interest (Faber et al., 2018c)

mance indicators (29,7%), *visualizations* (49%), *collected data is not processed* (19%), and *other* (14%). The answers of the questions which visualization types are already provided and in use and which are interesting for future usage is visualized in Figure 3.7. *Networks* are currently used by 19% and would be interesting for future use by 52%, *treemap visualizations* are used by 24% compared to 49% interested in this kind of visualization. 30% stated that *no visualizations are currently provided or in use.*

Perceived challenges

The final question of section six of the questionnaire addressed the perceived challenges within the business ecosystem analysis. More than half of the participants (65%) stated the *time-consuming processing of collected and documented data.* 46% selected that *several business units are involved, working rather uncoordinated.* No participant stated that *no challenge* is perceived within the business ecosystem analysis. All results are shown in Figure 3.8.

Valuable insight also delivered two statements within the free text field attached to the answer option other, stating a *lack of understanding in the higher management*, and *identify possible stakeholders for the Data/I'm collecting for completeness of EAM.*

Reasons for inactivity

The four participants completing the questionnaire not active in the analysis of their business ecosystem were asked three questions addressing their reasons for inactivity and their potential

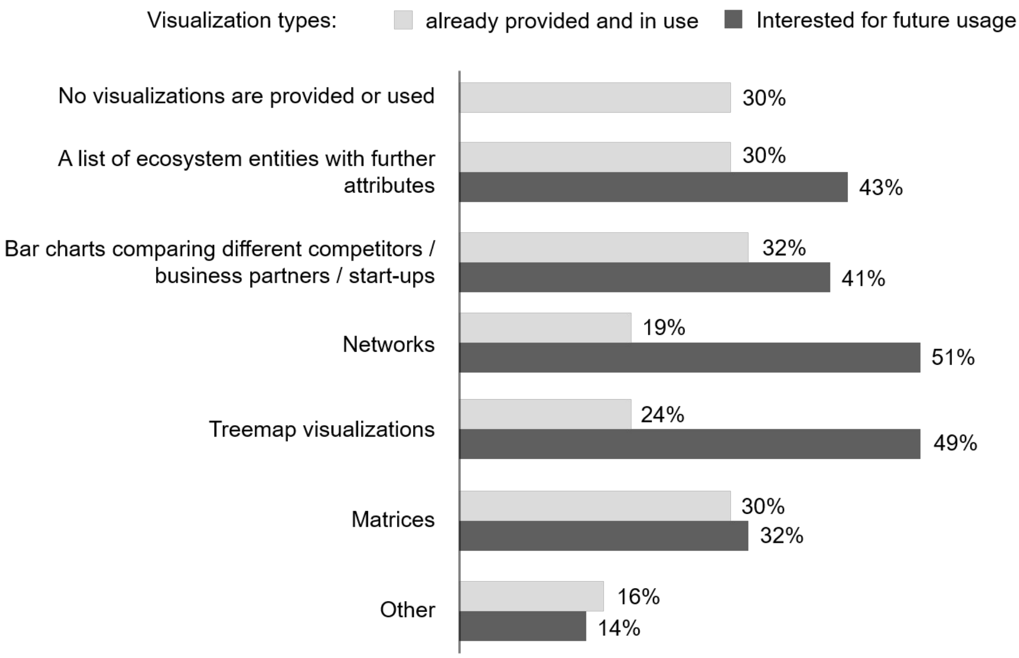


Figure 3.7.: Visualization types already in use (light grey) versus visualizations interesting for future usage (dark grey) (Faber et al., 2018c). 30% stated that no visualizations are provided or used.

interests. When asked for the reason why the enterprise the participant works for is not active in analyzing its business ecosystem, one participant replied that the *responsibilities within the company are unclear.* One participant selected *information gathering not possible / too difficult*, another one chose *no free capacities*, and a fourth participant answered in the free text in the answer option *other* that there is no holistic approach. According to the participants' answers information of the following entities would be interesting, *business partners, suppliers*, and *public regulatory institutes* (all selected by three participants), *start-ups* (selected by two participants), and *competitors, public research institutions* (both selected by one participant). The final question addressed in which area support within the business ecosystem analysis would be interesting for the participants. Three participants answered *provision of information visualizations*, two selected *provision of relevant information*, also two chose *tool support for the processing of information, e.g., providing a list of competitors / business partners / start-ups or calculated figures*, and one said *tool support for the documentation of information.* That indicates a perceived need to address the enterprises' business ecosystem analysis.

In summary, for the companies the survey participants work for it seems the analysis of business ecosystems is part of the daily business. Relevant information of ecosystem entities for the involved stakeholder are the business model, business area, and strategic decisions. More than half of the participants work collaboratively in teams when analyzing their business ecosystem. A third of the survey participants stated that they do not work alone but rather uncoordinatedly

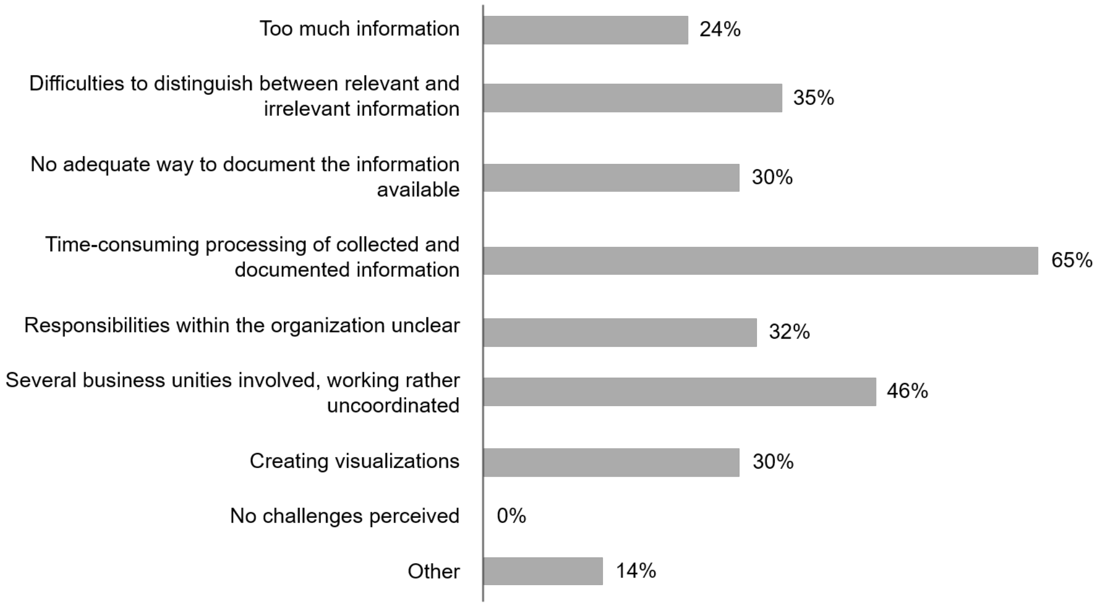


Figure 3.8.: Main challenges within the business ecosystem analysis perceived by survey participants (Faber et al., 2018c)

within the enterprise, which recurs as a major challenge as responsibilities within the enterprise are unclear. Regarding the used sources to collect ecosystem related information company internal sources or online search engines are used mainly. More than half of all participants notify colleagues on an ad-hoc basis, which indicated a missing alignment in the process of documenting, communicating, and discussing changes within the business ecosystems. This is reflected in the identified major challenge of time-consuming processing of collected and documented information.

Due to our selection of company representatives which we approached via email, the results are not representative for German companies in general. All these representatives have worked with or showed high interest in research projects indicating an openness for innovation and changes.

Nevertheless, the presented results indicate the lacking of a process to support the collaborative modeling of business ecosystems including a tool-support for visualizations of these ecosystems. This aspect will be discussed in the following chapter.

CHAPTER 4

Related Work

The results of the previous chapter indicate an unsatisfied need of ecosystem stakeholders who want to analyze the business ecosystems of their interest collaboratively. However, the sole need of practitioners does not provide enough motivation for scientific research as (scientific) solutions to model and visualize business ecosystems by including various data sources and ecosystem stakeholders might exist but have not yet been used. To ensure the rigorness of the research contribution, this chapter provides an overview of the state-of-the-art in the scientific literature of

- business ecosystem visualizations in Section 4.1,
- approaches to model and visualize business ecosystem dynamics in Section 4.2,
- business ecosystem visualization tools and systems in academia in Section 4.3, and
- visualization tools used in practice for business ecosystem analysis in Section 4.4.

To identify related work on these topics, we included *business ecosystem visualization* as characteristic in our concept matrix during the systematic mapping study. A record was labeled as relevant, if the record contained at least one business ecosystem visualization, described how a business ecosystem can be visualized or developed a visualization tool.

We conclude this chapter with a description of the identified research gap in Section 4.5.

4.1. Business ecosystem visualizations

Within our mapping study, we identified 43 records, which incorporate business ecosystem visualizations. They be divided into two groups: on the one hand, records using visualizations to describe the business ecosystem of a specific organization or market, the structure of a specific business ecosystem type or roles active in the business ecosystem. On the other hand, records discussing approaches to visualize business ecosystem data, evaluating visualizations with regard to ecosystem-related tasks, or presenting tools providing multiple interactive business ecosystem visualizations incorporated in one user interface.

As a first attempt to understand how and which visualizations are used in the context of business ecosystem literature, we counted the number of usage of particular visualization types. We identified 17 different types including list views, connection map, timelines, adaptations of Moore's framework (cf. Figure 2.1), bubble charts, and scatter plots as discussed in detail by Faber et al. (2019c). Overall, the visualization layout used most often are network visualizations (42 records of 43), in the form of node networks, directed networks, chord diagrams or matrices. Most of the visualizations types we identified will be described and depicted in the following.

4.2. Business ecosystem visualization approaches in academia

We identified two records that present approaches to visualize business ecosystems and one evaluating business ecosystem visualizations. For the following presentation, we use their chronological order of publication.

4.2.1. A data-driven approach to understand business ecosystem dynamics

To enable the study of business ecosystem dynamics, Basole et al. (2015) presented a data-driven visualization approach using both institutionally and socially curated data sets. The process consists of four steps as visualized in Figure 4.1. Through visualizing the business ecosystem data, important complementary triangulated explanatory insights into the dynamics of interorganizational networks in general and business ecosystems, in particular, are provided.

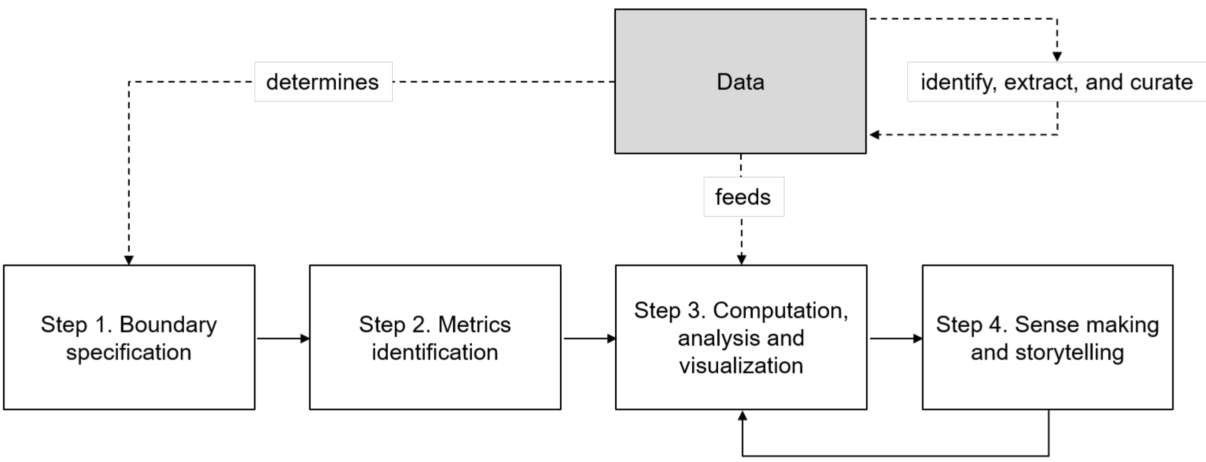
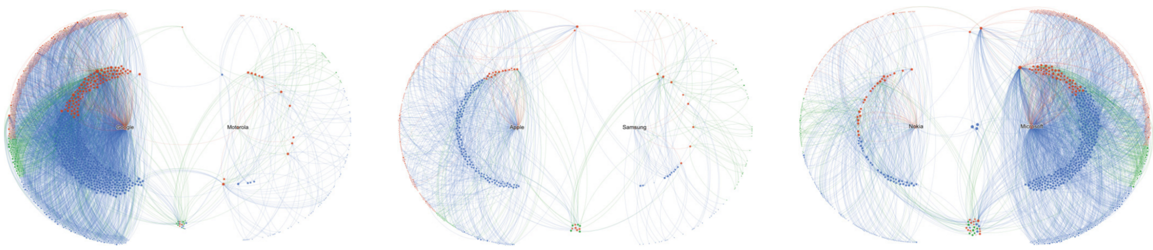


Figure 4.1.: Four-stage approach to data-driven business ecosystem analysis and visualization (Basole et al., 2015, p.6:9)

For the business ecosystem visualization, the researchers developed a novel visualization layout: the bicentric ecosystem layout. It provides a representation of two focal firms as well as their shared direct and indirect ecosystem partners. Two firms A and B are placed at a distance d apart; two concentric circles with radii d/2 and d, respectively, are drawn around each focal firm. The intersection points of the various circles are areas in which direct (first-tier) and indirect (second-tier) ecosystem partners are placed. Partners shared directly by both focal firms are placed in the middle. The bicentric ecosystem layout displays entities that belong to the main component at the top; all others are placed at the bottom of the intersection.

Within their paper, the data-driven method of data triangulation and visualization techniques are illustrated through three mobile industry cases: Google's acquisition of Motorola Mobility (see Figure 4.2a), the coopetitive relation between Apple and Samsung (see Figure 4.2b), and the strategic partnership between Nokia and Microsoft (see Figure 4.2c).



(a) Google and Motorola (p.6:16) (b) Apple and Samsung (p.6:19) (c) Nokia and Microsoft (p.6:22)

Figure 4.2.: Bicentric EFR ecosystems visualizations (Basole et al., 2015)

For these visualizations, the authors collected ecosystem data from three complementary data sources: deals and alliance relationships (DARs) using SDC Platinum[1], executive and funding relationships (EFRs) using the IEN Dataset[2], and public opinion and discourse (POD) using Northern Light[3]. However, the approach as presented is not limited to just these three data sources.

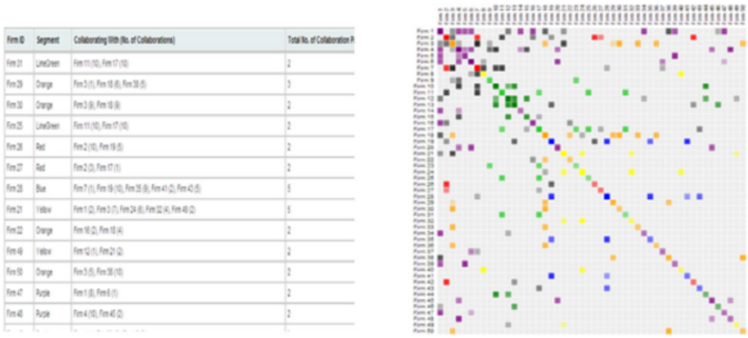
4.2.2. Visual decision support for business ecosystem analysis

In 2016, Basole et al. published results of a study with 14 participants which comparatively evaluated the effectiveness of three business ecosystem visualizations: list, matrix, and network views. They analyzed the influence of data complexity, task type, and user characteristics on decision performance in the context of business ecosystem analysis.

The researchers first identified business ecosystem decision making tasks from the literature. Second, they conducted six interviews with ecosystem stakeholders performing business ecosystem analyses for their work to identify four commonly performed types of tasks:

1. find a fact,

[1] `https://www.refinitiv.com/en/products/sdc-platinum-financial-securities`
[2] `http://www.innovation-ecosystems.org/data-driven/`
[3] `https://northernlight.com/`



(a) List view (b) Matrix (c) Node network

Figure 4.3.: Business ecosystem analysis views comparatively evaluated regarding their effectiveness (Basole et al., 2016, p.276)

2. determine a pattern,
3. make a decision, and
4. a compound task that could combine any of these elements, both individually and with other team members.

For their following experimental study, they implemented three visual representation (see Figure 4.3), performed extensive pre-testing, and finally conducted 14 laboratory sessions each lasting 90 minutes. The outcomes were quantitatively evaluated using two task performance measures: decision time and decision accuracy. After the experiment, a post-study survey was conducted containing questions regarding usability and usefulness of views and an assessment of decision making characteristics and perceived task load.

The results showed that in low complexity contexts, decision performance between visual representations differs but not substantially. In high complexity contexts, decision performance suffers significantly if visual representations are not appropriately matched to task types. Their study made several theoretical and practical contributions. Theoretically, the authors extended cognitive fit theory by investigating the impact of business ecosystem task type and complexity. Practically, the results of their study contributed to the design of business ecosystem intelligence tools and presentation of business ecosystem data for decision making.

4.2.3. Visualization to understand ecosystems

Iyer and Basole (2016) presented a structured visual approach which aims at supporting ecosystem stakeholder to map relationships between ecosystem entities. In their paper, Iyer and Basole apply the approach to the IoT ecosystem which they analyzed and visualized. In the previous chapter, we already used the approach to visualize the mobility business ecosystem (cf. Section 3.1.2) to evaluate the usefulness of visualizations to understand the ecosystem better.

The visual approach as depicted in Figure 4.4 consists of the four steps:

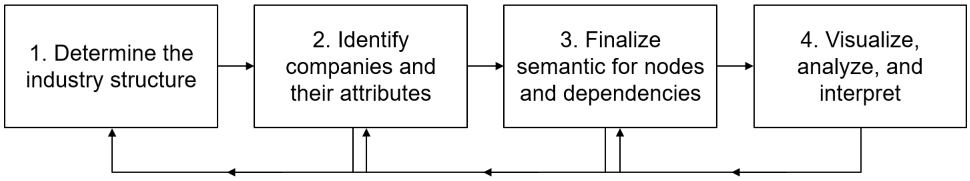


Figure 4.4.: Visual approach proposed by Iyer and Basole (2016)

1. *determine industry structure*, to identify the value chain or stacks of activities that deliver something of benefit to customers,
2. *identify companies and their attributes*, by using Internet search engines, news portals, socially curated news websites or social media sources to locate relevant articles,
3. *finalize semantics for nodes and dependencies*, to prepare the visualizations including eventual explicit specification of the visual encodings of nodes and edges, and particular consideration to data type, and
4. *visualize, analyze, and interpret*, to collect insights about companies in key network positions or clusters of interest, find any surprises, and identify companies that did not make the list.

The approach is not linear as there are feedback loops between the steps as indicated through the arrows in Figure 4.4.

4.3. Business ecosystem visualization tools in academia

Within our mapping study, we identified two business ecosystem visualization tools incorporating multiple interactive visualizations of the underlying business ecosystem data. The aim of both tools is to visualize the dynamic changes in the ecosystem. By analyzing further work presented by the research team of these two tools, we identified an additional similar tool visualizing supply network data.

The three identified tools are particularly interesting as they provide explicit requirements for the implementation based on studies with groups of ecosystem stakeholders and were all thoroughly evaluated.

4.3.1. dotlink360

dotlink360[4] was developed by a team of researchers from the Georgian Institute of Technology, namely Raul C. Basole, Trustin Clear, Mengdie Hu, Harshit Mehrotra, and John Stasko. The primary goal was to visualize the mobile ecosystem, with entities such as mobile network providers, platform providers, or device manufacturers. The tool drew on the Thomson Reuters

[4] https://www.cc.gatech.edu/gvu/ii/dotlink/

SDC Platinum database and Capital IQ Compustat for the company and financial data (Basole et al., 2013).

The development of dotlink360 was based on an in-depth field study consisting of a web-based survey and interviews with 24 senior industry individuals with significant work experience. The results of this field study led to the identification of a set of core design requirements that have driven the dotlink360 research:

Both top-down and bottom-up examination of an ecosystem are critical. These methods enable users to examine business ecosystems from a company, market segment or country perspective. The tool should provide navigation between higher-level ecosystem overviews and individual company details.

Understanding interfirm connectivity, composition, and temporality are vital. Interfirm relationships, the portfolio of interfirm agreements, and the longitudinal evolution of agreements as relationships, their compositions, and their temporal characteristics should be provided.

Comparative perspectives drive insights. Multiple, complementary perspectives on the data should be offered to allow ecosystem stakeholders to compare and contrast different aspects of the company agreements quickly.

Communicate agreement summaries first, then details as desired. Visualizations about the structural patterns between firms should be provided rather than details of the agreements in the early phases of ecosystem investigation. This allows users to examine high-level strategic behavior before understanding specific aspects of the relationships.

Provide a familiar metaphor. A simple user interface with familiar functionalities, such as scrollable lists, drag-and-drop, right-click for menus should be used to enable users to learn how to use the tool quickly and easily.

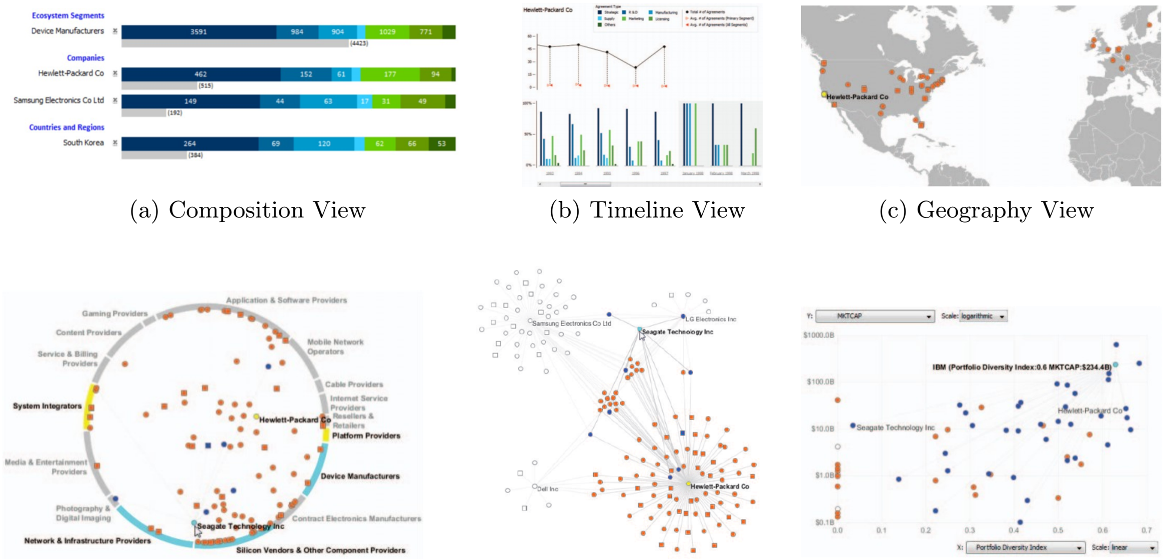
As additional non-domain-specific requirements, the dotlink360 team identified the necessity to support common network-related analysis tasks typical for social network analysis and visualizations.

dotlink360 offers six visualizations targeting three perspectives: compositional (1 view), temporal (1 view), and connective/structural (4 views) perspectives.

Composition view. In the composition view (see Figure 4.5a) horizontal bars display the different agreement types, such as strategic, research and development or manufacturing, of the ecosystem segment and the selected ecosystem entities. The view helps tool users to understand the composition of the agreement portfolio of an entity (company, market segment or country).

Timeline view. The timeline view (see Figure 4.5b) shows the temporal information of the agreements. The different agreement types are displayed in bar charts for a selected company broken down for months or years. In the top of the view, a line chart depicts the total agreement count relative to the primary segment of the selected ecosystem entity.

The following four views address the connectivity perspective of the ecosystem in the form of node-link representations.



(a) Composition View (b) Timeline View (c) Geography View

(d) Segment View (e) Path View (f) ScatterNet

Figure 4.5.: Visualizations offered by dotlink360 (Basole et al., 2013, p.2529f)

Geography view. The geography view (see Figure 4.5c) shows an interactive map positioning the ecosystem entities according to their main address. dotlink360 users can explore where the agreement partners of a selected entity are located and pan the map by clicking and dragging anywhere in the main visualization.

Segment view. The segment view (see Figure 4.5d) displays the selected entity in a larger circle. On the arc of this circle, the respective market segments are visualized, such as gaming provider, mobile network operator or system integrators, proportional to the number of entities in that segments across the entire ecosystem. The selected entity is positioned relative to the segment(s) the entity resides in. The respective agreements partners of the selected entity are positioned as well to quickly identify a company's "niche" within the ecosystem and discover possibilities of cross-segment convergence.

Path View. In the path view (see Figure 4.5e) the ecosystem entities are displayed as nodes, i.e. public (as circles) and private (as squares) companies, with their agreements as links connecting them. The user can select and drag an entity in the view and explore its agreement partners via double-clicking on the node leading to the display of all partners. When hovering over an entity, all partners are highlighted. The user can additionally drag-and-drop any node to a specific position of the canvas.

ScatterNet view. As the ecosystem data used for dotlink360 contained a wide variety of metrics, the scatternet view (see Figure 4.5f) displays this information in the form of a node-link diagram embedded in a scatterplot. The selected entities and its agreement partners are displayed on the x, y position within the scatterplot according to their value of the ecosystem attribute chosen as the two axes. Examples for the selectable attributes are portfolio diversity index, financial performance or market cap. The view provides the interactive features to expand the agreement partners by double-clicking on a node and highlighting an entity and its partners through mouse hovering.

The dotlink360 team decided to focus more on visualizing individual companies rather than the complete ecosystem. For each view provided, the user can drag an ecosystem entity into the view and through interactive features explore more about this entity.

To evaluate the usability and usefulness of dotlink360, the authors conducted a user study with six prototypical users. Each study participant's session was divided into three parts: first explaining the tool, second practicing the usage, and third evaluating the interaction by asking questions and assigning a task. The results showed that dotlink360 would be a relevant, flexible, and useful tool for business ecosystem analysis by providing an easy to use user interface.

4.3.2. Visual analytics for supply network management

The visual analytic system presented by Park et al. (2016) aims at understanding and managing supply networks through the provision of interactive visualizations and simulations. This work was not identified through the systematic mapping study as it addresses supply network analysis and not business ecosystems but through the analysis of related research presented by dotlink360 and ecoxight developers. Nevertheless, the results presented can be transferred to a business ecosystem visualization tool.

The involved team of researchers, Hyunwoo Park, Marcus A. Bellamy, and Rahul C. Basole, derived three salient system design requirements from the supply network management and information visualization literature, and through informal interviews and discussions with expert scholars:

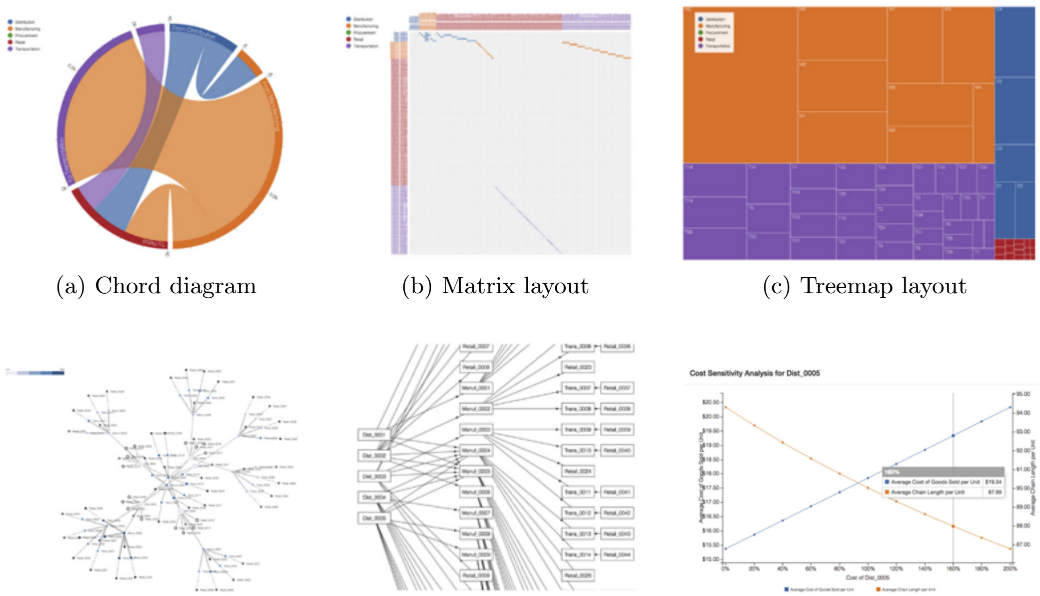
Support multiple views in an integrated interface. A visual analytic system must integrate various relevant views and perspectives that highlight different structural aspects of a supply network. The system should provide the user with the possibility to switch between these different views to integrate the discovered insights.

Enable interactive investigation of supply networks. The visualizations should provide an overall big picture of the supply network while enabling the user to gain more detailed insights through visual interactions. Modes of interaction are clicking, dragging, hovering, and filtering, all allowing the user to learn more about the underlying data.

Provide data-driven analytic capabilities. To enable exploration of alternative scenarios, the system should provide analytic and predictive capabilities and visualize disruptions such as unexpected costs or supply delays. In addition, potential alternatives should be provided to the tool user to explore different configurations of costs and delays to identify and focus on mission-critical activities.

For their prototype, the team used a well-documented supply network data set, which contains data for various industries and includes cost, delay, and demand data for each stage in the supply network.

The team developed an interactive web-based visual analytic system with five visualizations and



(a) Chord diagram (b) Matrix layout (c) Treemap layout

(d) Node network (e) Substrate-based layout (f) Sensitivity analysis chart

Figure 4.6.: Interactive visualizations provided in the visual analytic system by Park et al. (2016, p.96f)

a sensitivity analysis chart. As we incorporated the chord diagram, the matrix, the treemap, and the node network within the later presented prototypical implementation of a web-based application, we refer to Section 6.2.3.1 for a detailed description of these layouts. The sensitivity analysis chart provided insights about what-if analysis addressing the third requirement. The substrate-based layout was specifically developed for supply chain data (Willems, 2008). It imposes implicit layers as stages within the whole supply network context – visualized within this visual analytical system these are procurement, manufacturing, transportation, distribution, and retail (see Figure 4.6e) – on which nodes are placed. It displays the items flow within the supply network from a source (pictured on the left) to a destination (pictured on the right). As this layout works only for a small sized network, it is particularly useful in cases where flows among the nodes are mostly unidirectional, and only a few finite node classes exist.

The researchers evaluated the developed prototype using a multi-phase approach. After discussing the tool with 40 data visualization and visual analytic experts, the prototype was significantly revised. This version was evaluated first in two private in-person interviews with supply chain management experts and second in a focus group user study asking the participants to complete a set of tasks using the system prototype and rate its utility and usability. Overall, the focus group participants found the tool incredibly useful for discovering insights and asking insightful questions about the underlying data.

4.3.3. ecoxight

The most recent business ecosystem visualization tool identified is ecoxight (Basole et al., 2018). Like dotlink360, it was developed at the Georgia Institute for Technology. The team consists of Rahul C. Basole, Arjun Srinivasan and Shiv Patek from the Georgian Institute of Technology, and Hyunwoo Park, an affiliate of the Ohio State University. As an illustrative example of how the developed system works, they drew on data from ProgrammableWeb[5] and Crunchbase to depict the application programming interface (API) ecosystem.

For the identification of the five ecoxight design requirements, in-depth field interviews with seven global executives were conducted. The interview partners were primarily from the technology, software, and manufacturing industry and struggling with making sense of the complex business ecosystems in which they are operating.

Provide "triangulated" insight. Multiple perspectives should be incorporated into the tool. This enables users to see the underlying ecosystem data comprising of different types of entities such as organizations, people, technologies, products, and places and making informed data-driven decisions.

Understand multiplex relationships. The relations between ecosystem entities are multiplex, i.e. multiple relations exists between entities. The tool should provide appropriate mechanisms to explore these relationships.

Understand temporal ecosystem dynamics. To understand how the ecosystem grows and shrinks and which entities gain or lose prominence, the tool should enable users with appropriate techniques to explore dynamic networks, i.e. entities, relations, and their attributes changing over time.

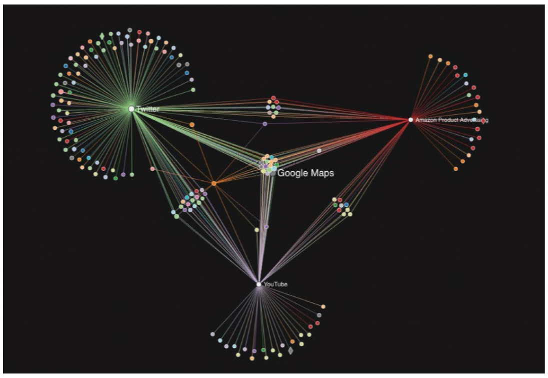
Facilitate multiple modes of inquiry. To support users in their way of ecosystem analysis, the tool should provide the possibility for bottom-up, i.e. starting with a specific part of the ecosystem and expanding the analysis from there, top-down, i.e. seeing first the big picture of the ecosystem and drilling down after, and middle-out analysis, i.e. choosing a specific subset and drilling down or expanding from there.

Easy-to-use and familiar design. The tool should incorporate best practice user interface design to provide an easy to use interface which is familiar to the users with less or no technical background.

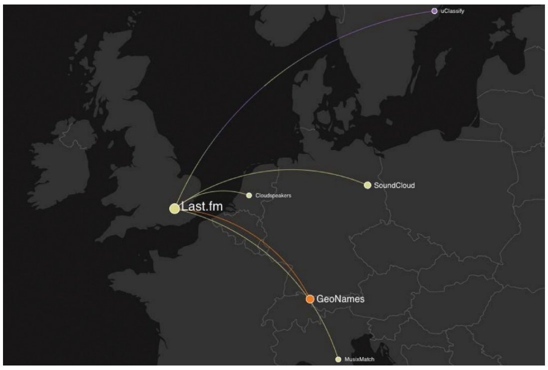
In their paper, the user interface of ecoxight is discussed in detail describing the five components:

1. data and view selection bar,
2. visualization workspace,
3. filter and encoding panel,
4. details panel, and

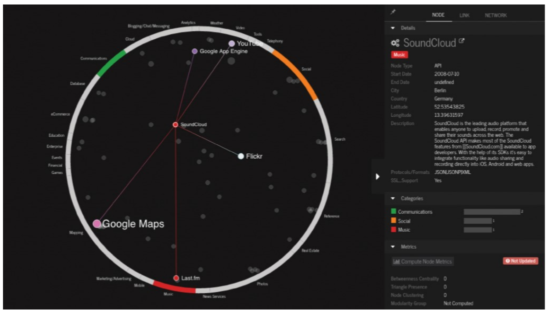
[5] `https://www.programmableweb.com/`



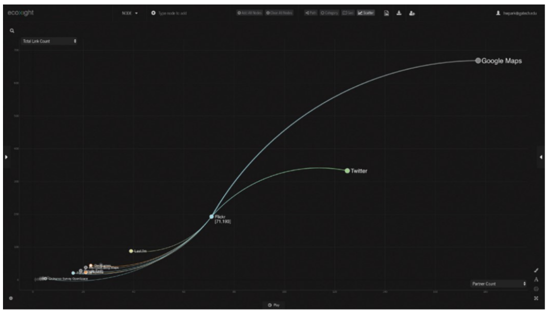
(a) Path View



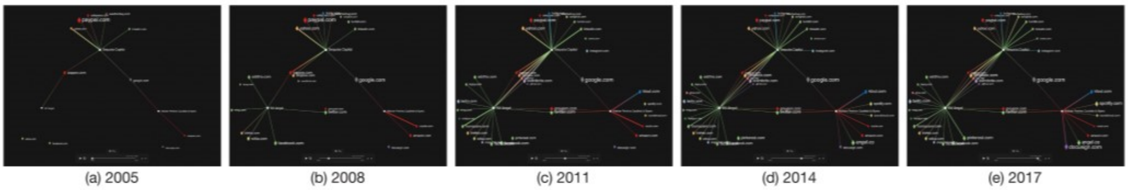
(b) Geography View



(c) Category View



(d) Scatter Plot



(e) Temporal View

Figure 4.7.: ecoxight's four ecosystem views (Basole et al., 2018)

5. playback panel.

Within the visualization workplace, one of the four available views is rendered. The views (see Figure 4.7) are similar to the ones provided in dotlink360. To gain temporal insights about the ecosystem, the tool offers a multi-speed playback mode depicting the changes over time (see Figure 4.7e).

The researchers evaluated the tool continuously with the involved industry collaborators. In addition, they conducted three user studies in the form of a laboratory experiment, similar to the evaluation of dotlink360, a short time user study, asking three participants to use ecoxight during a two-week span, and a long-term user study, inviting four participants to use ecoxight on a weekly basis allowing the participants to upload their own data curated in a specific way or to use any of the three available datasets. The results and the feedback of the study participants confirmed that ecoxight can support contemporary business ecosystem analysis.

4.4. Tools used in practice for business ecosystem analysis

The number of commercial visualization software available is vast. We will focus on software that was mentioned to us by ecosystem stakeholders or in business ecosystem visualization literature as presented above.

Within our online survey (cf. Section 3.2), we asked the participants if they use a tool for their business ecosystem analysis tasks. Tools in use were Microsoft Office software such as Word[6], Excel[7], PowerPoint[8], and OneNote[9], but also Google Drive[10], SugarCRM, and SAM were named, and as custom-developed tools Tableau, Qlik Sense, and PoolParty. Additional tools mentioned by Basole et al. (2018) are R[11] and Gephi[12]. These tools are briefly described with respect to their visualization features using descriptions from the respective software providers.

Microsoft Word. A word processor, which enables to include visualizations of data which are created with additional software for example Microsoft Excel or PowerPoint. The software focus is on editing text rather than visualizing data.

Microsoft Excel. A spreadsheet software which provides advances calculation features and various options to visualize data. The tool is versatile and has no focus on particular data.

Microsoft PowerPoint. A presentation program to display content using slides. Arbitrary visualizations can be created using forms and lines in any color or included originating from additional software such as Microsoft Excel.

Microsoft OneNote. The software enables users to document any information and share and collaborate with others. Visualizations such as equation graphs can be created within the software or additional visualizations added from other software.

Google Drive. A file hosting and synchronization service often used to share documents or collaborate on documents using cloud services provided by Google. The focus is not on creating visualizations.

SugarCRM. A customer relationship management software which includes customer support and marketing campaigns functionalities among others. The user can visualize stored data in the form of dashboards.

SAM. Also a customer relationship management software for e-mail marketing, direct marketing,

[6] `https://products.office.com/en-gb/word`
[7] `https://products.office.com/en-gb/excel`
[8] `https://products.office.com/en-gb/powerpoint`
[9] `https://products.office.com/en-gb/onenote/digital-note-taking-app`
[10] `https://www.google.com/drive/`
[11] `https://www.r-project.org/`
[12] `https://gephi.org/`

and marketing automation. Similar to SugarCRM, dashboards can be created to visualize data.

Tableau. A tool for interactive data visualizations focused on business intelligence. The tool does not focus on business ecosystem analysis but can be used to visualize business ecosystem data. Visualizations provided are bar charts, scatter plots, line charts, flow charts, and network graphs among others.

Qlik Sense. A tool for business intelligence and data visualizations using machine suggestions and automation to explore the underlying data. Similar to Tableau, the tool can visualize business ecosystem data in the form of bar charts, line charts, flow charts, and network graphs.

PoolParty. A knowledge management, data analytics, and content organization software. It can be categorized similar to Tableau and Qlik Sense but does not provide as many visualizations layouts.

R. An open software environment for statistical computing and graphics. It allows the user to define own functions or to modify existing ones to visualize the underlying data. It requires some programming knowledge.

Gephi. Similar to R, Gephi is an open-source visualization software which supports extensive and complex networks. Among other features, it allows social network analysis.

Within our survey, we did not include questions addressing how satisfied the survey participants are with their specific tool in use. However, the results of the *perceived challenges* questions, which was answered by no survey participants with *no challenges perceived*, indicate that even those using a tool are faced with challenges when analyzing and visualizing the business ecosystem of their interest.

In addition, within their research for ecoxight, Basole et al. (2018) asked executives about current tools resulting in the statement:

> *"When inquiring about current tools, all executives responded that they (and their teams) used off-the-shelf statistical (e.g., R or SAS) or visualization software (e.g., Excel, Tableau, and Qlik). In the case of statistical software, they lamented that these tools primarily provide means to examine aggregate ecosystem data. Interestingly, executives who use visualization tools commented that they had "to do a lot of data wrangling before it was in any usable form." Two executives who have had more exposure to visualization tools said that their teams used open source platforms like Gephi to depict ecosystem structure but feel frustrated with the inability to dynamically explore the data on the fly and primarily have to work with predefined visual snapshots."* Basole et al. (2018, p.5)

Overall, it should be noted that tools that can be used to visualize business ecosystems exist in practice and these tools are already in use by some ecosystem stakeholders, but do not meet all challenges ecosystem stakeholders face.

4.5. Identification of research gap

The presented tools, especially ecoxight, provide sophisticated business ecosystem visualizations and a reasoned design of the user interface. For the first two tools, dotlink360 and the supply network analysis tool, the datasets are fixed but made explorable to ecosystem stakeholders through the provisioning of the interactive visualizations. ecoxight allows the tool user to upload their own data or add custom node attributes and dynamically select them within the visualizations. Nevertheless, all tools and incorporated views have been developed based on the analysis of a specific data set or available data.

All tools address ecosystem or supply chain experts who already conducted analysis attempts. The tools target business ecosystem of specific markets or technologies, such as the API ecosystem, alliance ecosystem or start-up ecosystem. A collaboration of stakeholders within the tool is not supported but rather the individual usage of the tool and the following discussion of gained insights. The ecosystem stakeholders as tool users are not incorporated in the modeling process and only within ecoxight enabled to change the business ecosystem data model.

To address the collaboration aspect when modeling and visualizing business ecosystems, we search explicitly for collaborative business ecosystem approach. However, extant literature does not suggest collaborative processes that specifically address business ecosystem modeling and the instantiation of such models.

Collaborative modeling originated in the '70s and has since increasingly gained relevance together with the increased need for collaboration among experts (Renger et al., 2008). Collaborative modeling has been applied to various research fields, such as business process modeling (Dollmann et al., 2011), enterprise architecture modeling (Roth et al., 2013), or group decision support system modeling (Liu and Zhang, 2010).

In the presentation of the results of their literature review, Renger et al. (2008) describe the three most essential schools in collaborative modeling:

1. problem structuring methods,
2. group model building, and
3. enterprise analysis.

For group modeling, Richardson and Andersen (1995) identified five roles essential for the collaboration. We use these roles to propose a collaborative business ecosystem modeling process involving various stakeholders who instantiate the business ecosystem model collaboratively and are supported by tailored visualization within a web-based application. Therefore, these roles are transferred to business ecosystem modeling activities.

The main design artifact of this thesis is a framework comprising this collaborative process including various stakeholders and a web-based application incorporating different business ecosystem visualizations. For both, a knowledge management system is used to model the business ecosystem in focus. In the following chapters, we describe the requirements we identified using related work as presented in this chapter and the discussion rounds we conducted, the design artifact, and the evaluation we conducted.

CHAPTER 5

Identification of Tool Requirements

In order to develop a purposeful visualization tool, it is essential to identify the requirements of potential tool users and to address them conscientiously.

In this chapter, we focus on these business ecosystem visualization tool requirements as described by Faber et al. (2019c). We describe the tool-support we propose in Section 5.1, which is based on existing business ecosystem visualization tools as presented in the previous chapter linked with a knowledge management system providing collaborative features among other features.

In Section 5.2, the elicitation and specification of requirements for the visualization tool are based on the literature study, especially concerning visual analytic systems addressing business ecosystems, the discussion rounds with ecosystem stakeholders, and the results of the online survey.

Finally, we present an initial version of the web-based prototype in Section 5.3 comprising the ecosystem visualizations as one part of the tool-support. By providing an early prototype to integrate end users into the following design process (Davis, 1992; Bullinger et al., 2011) throughout the next iterations of design and development phases, we aimed at creating an initial version of a purposeful IT artifact (Hevner et al., 2004). We present the evaluation of this preliminary prototype version in Section 5.3.3.

5.1. Tool-support to collaboratively model and visualize business ecosystems

As described in detail in the previous chapter, visualizations of ecosystems have proven to enable ecosystem stakeholders to make better-informed decisions (Basole et al., 2016; Huhtamaki and

Rubens, 2016; Evans and Basole, 2016). In the context of visual decision support, visual analytic systems (VAS) visualizing business ecosystems have been proposed and evaluated against the related benefits (Park and Basole, 2016; Park et al., 2016). In the presented systems interactive visualizations are offered to the user to learn more about the ecosystem. Thereby, the user is merely a consumer of the visualizations, but cannot participate in the modeling of the ecosystem.

To not only provide business ecosystem visualizations but also to include ecosystem stakeholders in the modeling process, we propose a tool-support as depicted in Figure 5.1. It consists of two components: a web-based application that contains the business ecosystem visualizations and a knowledge management system.

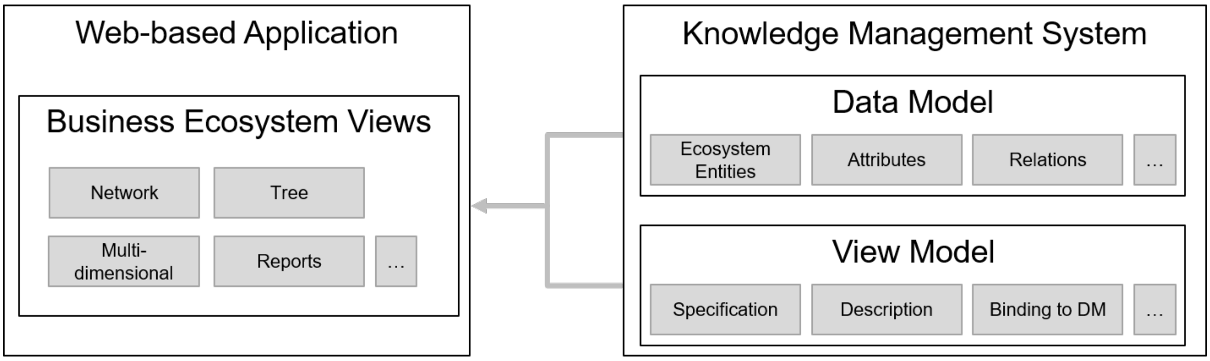


Figure 5.1.: Tool-support to model and visualize business ecosystems

For the development of the web-based application which provides multiple ecosystem visualizations, we draw on the visual analytic systems presented by Basole et al. (2013), Park et al. (2016), and Basole et al. (2018) (cf. Chapter 4.3). Thereby, the business ecosystem visualizations can range from network visualizations, tree visualizations to reports. We aim at providing visualizations tailored to the ecosystem stakeholders as tool users and the defined business ecosystem focus.

The knowledge management system stores the business ecosystem data and view models. The data model comprises the ecosystem entities, including attributes describing them, and the relations between these entities. The business ecosystem visualizations are defined in the specification of the view model. Through the binding between the view model and the data model, the visualizations are updated in run time whenever the data model has changed. The knowledge management system we use is a social information modeling platform for collaborative, evolutionary data and process management as described by Neubert (2012) and Reschenhofer (2017). It has been used successfully in different use cases for different domains and is described in more detail in Section 6.2.1.

We envision to separate the visualization and the modeling environment aiming at a lightweight provision of business ecosystem tailored visualizations especially for business ecosystem stakeholder with no technical knowledge and background. The views are provided in an easy-to-use web-based application, whereby the data and view model are both stored in a knowledge management system.

5.2. Identification of requirements

The ten requirements we identified and present in the following originate from

- the explicit requirements proposed in the work of Basole et al. (2013), Park et al. (2016), and Basole et al. (2018) describing business ecosystem visualization tools and the requirements described by Reschenhofer (2017) for the knowledge management system,
- the references and statements made by literature which have been studied during the structured literature research (cf. Chapter 2), and
- the experience and knowledge we gained through the discussion rounds with industry partners active in the mobility business ecosystem.

In the following, we first present the requirements in general and then emphasize the relevance when modeling and visualizing business ecosystems. The requirements are designed to support business ecosystem stakeholders in their modeling of the business ecosystem providing a tool-support.

We start with the requirements for the web-based application which provides the tailored business ecosystem visualizations, followed by requirements addressing the knowledge management system to support collaborative model. In addition, the system should support changes of the business ecosystem model to address the changes of the ecosystem.

5.2.1. Requirements for business ecosystem visualizations

> **Requirement R1: Provision of visualization displaying the relation.**
> Display relations between the entities and provide attributes describing these relations.

A business ecosystem include both the static network of entities, e.g., firms, technologies, and services, as well as the dynamic network characteristics, i.e. the relationships between entities and activities, all changing over time. The ecosystem entities are linked via different kinds of relationships, such as collaborations, co-funding or ownership (Faber et al., 2018d). For ecosystem visualizations it is essential to display these links and also additional attributes describing the nature of these (Basole et al., 2018).

The describing attributes can vary between relation types. While a start date might be interesting when describing a collaboration between companies, in a funding relation it might be the amount of money that has flowed.

> **Requirement R2: Provision of interactive visualization features.**
> The provided visualization should comprise interactive features such as clicking, dragging, hovering, and filtering.

As business ecosystem data is vast, the visualizations can become complex displaying all ecosystem entities and their relations. While visualizing all documented ecosystem information can provide the ecosystem stakeholder with a big picture of the business ecosystem, it is necessary to enable interactive features to focus on specific aspects of the business ecosystem.

Ecosystem stakeholders should be able to learn more about the ecosystem using the visualizations through various modes of interaction with visualization such as clicking, dragging, hovering, and filtering (Park et al., 2016), making the ecosystem explorable.

Through clicking on or hovering over visualizations of ecosystem entities additional information about the ecosystem entity can be provided to the user in the form of another view or a small tip-over. Dragging entities can rearrange the view centering a specific ecosystem entity. Providing filter options to the users enables them to choose only specific business ecosystem information to be visualized.

Requirement R3: Provide temporal insights.
Support appropriate techniques to explore the changes and temporal dynamics of underlying data.

Business ecosystems are dynamically changing over time as entities continuously entering and leaving the ecosystem, are gaining or losing prominence (Basole et al., 2018), and new relations between entities are established, or existing ones change. Visualizations addressing these dynamical characteristics should be provided to support an understanding of how the ecosystem grows and shrinks.

5.2.2. Requirements for a tool-support providing business ecosystem visualizations

Requirement R4: Provide multiple views.
Offer multiple perspectives on the data by providing multiple views and provide flexible navigation between these visualizations.

As every visualization is limited in the insights it can offer, having multiple perspectives on the business ecosystems data allows practitioners to look at business ecosystems from different angles, set focuses where needed, and gain more insights. Park et al. (2016) described that multiple visualizations of the same ecosystem data can lead to different insights about the ecosystem. For example, a force-directed layout is very suitable for identifying key entities and clusters in the ecosystem, an adjacency matrix allows users to identify existing and missing relations easily. The tool should be able to provide different visualizations, and ecosystem stakeholders should be able to switch between these visualizations.

Requirement R5: Provide an easy-to-use interface.
Provide a familiar and easy-to-use user interface to display visualization(s).

As the visualization should be used not only by modeling experts with technological knowledge, but also by non-technical business ecosystem stakeholders, the visualizations should be provided in an easy-to-use interface. The navigation between provided visualization and the application of interactive features should be intuitively to understand.

Requirement R6: Support usage of semi- and non-structured data.
Allow the inclusion of structured information in the form of attributes and non-structured information to describe the entities in the data model.

When focusing on business aspects of a company's business ecosystem, information about business partners, competitors, interesting start-ups and their strategies, partnerships and offered solutions, and cooperative initiatives becomes relevant (Faber et al., 2018a). Data containing this information can come from various sources, such as existing databases, newspaper articles or blogs addressing recent developments within the ecosystem, but also company and institutional web presences and publications. A tool visualizing business ecosystem data should allow different data formats to be included.

Requirement R7: No predefined structure of content.
No structure of the model should be imposed. The model should be dynamically enriched with additional, not yet defined structure.

When ecosystem stakeholders initially start to model their business ecosystem in focus and existing models and tools are not available, it is unclear what information will be available with what accuracy and frequency. However, stakeholders should be given the freedom to model the ecosystem without a pre-defined structure as they see fit to answer and fulfill their ecosystem specific questions and tasks.

Requirement R8: Adaptability of data and view model.
Tool users should be able to change the model at run-time. The model should iteratively be defined in an instantiation phase, and subsequently refined and tailored to the potential environmental changes.

The business ecosystem data model describes how the ecosystem entities and their relations are modeled. Ecosystem entities are companies actively innovating, creating and distributing their products and services within the ecosystem, start-ups newly entering the ecosystem or public legislative institutions influencing the market with new laws and guidelines. As these ecosystems change dynamically, ecosystem stakeholder should be able to adapt the data model according to these changes – as new entities enter and leave the ecosystem, and existing relations are changed or new relations established. During the initial modeling process it is often unclear which data is relevant and available for collection, therefore, the ecosystem data model should be adaptable to new insights and increased experience of ecosystem stakeholders.

The business ecosystem view model describes how the ecosystem data is visualized, e.g., the size and form of nodes, the line type and color of relation types. As the ecosystem stakeholders should use the provided visualizations to explore the ecosystem in focus, their feedback towards the usability of the visualizations is essential for future engagement. In case a visualization does not support stakeholders in their ecosystem-specific decisions, the visualizations should be adaptable according to the needs of the ecosystem stakeholders.

> **Requirement R9: Collaborative content creation.**
> Multiple stakeholders with different roles and different kinds of expertise should be enabled to contribute to the collaborative instantiation and creation of the model.

To include diverse aspects and perspectives of the business ecosystem in focus – such as legal aspects of concluded agreements, software related issues or legal perspectives – it is vital to involve groups of stakeholders with diverse skills and expertise in the modeling process. These stakeholders should be able to access the system separately, but collaboratively update and adapt the business ecosystem data model.

> **Requirement R10: Binding of data and view model.**
> The data and view model should be bound to ensure information implemented in the data model are visualized at any time.

As the visualization of the business ecosystem should be used to contribute to a better ecosystem understanding, the visualizations should be up-to-date at all time displaying all information of the ecosystem data model. In case changes in the data model happen, the according visualizations should be updated as well, which requires binding of the two models.

The requirements as mentioned above provided the basis to develop a tool-support to collaboratively model and visualize business ecosystems. The main prototype developed in this research project is described in detail in the following chapter. We recapitulate on these requirements and how they were addressed and fulfilled with the developed prototype in Chapter 8.

In the following, we describe the development of the initial prototype and its preliminary evaluation, which provided us with valuable feedback for our further iterative development.

5.3. Development of an initial prototype to visualize business ecosystems

Considering the identified relevance of business ecosystem analysis and the related work on tool-supported interactive visualizations of business ecosystems, we developed a first version of a web-based tool-support. The tool provides interactive visualizations and, in a first attempt, an additional view that allows tool users to implement their knowledge about the ecosystem.

According to the three cycle view of design science by Hevner (2007), the goal of an early available prototype in the design process is to integrate potential users in the design process, evaluate the existing prototype, and incorporate their feedback to refine the design in the following design cycles.

For this first version of the prototype, two aspects were particularly important: First, ecosystem stakeholders should be able to easily explore the ecosystem in focus through multiple visualizations with interactive features such as clicking, hovering, and dragging. Second, we targeted the collaborative modeling aspect by providing a feature to easily implement information about relation between ecosystem entities. The aim of the second aspect was to identify if stakeholders can be encourage to implement their knowledge about the ecosystem and thereby contributing to a more accurate presentation of the ecosystem. The initial prototype was developed within the master's thesis by Arendt (2016).

The aim of this first version of the prototype was creating a minimum valuable artifact of the web-based application (cf. Figure 5.1, left side). The previously described requirements were deliberately not all addressed as the preliminary evaluation of the prototype was incorporated in these requirements.

In the following, we describe the underlying business ecosystem data (Section 5.3.1), and specific aspects of the initial prototype, such as the navigation within the application and the interactive features (Section 5.3.2). We conclude with results of the preliminary evaluation of this prototype in Section 5.3.3.

5.3.1. Business ecosystem data

The TUM LLCM project ecosystem was used as an initial business ecosystem to visualize with the prototype. As a business ecosystem data set was not available during the prototype development phase, we collected the data ourselves. A preliminary set of mobility business ecosystem entities, such as companies, projects or public institutions with which the project team already interacted or which were potentially interesting to engage within the establishment of the business ecosystem were gathered.

Based on the identified industry stack of mobility presented in Table 3.1, we identified overall eleven interesting categories, such as smart city/smart mobility project, automotive OEMs, part supplier or public institution. Besides, we modeled different relations types to describe the interactions within the ecosystems, such as cooperation, ownership, funding, and talks, i.e. if an exchange between two ecosystem entities happened

To describe the ecosystem entities, the attributes abbreviation, company's web page (URL), legal form and logo, were gathered whenever possible. For relation between ecosystem entities, the starting date and end date were set as describing attributes.

After the collection phase, the business ecosystem data comprised 52 ecosystem entities, such as BMW AG[1], AUDI AG[2], moovel Group GmbH[3] or Zentrum Digitalisierung.Bayern[4] and the project itself, and 57 relations between these entities, e.g., existing collaboration between iteratec GmbH[5] and DriveNow GmbH & Co KG[6] or the ownership of BMW AG of mobility providers such as ParkNow[7].

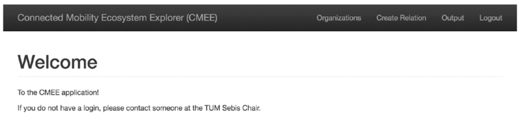
[1] https://www.bmw.de
[2] https://www.audi.de
[3] https://www.moovel.de
[4] https://zentrum-digitalisierung.bayern/
[5] https://www.iteratec.de
[6] https://www.drive-now.de
[7] https://de.park-now.com/en/

The business ecosystem data model was implemented in the knowledge management system we describe in Section 6.2.1.

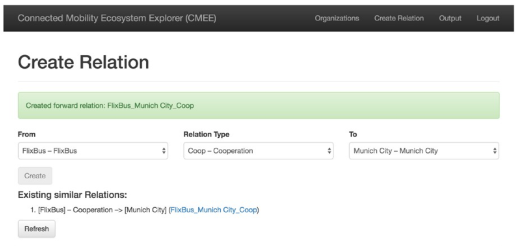
The collected data set can be considered as relatively small compared to data sets visualized in existing business ecosystem visualization tools. Nevertheless, as the prototype was designed to provide a minimum valuable product, the data set was large enough to be visualized in a web-based tool.

5.3.2. Details of the initial prototype

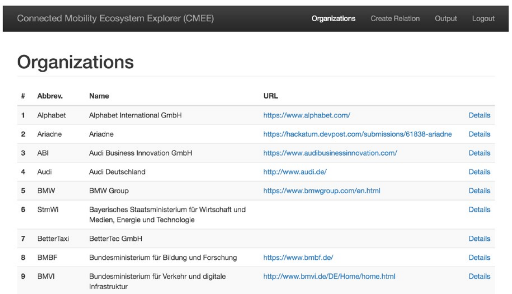
A single-page web application was created consisting of four views (see Figure 5.2): a landing page with a brief welcome message, a page to add new relations between implemented ecosystem entities, a list of all ecosystem entities including the attributes describing them, e.g., company's URL, and a view showing the three available visualizations: two force-directed layouts and one matrix layout.



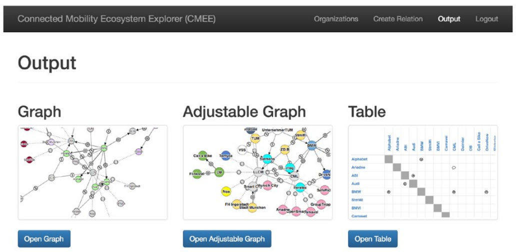
(a) Landing page



(b) Create new relation between existing entities



(c) List view



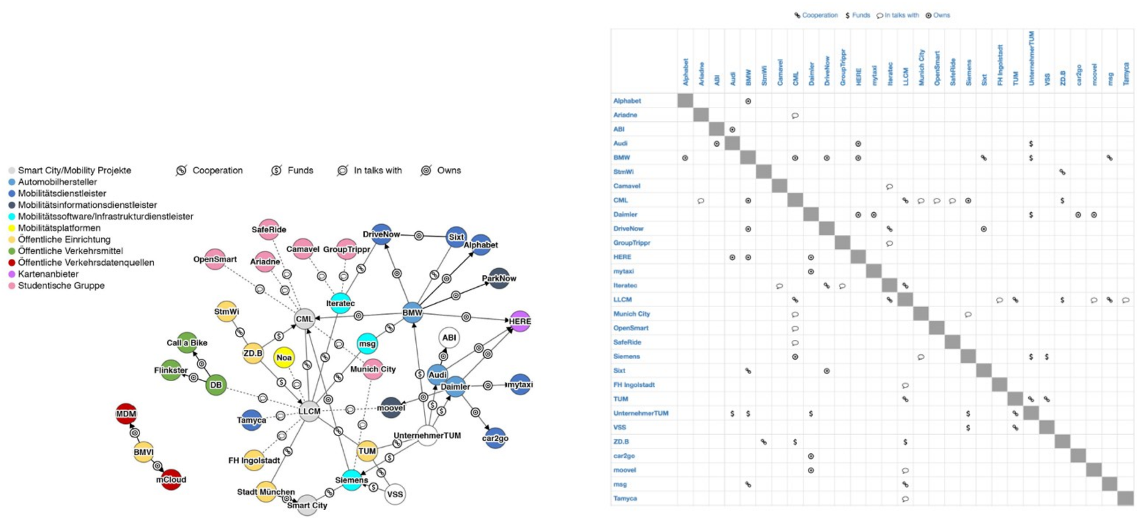
(d) Overview of visualizations

Figure 5.2.: Visualizations of the inital prototype (Arendt, 2016)

In the following, we describe highlights of this prototype version.

The top bar of each page enabled the tool user to navigate through all existing pages. To access the visualizations the according visualization layout had to be selected clicking the button below the pictures (see Figure 5.2d).

One page, as depicted in Figure 5.2b, provides the user with the option to implement relations between existing ecosystem entities. The page comprise a form with three drop-down fields: *From*, *Relation Type*, and *To*. In both *From* and *To* fields, the drop down shows all available ecosystem entities, the field *Relation Type* all relation types. When inserting a relation using the form field already existing identical relations were displayed below the fields to prevent implementation of duplicate relations. To change these existing relations, the user is directed to the knowledge management system.



(a) Force layout

(b) Adjacency matrix

Figure 5.3.: Visualizations of the mobility business ecosystem of the LLCM project provided in the first prototype (Arendt, 2016)

Both visualization layouts described in detail in Section 6.2.3.1 are typical for business ecosystem visualization layouts (cf. Section 4.3) and are included in the work of Park et al. (2016) and Basole et al. (2018). The force-layout was included twice, as the *Adjustable Graph* allowed users to move and fix nodes by dragging and dropping them to a specific position within the view after rendering.

The adjustable force-directed layout (see Figure 5.3a) displayed the organization of the ecosystem as nodes and the relation between these organizations as links connection these nodes. The nodes were colored according to the organization category. All organization categories were listed in the legend in the upper left corner including the applied color coding. The companies' abbreviations were displayed on top of the node. The four relation types were displayed as icons described in the top of the view. Between two organization with a connection the according relation type is depict using the respective icon.

The adjacency matrix displayed the same relation icons in a cell connection two organization in case a relation existed. The matrix is symmetric as all organizations were listed in both the first line and column. Hyperlinks were attached to organizations and relationships in this view allowing users to click either, and access the respective entity in the knowledge management system. Applying the HTML title attribute the tool-tip provided full organization names and relationship descriptions for the organization and relation respectively when hovering over a specific cell showing an existing relation.

5.3.3. Preliminary evaluation

To get feedback from potential users and ecosystem stakeholders for the next design cycle iteration as described by Hevner (2007), two rounds of semi-structured interviews were conducted presenting and discussing the prototype and potential fields of application as visualized in Figure 5.4.

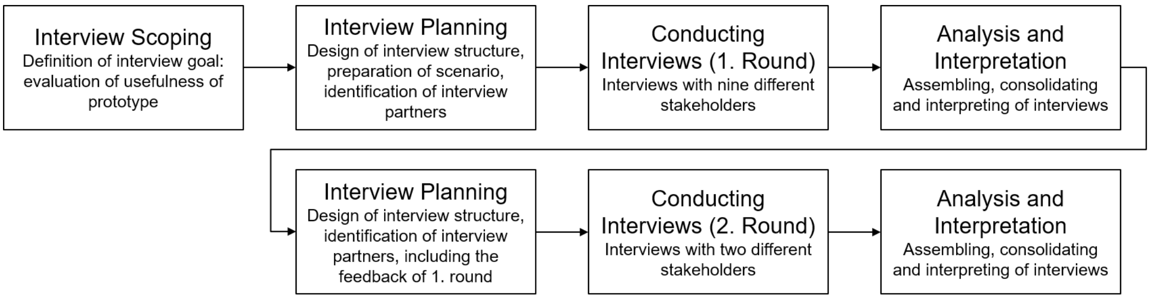


Figure 5.4.: Preliminary evaluation process of the first version of the prototype

We chose interviews as evaluation method, because the flexibility of interviews allow interviewees to focus on aspects that are related to them. Semi-structured interviews adapted from Weiss were utilized to evaluate the prototype (Weiss, 1994) as this format adds the ability to vary the depth of topics (Gläser and Laudel, 2010).

5.3.3.1. First round of interviews

The first interview round is described in detail by Arendt (2016) including a quantitative and qualitative evaluation of the initial prototype.

Participants. Participants of nine different companies were interviewed, with seven stationed around the Munich area. The job titles of the participant included research associates, engineers, IT consultants, product managers, and CEOs. Participants were selected due to their expertise, feasibility as users, and experiences. None of the interviewees were related to the TUM LLCM project.

Interview procedure. The interview consisted of two parts. In the first part, a previously defined mobility business ecosystem scenario[8] was presented to the interviewees. In the follow-

[8]Scenario given to the interview partners: You are leading a research group that wants to rent out private vehicles, in the times that they are not being used (i.e. during the week while the owners commute by public transportation). Your investors want to see a prototype working in the real world, and it is your job to find

ing, the participants were asked to answer four questions all related to the scenario. The questions targeted to identify which kind of information – only company information, relations between organization, the combination of company information and their relations – are potentially useful for ecosystem specific tasks. This part aimed at a quantitative evaluation.

In the second phase, the prototype was shown to the interview partners. The interviewees were asked to share their thoughts about the prototype, the visualizations, and potential application fields leading to qualitative feedback.

Results of the first interview round. In the following, we discuss the evaluation part focusing on the prototype as part of the qualitative evaluation, while we refer for details of the quantitative evaluation to the master's thesis by Arendt (2016).

The interactive visualization caught immediate interest of all interview partners. The visualizations were perceived helpful to understand the visualized business ecosystem. It was noted that additional information about the relations would be beneficial, such as information about what type of funding was provided and the amount. Another remark was on the relation type cooperation, as participants felt it was too ambiguous. All participants discussed specific relations as they were particularly interesting for them. Comparing the two provided visualization layouts, the force-layout visualizations focused peoples attention and imagination more.

As potential application fields, one interviewee drew discussed the patent situation in the pharmaceutical industry, as it is very difficult to remember which company owns which patent, when it runs out, and who has bought rights to produce it.

A second round of interviews was conducted to evaluate the initial prototype in more depth.

5.3.3.2. Second round of interviews

In the second round of interviews, three in depth semi-structured interviews were conducted in which the prototype was presented and discussed.

Participants. We identified three stakeholders of the project mobility business ecosystem as potential users of the tool. One stakeholder was the leader of a mobility project working for a automotive OEM, whom we interviewed in November 2016. The second interview was conducted with two stakeholders, working for a conglomerate company active in the business field of automotive supplement, whom we interviewed in December 2016. Finally, two stakeholders from an entrepreneur center interested in promoting mobility-related start-ups were interviewed in February 2017.

Interview procedure. All interviews consisted of two phases. In the first phase, the prototype was presented demonstrating all implemented views and interactive features. In addition, the

companies which allow you to collaborate and realize this goal/desire. One of your first tasks is to analyze and contact potential partners. These could be competitors offering similar products, companies offering advice/parts or independent contractors.

underlying data set was explained. Questions of the interviewees regarding the prototype were answered. This phase lasted about 15 minutes.

In the second phase, the interviewees were asked for feedback towards their perception of the usefulness of the prototype, a possible tool usage in their daily work, and additional possible business ecosystem application fields besides the mobility case. This phase lasted between 30 and 90 minutes.

Results of the second interview round. The first stakeholder stated that, currently, activities related to competitor analysis are conducted within the organization. A team of approximately 25 employees working on the competitor analysis uses a tool, which provides no visualizations. The presented prototype was evaluated as a beneficial extension. As an interesting application field, the mobility business ecosystem in which the organization is active was named to 'keep track of mobility companies'. For the overall evaluation of the framework, a case study was conducted with this company as presented in Chapter 7.

The tool was evaluated by the interviewees of the second organization as intuitive to use and the provided visualization as beneficial to get an overview of the visualized business ecosystem. One interview participant noted that the visualization of publicly available ecosystem data of organizations, key persons, and their relations would be interesting. As a proposed additional feature she suggested the provisioning of filter options for specific organization types and a search function to identify a specific ecosystem organization. As a possible application field both participants identified the modeling and visualizing of the company's business ecosystem with a focus on contracts established or in planning with external business partners but on business unit level.

The participants of the third interview round already analyzed the mobility business ecosystem due to their interest of identifying mobility-related start-ups which can be integrated in their accelerator program. For the analysis no visualization were in use at the time of the interview. The prototype was perceived as helpful to understand the business ecosystem visualized. As main focus, organization categorized as *Studentische Projekte* (engl. student projects) were discussed as they potentially could develop into start-ups. One participant mentioned the necessity to change the modeled organization and relation categories to create meaningful visualizations tailored to their business ecosystem focus.

The results of the interview rounds indicate that ecosystem stakeholder are interested in modeling and visualizing the business ecosystem of their interest and using a tool like the prototype to support the modeling. They also pointed out necessary prototype changes relevant to get a tool useful for their daily business ecosystem related tasks. Especially the idea of modeling business ecosystems with various focuses and the adaptability of the ecosystem data model were identified as relevant for the next design cycle. The preliminary evaluation contributed to the refinement of the requirements leading to the set presented in this chapter.

5.4. Summary

The described elicitation phase lasted over one year and gave us the opportunity to develop an initial prototype as presented in this chapter. We used this first version of the prototype to foster the discussion with ecosystem stakeholders and identify potential practical environments for a joint modeling and visualization of business ecosystems relevant for the stakeholders.

The results of this chapter present the first iteration of the design cycle as presented by Hevner (2007). We used the feedback collected in both interview series to further develop a tool-support for ecosystem stakeholder modeling and visualizing business ecosystems. We have also designed a collaborative process that uses the tool and adapts it to the needs of different ecosystem stakeholders. We present the process including identified roles and the final prototype as main results of this research in the following chapter.

CHAPTER 6

Tool-Supported Business Ecosystem Modeling

This chapter is dedicated to the design artifact developed within this research project: a method to collaboratively model business ecosystems involving various ecosystem stakeholders in the form of an iterative process we designed, and a tool supporting this process by providing interactive and tailored business ecosystem visualizations.

In Section 6.1, we present the iterative process and describe in detail the six process activities which are distributed over five process phases, the identified roles, and artifacts created and used within the process as described by Faber et al. (2018a,d, 2019b).

The tool-support which includes a web-based application providing interactive visualizations and a meta-model based knowledge management system as visualized in Figure 5.1 are discussed in Section 6.2. The prototype of the web-based application is the result of the second design cycle as discussed by Hevner (2007). We refer to the prototype as *Business Ecosystem Explorer (BEEx)*. It addresses the previously identified requirements (cf. Section 5.2) and incorporates the collected feedback of the first prototype evaluation (cf. Section 5.3.3).

Finally, two use cases as possible applications of the developed framework are discussed which we identified during the design phase and the interactions with ecosystem stakeholders (see Section 6.3). First, the company-internal usage is described in which only employees are involved in the modeling process. Second, providing the visualization to the public in form of a publicly accessible tool to model and visualize a business ecosystem. The business ecosystem can be initially modeled using Internet data sources and the resulting visualizations are eventually provided to the public to incentivise the ecosystem crowd, i.e. all potentially interested stakeholders, to participate in the modeling process.

6.1. Process model for tool supported modeling and visualizing of business ecosystems

As outlined in the previous chapters, modeling business ecosystems is a complex and challenging task mainly due to three aspects:

First, ecosystem data is large and heterogeneous (Basole et al., 2015), ranging from technology-related data about applied standards and platforms, to market information and legal regulations. When focusing on business aspects of a company's business ecosystem, information about business partners, competitors, interesting start-ups, their strategies, partnerships, offered solutions, and cooperative initiatives becomes relevant (Faber et al., 2018c). Data comprising this information can come from various sources, such as existing databases, newspaper articles or blogs addressing recent developments within the ecosystem, but also company and institutional web presences and publications. The challenges associated to data collection in emergent business ecosystems are not yet resolved (Iyer and Basole, 2016; Hao et al., 2015) and this poses particular challenges for utilizing visualizations for ecosystem analysis or business development (Rehm et al., 2017).

Using three complementary data sources, Basole et al. (2015) proposed a data-driven visualization process to understand business ecosystem dynamics (cf. Section 4.2.1). The process comprises four process steps:

1. boundary specification,
2. metrics identification,
3. computation, analysis, and visualization, and
4. sense making and story telling.

Second, analyzing business ecosystems is generally impossible for one single stakeholder to achieve because of the abundance and complexity of processes and data that would need to be observed, recorded, documented, and made visible (Faber et al., 2019b). For the modeling within an enterprise context, various data sources and stakeholders of several business units within the enterprise should be included in the business ecosystem analysis to involve diverse aspects and perspectives on the ecosystem.

Roth et al. (2014) presented an iterative process to create enterprise architecture visualizations including various stakeholders. The process comprises three process steps:

1. conceptualization of the enterprise architecture model and initial data collection,
2. provision of the enterprise architecture model including explanation, and
3. reflection and possible adaptation of the enterprise management function.

This process, even though not focusing on business ecosystems, is particularly relevant, as visualizations are provided in the second process step, various stakeholders are included in all process steps, and it proposes iterations to address feedback and necessary changes to the modeling output.

Third, as business ecosystems dynamically change over time, the business ecosystem models must be adaptable to address changing ecosystem information. We realize this by proposing iterations of the critical process activities and using a system which provides respective features.

We propose a process which is based on the four-stage approach to data-driven business ecosystem analysis and visualization by Basole et al. (2015) and the iterative process of Enterprise Architecture Management function by Roth et al. (2014). It is adaptable to different types of teams or communities and various business ecosystem types and involves six activities, in five phases, with three stakeholder groups and four types of artifacts created and used. Overall, the process differentiates between several elements, which are:

Artifacts. Objects, such as documents, models or definitions, which are created, modified or used by human actors are called artifacts. They can be used as input or be designed as output of an activity.

Activities. An activity describes a condition in which things are happening or being done, or a specific function is being performed for the desired outcome, such as creating or updating an artifact, e.g., documents, models or visualizations.

Roles. A role is defined as a specific pattern of behavior (Rittgen, 2010) performed by an individual or group. The performing actor can exercise multiple roles within one process or various processes.

The process has been applied and evaluated in two case studies and a simulation which we present in Chapter 7.

6.1.1. Iterative process

Figure 6.1 illustrates the iterative process to model and visualize business ecosystems using four different rows, namely *phases*, *activities*, *roles*, and *artifacts*. Each row is divided into the five phases: *focus*, *build*, *use*, *revise*, and *reflect*.

6.1.2. Phases and activities

We describe the six activities within the five phases of the iterative process.

Focus phase

In the initial *focus phase*, the implementation and use of the process and the tool-support are motivated, and the focus of the business ecosystem is defined. The business ecosystems focus can vary between ecosystems around one focal firm, such as Wal-Mart or Microsoft (Iansiti and Levien, 2004b), ecosystems of a specific market exploiting specific digital technologies, such as API (Evans and Basole, 2016) or mobile phones and platforms (Sørensen et al., 2015), or ecosystems established around a singular technology platform, such as Google and Apple (Sako, 2018) (cf. Section 2.4).

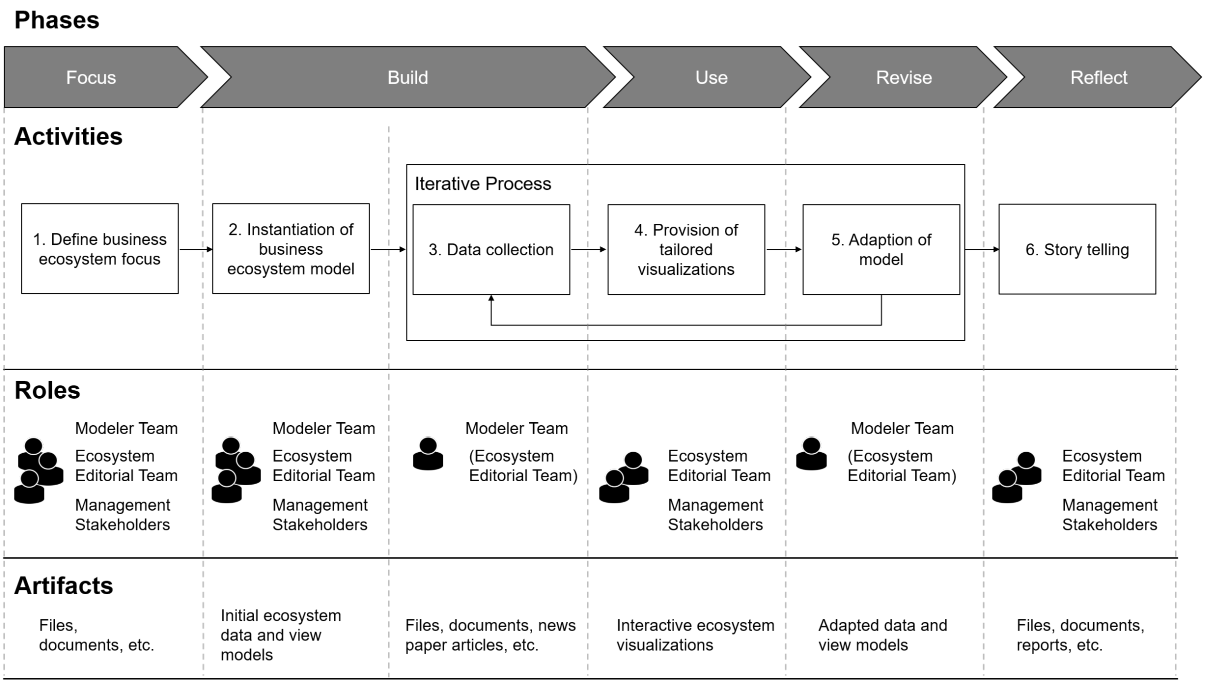


Figure 6.1.: Iterative process to collaboratively manage and adapt the business ecosystem model (Faber et al., 2018a)

For the initiation of the process, the business ecosystem focus which should be modeled and visualized is defined collaboratively by involving all stakeholder groups. The management stakeholders can be the deciding factor in case of disagreement between the involved stakeholder groups, as each stakeholder group owns specific requirements towards understanding aspects of the ecosystem and the functioning and use of the tool-support.

Basic requirements for engaging in an ecosystem modeling initiative should stem from management stakeholders, such as enterprises top management or strategy team representatives, to ensure commitment throughout the process conduction. Together with domain experts, e.g., business case owners, specific questions about the ecosystem and its development or structure are formulated. These mirror the business strategy that underlies the modeling initiative at large. These questions and respective requirements are taken up by the ecosystem editorial team (as described later), facilitating the initiation of the process. The modeler team, which later performs the main work of continuously collecting business ecosystem data and adapting the view models according to collected feedback, is involved from the beginning.

Build phase

The next phase, *build phase*, consists of two activities: First, the initial business ecosystem model is created which includes the ecosystem data and view models. Second, business ecosystem data is collected. This activity is performed iteratively to capture changes of the business ecosystem in focus.

Within the data model instantiation, relevant ecosystem entities, categories of entities, and relation types are defined, including their attributes. For the view model, the visualization layouts including the visualization specifications are established. Both initial models are not predefined and are adaptable in later stages of the process.

The requirements for both models should be collected – even in the instantiation phase of the models – by several stakeholders to ensure tailored visualizations in a later stage of the process. Different stakeholder groups might ask for specific visualizations, components or features. Representatives of the legal department might be only interested in legal forms and contracts with business partners, while a strategy team might focuses more on platforms and technologies related to ecosystem members and cooperative initiatives, to inform the search for potential future business partners. We propose to collect these requirements in workshops with representatives of each stakeholder group lead by the ecosystem editorial team. In a later phase of the process, the changing requirements and feedback can be collected within the tool-support.

In the second activity of the build phase, the collection of business ecosystem data is carried out. For the initial instantiation, either company internal information systems can be used as data sources, entailing already collected information about competitors, business partners or interesting start-ups, or publicly accessible data sources. Especially in the case of a process execution within a single company, each stakeholder group should be motivated to implement their specific knowledge and to communicate the sources used to gather information. In case no business ecosystem analysis was performed yet or the process is executed with the aim of providing publicly available business ecosystem visualizations, public data sources can be used. In case such Internet data sources are used, the business ecosystem information collected should be additionally assessed for appropriateness and trustworthiness. How to identify and assess Internet data sources is discussed later for the case of modeling and visualizing the Munich smart city mobility business ecosystem (cf. Section 7.4). Available data sources which might comprise business ecosystem related information are for example Crunchbase and Anglelist as international databases, or Gründerszene and Bayern-International for German specific data as mentioned before.

The activity of data collection is revisited within the iteration process phase. New information about the business ecosystem in focus might be released on a daily, weekly or monthly base and should be included to provide up-to-date visualizations of the business ecosystem. The data collection can be done manually or automatically, e.g., using the previously mentioned databases or news feeds, blocks or trade publications.

Especially during the instantiation of the process, the ecosystem editorial team orchestrates the data collection. With increasing experience of the modeler team, this activity might be performed only by them.

Use phase

In the *use phase*, the tailored and interactive business ecosystem visualizations are provided. To ensure tailored visualizations, the collected requirements of the management stakeholders within previous process activities should be addressed.

For the first iteration of the process, the tool-support becomes available first time in this process step. After this initial deployment to the process participants, the tool-support remains permanently available throughout process iterations to keep all business ecosystem stakeholders motivated to contribute with their ecosystem knowledge.

The visualizations are incorporated in a web-based application – as the tool-support – with an easy-to-use user interface. In case various visualizations are provided, such as network layouts, treemaps or reports, the navigation between these layouts is intuitively. The visualization layouts including specifications are defined in the initial business ecosystem view model which is adapted throughout the process execution. All visualizations provide the interactive features necessary to enable ecosystem stakeholders to focus on specific aspects of the business ecosystem visualized, such as searching for a specific ecosystem entity, highlighting the relations of one entity or visualizing only a specific organization category.

Revise phase

The *revise phase* comprises the feedback of the management stakeholders on achieved results and validity of the business ecosystem visuals. A vital role in this process is assumed by the modeler team, whose modeling expert members require domain knowledge to be capable of adapting the ecosystem data and view models according to the collected feedback. It is essential that all stated feedback is understood and addressed to keep the motivation high and to ensure that the data and its visualizations provide meaningful content and contribute to a better understanding of the business ecosystem and support stakeholders in their ecosystem specific decisions. The ecosystem editorial team again acts as a process coach enabling the modeler team especially in the instantiation of the process in successfully implementing the required changes.

In this phase, additional input from external domain experts can be sought depending on upcoming tasks (Basole et al., 2016) in case the implemented layouts are not providing the insights as expected, or additional data sources are needed to model the business ecosystem in focus. For this activity, the ecosystem editorial team is responsible for staying informed about current business ecosystem research.

With an increasing number of process iterations, we expect fewer changes to the view model but rather to the data model. This is because users of the tool might find visualizations that are appropriate for their tasks and do not change them any further while the business ecosystem and thus the information continues to change.

Reflect phase

In the final *reflect phase*, the created visualizations are used to ‘tell a story’ about the business ecosystem in focus, i.e. to extract knowledge that contributes to a better understanding. Clusters within the ecosystem are determined, anomalies are spotted and investigated, or keystone and niche players of the ecosystems are identified (Leonardi, 2011).

The insights acquired through the business ecosystem visualizations can be collected in status reports or presentations to even higher management representatives not actively involved in the process but interested in the business ecosystem in focus.

Within this phase, the previously defined business ecosystem focus can be adapted leading to a new setup of the process, e.g., due to a new company's business area. The more frequently the process is carried out, the more targeted information on the ecosystem can be collected and visualized, which leads to more focused findings in the final process activity.

6.1.3. Roles

To include multiple perspectives on the business ecosystem in focus, it is necessary to involve various business stakeholders with diverse background in the modeling process. The concept of collaborative modeling addresses this need for collaboration among experts (Vennix et al., 1992; Renger et al., 2008). We have grouped relevant stakeholders for the collaborative modeling and visualizing of business ecosystems into three teams, namely the *ecosystem editorial team*, the *modeler team*, and the *management stakeholders*. For each group, we have identified up to three roles, which might be held by more than one person. To successfully model business ecosystems, one has to identify relevant stakeholders at an early stage and involve them throughout the entire process to achieve a shared and satisfying outcome.

The defined roles of the reference process in Figure 6.1 are based on roles for collaborative modeling as described by Richardson and Andersen (1995):

1. *facilitator,* who monitors the group process and stimulates the model building effort,
2. *modeler,* focused on the model outcome,
3. *process coach,* who observes the dynamics between the participants and influence the execution of the process,
4. *recorder,* documents the modeling process, and
5. *gatekeeper,* who is responsible for the instantiation of the process and acts as a major decision maker.

In addition to these roles, we identified the role of an *explorer expert* (based on the name of our prototype BEEx), responsible for the provision and adaptation of the tool-support including the tailored business ecosystem visualizations, and additional stakeholders, such as higher management representatives, which can be included whenever considered feasible.

For each team, first, the role with its general description of group modeling is presented as provided by Richardson and Andersen (1995), which is followed by a mapping of these roles to specific business ecosystem modeling activities.

Ecosystem editorial team

During the first iterations of the modeling process, the ecosystem editorial team is active in all process steps. It contributes highly to the outcome of the modeling initiative and the perceived overall success as it is mainly responsible for the successful implementation of the process. For later iterative process executions, we envision that the team withdraws somewhat and becomes less actively involved in the process steps. This team comprises two roles of the collaborative modeling approach by Richardson and Andersen (1995) and one additional role specific for the provision of the web-based application.

Process Coach. The process coach focuses on the dynamics of the process participants and subgroups eventually created within the modeling process. The coach is not focused on the created outcome (Richardson and Andersen, 1995). She helps the involved stakeholders to follow the process steps and to perform the associated activities to achieve the desired objective. She is aware of all artifacts created and used within each process step.

Within the business ecosystem modeling, the process coach guides the entire process of modeling and visualizing the ecosystem in focus. She is experienced with process executions and understands the relevance of each process activity. Also, she is aware of the ecosystem-specific challenges in each process step and can intervene whenever needed. During the case studies we conducted (see Chapter 7), we identified challenges such as a loss of motivation during the process or missing modeling expertise. These and possibly other problems are identified and addressed by the process coach.

Explorer Expert. The explorer expert is responsible for providing the web-based application including the interactive visualizations. She has background know-how about the knowledge management system and is able to initially set up the required models. Her tasks requires a technological background. In addition, the explorer expert is responsible for capturing the requirements and challenges for creating tailored visualizations.

Within business ecosystem modeling activities, the explorer expert is responsible for providing the web-based application including the interactive visualizations tailored to the requirements. With her background know-how about the knowledge management system in use she is able to create the business ecosystem data and view models. She is an expert of the declarative visual language in use, which she can apply to develop interactive and tailored business ecosystem visualizations. We envision her to train the modeler team during the initial process iterations to enable the modeler to adopt changes not only to the data but also to the view model. After the initial provision of the web-based application, she solves technical problems arising within the usage but empowers the modeler team to adjust the business ecosystem models within the knowledge management system independently.

Recorder. The recorder is responsible for documenting relevant developments and decisions during the group modeling. The records generated together with documentation created by the facilitator, should allow a reconstruction of the ideas and activities of the group during the modeling (Richardson and Andersen, 1995).

For the reference process, the recorder documents the business ecosystem focus, the questions to be answered using the created visualizations, all relevant decisions made by anyone in the group regarding chosen entity and relation types to model, data sources used and visualizations selected, especially during the initial process iterations. The recorder also documents the knowledge extracted within each *story telling* process step. She should have the skill to distinguish important and less important information of the modeling process outcomes.

Modeler team

The members of the modeler team contribute their knowledge about the ecosystem in focus and are vital for creating and continuous updating the model. The facilitator acts as a bridge between the management stakeholders, the ecosystem editorial team, and the modelers. Group members acting as modelers identify suitable data sources to use, both company internal and external, relevant entities, attributes, and relations for the data model. The use of a declarative visual language as taught by the explorer expert enables the modelers to adapt the view model by themselves.

Facilitator. The facilitator continuously monitors the group process, the participation of the individuals, and the outcome of the modeling process. It is the most visible of all roles of collaborative modeling (Richardson and Andersen, 1995). She makes the process easier to follow and helps to achieve the desired outcomes.

The facilitator is involved in the business ecosystem focus decision to support the initiation of the process. She works closely together with the modeler, ecosystem editorial team, and management stakeholder team. In case questions arise during the data collection, she acts as a decision maker. She encourages the management stakeholders to provide feedback and ensures the feedback is addressed during the business ecosystem model adaptation activities. Her skill set should include experience with modeling initiatives and decision making.

Modeler. The modeler focuses on the outcome of the process: the model(s) created explicitly and sometimes implicitly (Richardson and Andersen, 1995). She works independently and has a high interaction with the facilitator. By focusing on the model outcome, the process as such is not her main concern.

The modeler is responsible for the business ecosystem model creation. She is involved in the instantiation of the business ecosystem data and view model, to be able to start with the business ecosystem data collection immediately. She might use both companies internal and external data sources, scans newspapers and news feeds and searches for existing databases to be included in the business ecosystem model. She is also responsible for addressing the feedback of the management stakeholder team. In later stages of the iterations, we envision the business ecosystem view model to be also part of her responsibility. She should be experienced with modeling and the identification of relevant and trustworthy data sources to be used and ecosystem information to be collected and visualized.

Management Stakeholders

The management stakeholders are the process participants consuming the business ecosystem visualizations created in the process for their business ecosystem related tasks and decisions. They are continuously encouraged to provide feedback on how to adapt the visualizations for future use and which ecosystem information might be missing, without addressing concrete changes in the business ecosystem models. This team is mainly responsible for the business ecosystem focus set in the beginning, and they provide resources for the business ecosystem modeling process.

Gatekeeper. The gatekeeper is responsible for the entire group modeling and usually initiating it. Following Richardson and Andersen, who defined the gatekeeper as "an advocate in two directions: within the client organization he or she speaks for the modeling process, and with the modeling support team he or she speaks for the client group and the problem. The locus of the gatekeeper in the client organization will significantly influence the process and the impact of the results" (Richardson and Andersen, 1995, p.2).

The gatekeeper is a decision maker responsible for the business ecosystem focus. We envision her to understand the benefits of modeling and visualizing the business ecosystem and to provide resources for the process. She consumes but also present the visualizations or visualization based stories to a higher management level. Due to her connection to additional stakeholders, she decides which other stakeholders to include and whom to report to.

Additional Stakeholders. Additional stakeholders are not immediately involved in the modeling process but might be interested in the visualizations created. Eventually, they also can contribute to the modeling process with their knowledge as process outsiders. Higher management stakeholders consuming specific reports or stories about the business ecosystem are included in this role.

The additional stakeholders might receive the created business ecosystem visualizations or specific parts of it by the gatekeeper. In case additional feedback towards the visualization is needed, they can get involved acting as consultants.

6.1.4. Artifacts

During the process execution, artifacts, such as files, documents, models, and visualizations, are created, used or modified. The main artifacts are the business ecosystem visualizations based on the business ecosystem data and view models.

Files, documents, reports, news paper articles. For the business ecosystem modeling, information about the ecosystem has to be collected using company internal and/or external data sources. Ecosystem information already available in the form of documents or files should be considered for the data collection.

The recorded information – including the business ecosystem focus set during the modeling process – can be shared through documents.

Data model. The business ecosystem data model comprises the ecosystem entities including their describing attributes, the organization categories, relation types, and the relations between the ecosystem entities. The ecosystem entities can be companies, public institutions or key persons. Relation types are the various forms of collaboration and competition between ecosystem entities.

View model. The view model describes the interactive business ecosystem visualizations. The specifications of all visualizations are documented individually, such as the node size, color for specific organization category or relation type. In addition, interactive features such as hovering, clicking or zooming but also filter options are specified. Within each specification the visualization is bound to the data model to ensure up-to-date visualizations at all time.

Interactive ecosystem visualizations. The visualizations are comprised in a web-based application. They provide interactive features as suitable for the specific visualization type. The visualizations can be network layouts, treemap layouts or reports among others. The application allows the user to navigate between the visualizations provided.

6.1.5. Summary

The primary outcomes of the process are the interactive business ecosystem visualizations comprised in the web-based application. We presented a process which addresses especially the instantiation of business ecosystem modeling activities by bringing together ecosystem modeling experts setting up the application and enabling and empowering modelers to adapt the business ecosystem model.

We envision to conduct the activities three to five in short-term iterative cycles. Whenever feasible the visualizations are shared with additional management stakeholders to communicate interesting aspects about the business ecosystem. Through a continuous adaptation of both the ecosystem data and view model, changes of the business ecosystem are captured and visualized. To ensure the visualizations support business ecosystem stakeholders, their feedback for changes is significant for the successful process execution.

With the iterative cycles, we envision to provide visualizations useful for ecosystem stakeholder to act flexibly and proactively when making business ecosystem-related decisions. Insights achieved about the ecosystem inform conceptualization of adapted business strategies, thus creating new questions towards the ecosystem and motivating formulation of modified decisions or amended tasks, which in turn create new impetus to change the model, collect data, and improve or alter visualizations.

6.2. Prototypical implementation of business ecosystem visualizations in a web-based application

Considering the feedback received through the preliminary evaluation (cf. Section 5.3.3), the requirements collected and the proposed reference process as outlined previously, we conducted a second design cycle (Hevner, 2007).

This section is dedicated to the prototypical implementation of the tool-support developed within this research project. First, the knowledge management system comprising the business ecosystem data and view models is described (cf. Figure 5.1, right side). Next, the web-based application BEEx is outlined in detail including all provided views. It provides the exemplary implementation of a business ecosystem visualization tool.

6.2.1. The Hybrid Wiki approach to collaborative work, and architecture

The identified requirements to the ecosystem modeling process caused us to use an agile framework for modeling ecosystems as integrated, adaptive collaborative work system supporting the evolution of both the models and the created visualizations at run time by ecosystem experts and stakeholders, i.e. users who potentially have no programming knowledge or skills. Developing and maintaining such collaborative environments can be considered a difficult task. Research results have suggested the Hybrid Wiki approach to address this challenge (Matthes et al., 2011). The Hybrid Wiki approach has been used in different use cases and domains such as Enterprise Architecture Management (Matthes and Neubert, 2011; Buckl et al., 2009) and Collaborative Product Development (Rehm et al., 2014; Hauder et al., 2013).

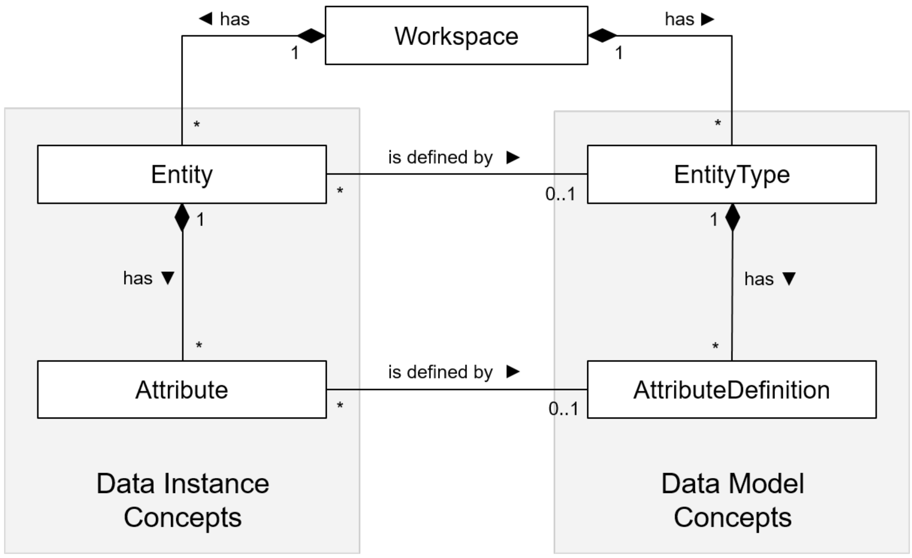


Figure 6.2.: The Hybrid Wiki meta-model (adapted from Reschenhofer (2017))

The Hybrid Wiki meta-model contains the following model building blocks: Workspace, Entity, EntityType, Attribute, and AttributeDefinition. These concepts structure the model inside a Workspace and capture its current snapshot in a data-driven process (i.e. bottom-up process). An Entity contains a collection of Attributes, and the Attributes are stored as a key-value pair. The attributes have a name and can store multiple values of different types, for example, strings or references to other Entities. The user can create an attribute at run-time to capture structured information about an Entity. An EntityType allows users to refer to a collection of similar Entities, such as organizations or persons. The EntityType consists of multiple AttributeDefinitions, which in turn contain multiple validators such as multiplicity validator, string value validator, and link value validator.

Additionally, an Attribute and its values can be associated with validators for maintaining integrity constraints. The EntityType and AttributeDefinition are loosely coupled with Entity and Attribute respectively through their name. These elements specify soft-constraints on the Entities and Attributes. The use of soft-constraints implies that the users are not restrained by strict integrity constraints while capturing information in Entities and their Attributes. Therefore, the system can store a value violating integrity constraints as defined in the current model.

The system we use rests on the Hybrid Wiki approach as discussed by Reschenhofer et al. (2016) that serves as knowledge management system application development platform and contains features for data management as well as collaboration and decision support. To create the business ecosystem model we use the Hybrid Wiki meta-model.

As presented by Reschenhofer (2017), on the top of data management and structuring concepts, the knowledge management system also provides the following relevant basic collaboration and content management features (Neubert, 2012):

Access control. The knowledge management system provides an extensive access control concept which defines which users are allowed to see and/or edit entities. For each entity the respective administrator can specify users or groups as readers, writers or administrators. The access rights can be set on the level of Workspaces and is valid for all entities within this Workspace.

Version history. The knowledge management system automatically tracks the evolution of entities within their life-cycle in form of a chronologically ordered list of changes which is referred to as version history (Büchner, 2007). The list captures contextual meta-information, e.g., the time when the change occurred or the user who implemented the change. Thereby, change of the business ecosystem model are documented.

File attachments. Users can attach an arbitrary number of files to entities. Those files are also captured by the system's access control and version history mechanisms.

Full text search with facets. The knowledge management system provides a full text search to find entities. The search results can be further filtered according to their structure.

Watching. Users can watch specific entities of their interest as the system triggers notifications in case of changes.

In this sense, the knowledge management system does not only provide useful properties regarding the iterative definition of data models, but also a variety of collaboration features. The development of the design artifact relied heavily on the described knowledge management system features. In Figure 6.3, an ecosystem entity as implemented in the prototype is depicted. The Workspace set up is called *CMEE*, i.e. Connected Mobility Ecosystem Explorer, and all EntityTypes included are listed in the left side bar. The ecosystem entity shown is the TUM LLCM project itself. For this ecosystem entity, a text provides insights about the entity as non-structured information. Below structured information in form of AttributeTypes are shown.

For the following prototypical implementation of the web-based application, a new Workspace was set up without a pre-defined structure specified.

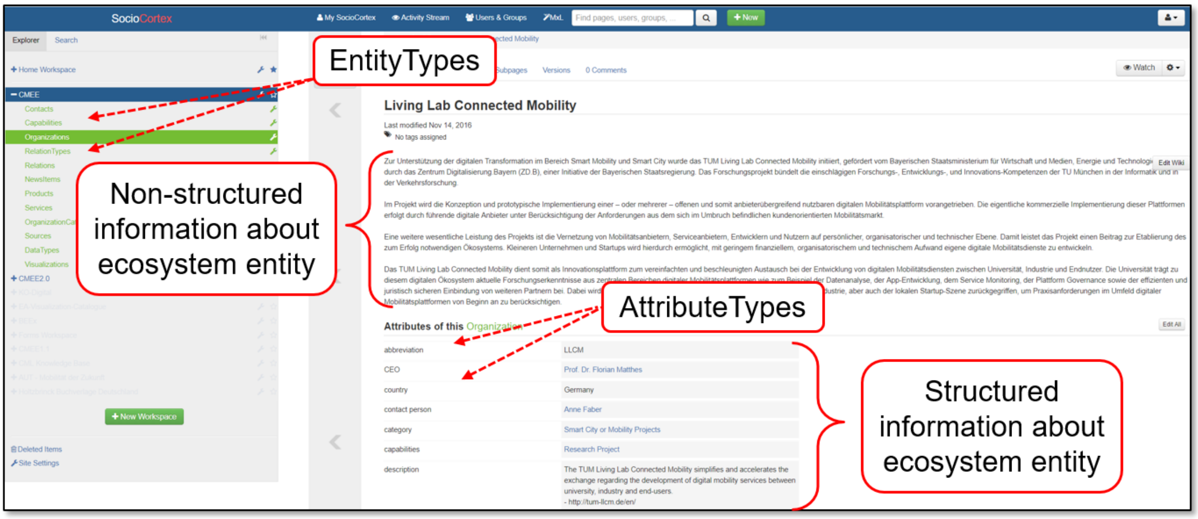


Figure 6.3.: View of an ecosystem entity in the knowledge management system displaying among others the name, non-structured information, and structured information in form of attributes

6.2.2. Business ecosystem model

The business ecosystem model we propose comprises the (a) ecosystem data model, and (b) ecosystem view model, each with respective features for creation and adaption. Both models are encoded using the Hybrid Wiki meta-model.

The ecosystem data described and visualized in the following is again the business ecosystem of the TUM LLCM project. The corresponding data model contains two entity types within the Hybrid Wiki meta-model: organizations and relations. As described in Section 5.3.1, organizations are automotive OEMs, their suppliers, public institutions, mobility-related projects, etc. The attribute types in the organization are company name, abbreviation, logo, URL, short description, headquarter, CEO, category, and legal form. The organization category is an entity type itself. Additionally, the relations describe different types of interaction between organizations, as information coming from companies web pages, newsfeed, social media, etc. Therefore, the attributes of the relation are the type of relation, e.g., cooperation, (partially) ownership, funding, etc., involved companies, the date, and the source.

Overall, the business ecosystem data comprises 52 ecosystem entities and 57 relations between these entities.

The ecosystem view model is encoded as one entity type called visualizations. Each visualization has two elements: the first element is the link between the data model and the visualizations. The second element is the specification of the visualizations, which are described using the visual encodings of the visual grammar Vega, as presented and described by Heer and Bostock (2010) and Satyanarayan et al. (2016). The Vega visualization grammar introduces a declarative language to describe visualizations in a JSON format. The main building blocks, which enable static and dynamic visualization features, are

1. data, including the data as such but also all data transformations,
2. marks, covering the basic description of the visualized symbols, e.g., shape and size of a node,
3. scales, containing visual variables, such as the color coding,
4. signals, including the different interaction options, e.g., dragging and dropping of entities, and in some instances
5. legends.

The knowledge management system provides the feature of adapting the models at runtime. An example within the business ecosystem scenario is the categorization of organizations. We categorized the ecosystem entities into automotive OEMs, map provider, mobility platforms, etc., as depicted in the background of Figure 6.4. The list shows the representation within the knowledge management system. In case a new category is added, or an existing category is changed or deleted, all visualizations using these categories, such as the treemap layout (as pictured in the front of Figure 6.4) or the chord diagram layout, are adapted at runtime as well.

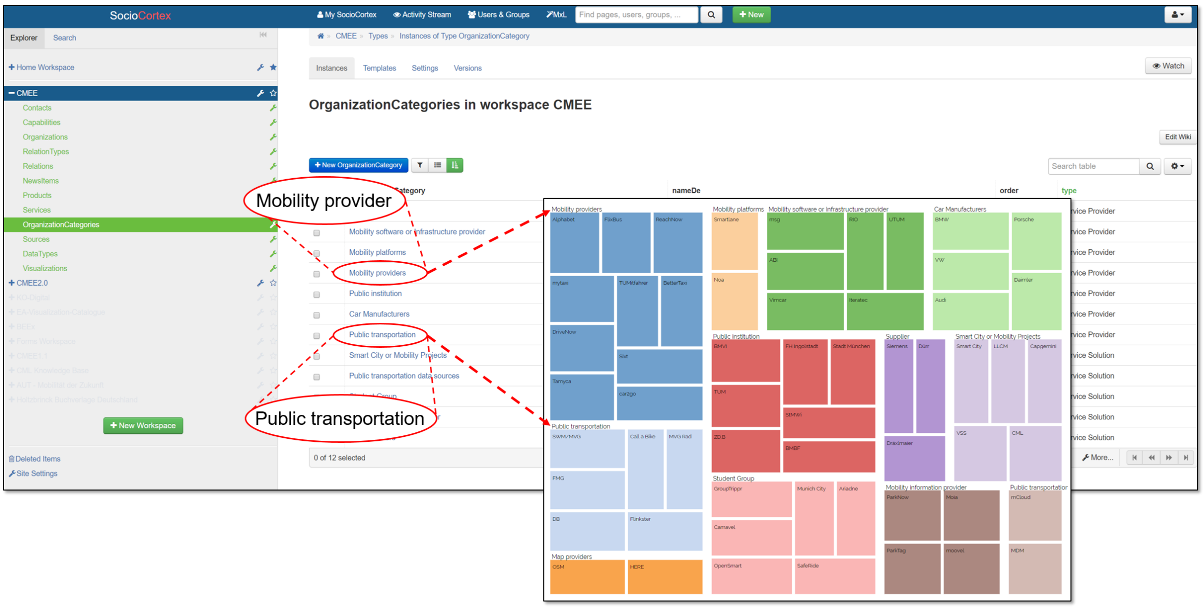


Figure 6.4.: List of organization categories in the BEEx prototype and conversion to the treemap layout (Faber et al., 2018a)

6.2.3. Web-based application for business ecosystem visualizations

The developed prototype BEEx comprises four views in addition to four visualizations as displayed in Figure 6.5: a landing page, a list view of all ecosystem entities, a view displaying details of each ecosystem entities individually, and an overview view offering all available business ecosystem visualizations.

For all views, a menu bar at the top of the page provides the option to switch to other views allowing the user to navigate through the prototype.

The landing page (see Figure 6.5a) displays the prototype name, *Business Ecosystem Explorer*, brief information about the aim of the prototype, *Discovering Insights in Business Ecosystems*, and below two links: *Explorer*, navigating the user to the additional views of the prototype, and *Modeler*, navigating the user to the knowledge management system. The landing page further describes the visual modeling approach we applied using a graphic. By scrolling down, more information about the researcher team is available.

The list view (see Figure 6.5b) presents the ecosystem entities in a table form. Each row contains one ecosystem entity displaying the entity's name. If the list is long, a scroll bar at the side allows the ecosystem stakeholder to scroll down accessing the ecosystem entities at the bottom of the list. The search bar at the top of the list allows the stakeholder to search for specific entities. The results are dynamically adapted during the search. The ecosystem entities are displayed in a random order. The list provides the interactive feature to highlight the ecosystem entity when hovering over the name as visualized in Figure 6.7a. When clicking on the entity name the user is directed to the detail view of the specific entity.

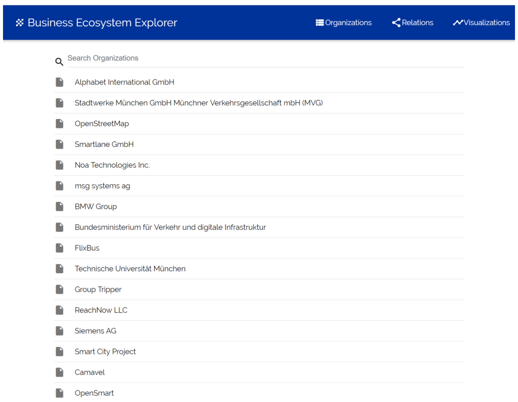
The detail view (see Figure 6.5c) depicts additional information collected for each ecosystem entity individually. This view comprises seven components:

1. in bold letters the company name including the legal abbreviation if available, such as "AG" or "GmbH",
2. underneath the name, the abbreviations as used in the visualizations are shown,
3. next to it, if available, an URL as a clickable link directing the user to a company or project website,
4. in a rounded box below, the organization category is visualized,
5. underneath the description of the ecosystem entity is displayed,
6. in the lower left box additional structured information, *attributes* are shown; for the project business ecosystem we chose the headquarter location, the Chief Executive Officer (CEO), and the legal entity type, and
7. in the lower right box all existing relations to other ecosystem entities are listed in a dynamic list.

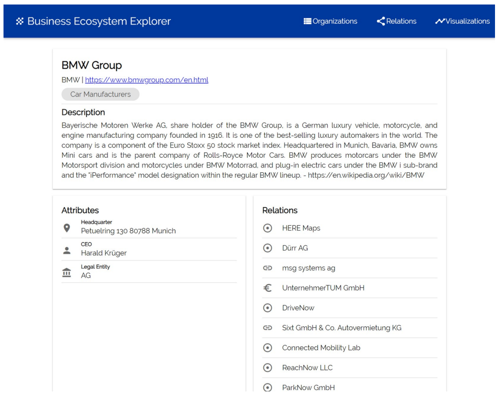
The list, *relations*, consists of the relation type icon and the name of the ecosystem entity to which a relationship exists. All entries in the list are links, enabling the user to navigate to another entity by clicking on the name.

The last view presents an overview of the available interactive business ecosystem visualizations (see Figure 6.5d). In this implementation of the prototype, four visualization layouts are provided: an adjacency matrix, a force layout, a treemap, and a chord diagram. All visualizations

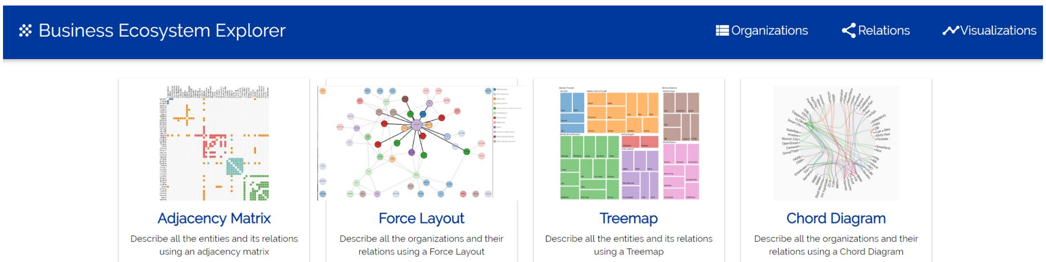
(a) Landing page



(b) List view



(c) Detail view



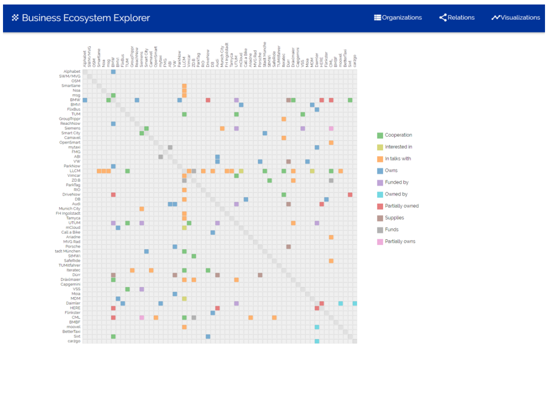
(d) Overview of visualizations

Figure 6.5.: Overview of available views of the BEEx prototype

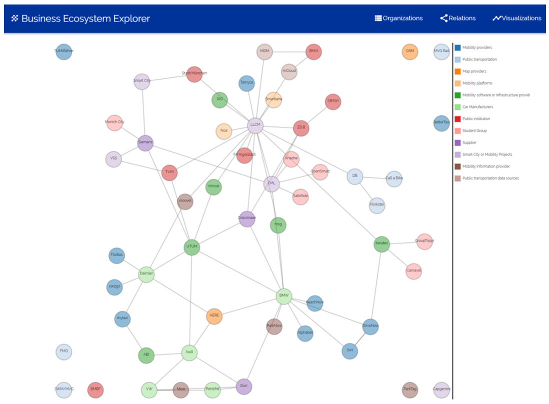
are described with an exemplary picture of the visualization, its name, and a short description of the visualization. The user can navigate to any visualization by clicking it.

6.2.3.1. Business ecosystem visualizations provided within BEEx

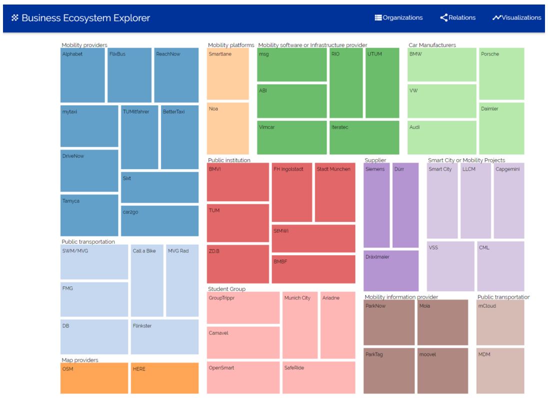
To visualize business ecosystems, we selected four visualizations as depicted in the overview in Figure 6.5d: an adjacency matrix, a force layout, a chord diagram, and a treemap. The provided visualization layouts are inspired by the system for visual analytics for supply network management by Park et al. (2016) (cf. Section 4.3.2). In the following, we describe these visualizations and their interactive features as they are implemented in BEEx.



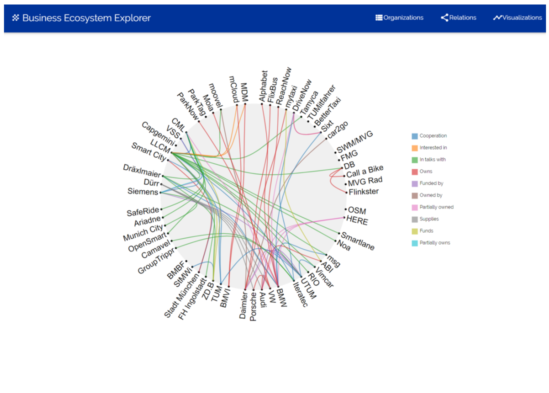
(a) Adjacency matrix



(b) Force layout



(c) Treemap



(d) Chord diagram

Figure 6.6.: Visualizations of the BEEx prototype

Adjacency matrix. An adjacency matrix is a symmetric matrix representing existing connections between entities (see Figure 6.6a). All ecosystem entities are listed in the first row and column in the same order, displaying the entities' abbreviations. In case a link between two entities exist, the according off-diagonal cell is marked. As for the business ecosystem case, the entities have no links to themselves, the cells in the diagonal are empty and greyed out.

A colored cell within the adjacency matrix indicates an existing relationship between the respective ecosystem entities. The different relation types are visualized with different colors explained in the legend on the right of the view.

The adjacency matrix offers the interactive feature of highlighting the row and column including the entities' abbreviations when hovering over a cell as shown in Figure 6.7c. The abbreviations are links leading to the detailed view of the according ecosystem entity when clicked.

The main advantage of an adjacency matrix is the easy way to find out if a relation between two entities exists (i.e. colored cell) or not (i.e. empty cell). The main disadvantage is the space required, as all possible connections are listed with mostly empty cells, leading to a sparse matrix.

Force layout. A force layout is a visualization method which purpose it is to position the nodes and the edges in an aesthetically pleasing way (Crippa et al., 2011). When visualizing business ecosystem, the ecosystem entities are nodes and relations between ecosystem entities are edges connecting these nodes. The graph is created using an algorithm calculating the positions of nodes by using multiple forces (Zabiniako, 2010). It models a graph as a physical system and tries to find a layout for the nodes and edges of the graph such that the total energy of the system is minimal (Crippa et al., 2011). Nodes with a connection are drawn closer to each other with the goal of a minimum number of crossing edges.

The ecosystem entities are visualized as nodes with the abbreviation displayed. The nodes are color-coded according to the organization category with a legend of all organization categories provided on the right side of the view.

The force layout as included in the BEEx prototype (see Figure 6.6b), provides multiple interactive features. When hovering over an ecosystem entity, a node, the according entity, and all entities with a connection are highlighted as depicted in Figure 6.7d. The same feature is available for the organization categories in the legend as shown in Figure 6.7b. When hovering over an organization category all according entities are highlights in the view. Clicking on a node directs the user to the detailed view of the respective ecosystem entity.

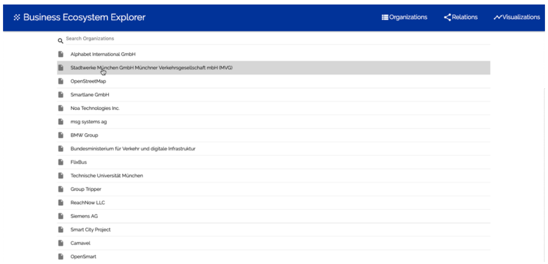
The main advantage of a force layout is its intuitive understanding of the graph, providing an easy-to-understand overall picture of the ecosystem. The main disadvantage is that force layouts produce good results for relatively small or medium-sized graphs, but they do not scale well with size (Cui and Qu, 2008).

Treemap. A treemap layout originated from visualizing hierarchical information structure (Johnson and Shneiderman, 1991) utilizing full rectangular space given as a canvas. A treemap divides a given rectangle into sub-rectangles based on the top hierarchy classification (Park et al., 2016).

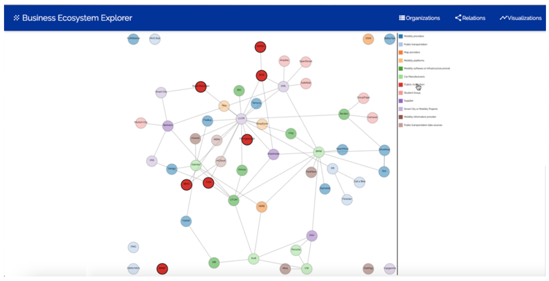
Within the BEEx prototype, ecosystem entities are grouped by the organization type and displayed in sub-rectangles representing these categories. Each ecosystem entity is represented with a rectangle displaying the abbreviation. The organization category name is shown left above the according sub-rectangle. The treemap as implemented within BEEx is visualized in Figure 6.6c.

The treemap provides the interactive feature of highlighting an ecosystem rectangle when hovering over it (see Figure 6.7e). By clicking on the rectangle, the user is directed to the detailed view of the ecosystem entity.

The main advantage of the treemap is the canvas filling appearance and its easy way to indicate the number of ecosystem entities within one organization category. Its main disadvantage is the missing representation of the relations between entities as they are not considered in this visualization.

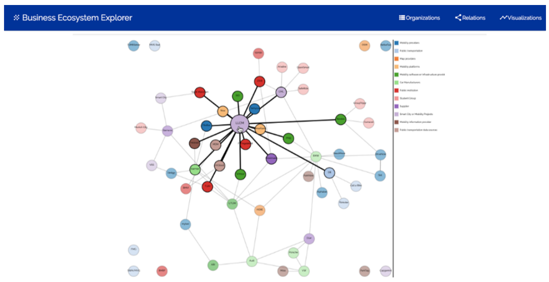


(a) List view with highlighted entity

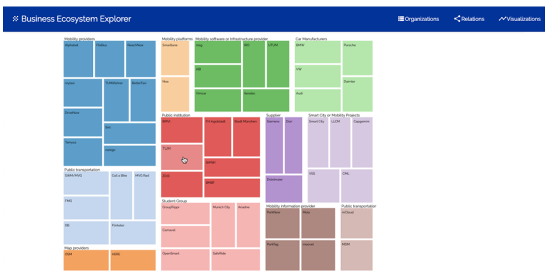


(b) Force layout with highlighted organization category

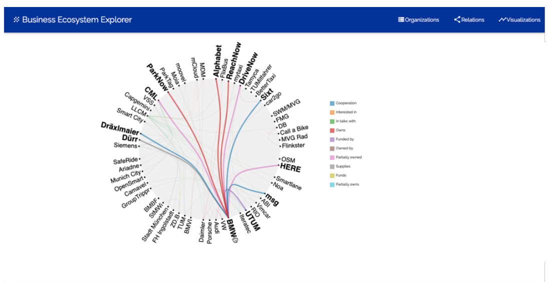
(c) Adjacency matrix with highlighted cell



(d) Force layout with highlighted organization entity



(e) Treemap with highlighted entity



(f) Chord diagram with highlighted entity

Figure 6.7.: Interactive Features of the visualizations of the BEEx prototype

Chord diagram. A chord diagram displays the entities on the circumference of a large circle. The critical aspects of the chord diagram that depart from the generic circular layout are that nodes are depicted as arcs around the encompassing circumference and edges are drawn as filled Bézier curves among arcs (Park et al., 2016).

The ecosystem entities are grouped in their respective organization category displaying the abbreviation as depicted in Figure 6.6d. The relations between ecosystem entities are shown as curved lines within the circle connecting the entities colored according to the relation type. The color code for the relation types is explained in a legend on the right side of the view.

The chord diagram provides the interactive feature of highlighting all relations and connected entities when hovering over an ecosystem entity (see Figure 6.7f). When clicking on the abbreviation, the user is directed to the detail view.

The main advantage of the chord diagram is the easy identification of relation type dominating the visualized business ecosystem. The main disadvantage is that the restricted space around the circle limits the number of entities displayable.

6.3. Use cases for a tool-supported business ecosystem modeling and visualizing approach

For the application of the tool-supported process, we envision two use cases as the process is adaptable to different types of teams and communities (Faber et al., 2018a). On the one hand, enterprise internal working groups can constitute the stakeholders of an ecosystem modeling initiative as described in the previous section. On the other hand, a public ecosystem model and the provision of interactive visualizations can be conceived that serves both the public and policymakers. In the following, we present these two use cases in more detail as we applied both within our evaluation.

6.3.1. Firm-internal usage of a tool-supported process for business ecosystem modeling and visualizing

As a more obvious application scenario, the framework can be applied within an organization to model and visualize the business ecosystem of interest. All roles are filled with employees and eventually external consultants supporting the process execution. The visualizations are tailored to management stakeholders and exclusively available within the organization.

In case the business ecosystem has been modeled previous to the implementation of the tool-supported process, the already collected ecosystem information is used as a starting point and continuously enriched by the iterative data collection process step.

The business ecosystem to be analyzed is not limited to the company's ecosystem but can also be the ecosystem around a technology depending on the company representatives' main concern.

One advantage of the company's internal ecosystem modeling is the quality of the data. Only employees of the modeling organization contribute with ecosystem information. If the data sources are carefully selected and employees are encouraged to provide accurate data, a higher quality of the information can be assumed in comparison to the public provision. A disadvantage for this application field is the missing inclusion of further ecosystem participants in the modeling process. There is a danger that a one-sided picture of the ecosystem will be created because additional perspectives are missing or only insufficiently covered. This is particularly the case if a business ecosystem of a market or technology is to be modeled.

Another advantage is that employees may be more easily motivated to share their ecosystem-specific knowledge. Since the visualizations are only accessible to employees, there is no risk of sensitive information being lost or made accessible to a competitor.

We evaluated the proposed tool-supported process in two case studies with two organizations. The results will be presented in the following chapter.

6.3.2. Publicly accessible tool usage for business ecosystem modeling and visualizing

For the motivation and explanation of this use case of providing the business ecosystem visualizations publicly and eventually including the crowd into the modeling efforts, we will use the mobility case as presented previously (cf. Section 3.1).

As described already earlier, understanding the evolution of such mobility business ecosystems is instrumental for developing public policies, making strategic decisions about business and technology partnerships, or identifying gaps in the services provided to citizens and businesses as service customers (Basole et al., 2012b). Hence, the proactive management of the business ecosystem is gaining relevance for all ecosystem entities, ranging from firms to city authorities.

As we already pointed out, analyzing business ecosystems is generally impossible for one single stakeholder to achieve because of the abundance and complexity of processes and data that would need to be observed, recorded, documented or otherwise be made visible. For the analysis of a specific market or technology, this could be addressed by providing business ecosystem visualizations as incentives for the ecosystem participants to contribute to the modeling process with their ecosystem knowledge. The ecosystem data would be enriched with data collected in a crowdsourcing manner resulting in the inclusion of various perspectives.

Such a modeling approach involves challenges. First, if it is possible for any interested user to enter data, ensuring data quality is one major challenge which needs to be addressed. Second, visualizations must be provided as a starting point for the crowdsourcing activities to serve as an incentive. Third, identifying individuals executing the roles as described earlier have to be done crossing organization borders.

For the case of modeling and visualizing the mobility business ecosystem for the Munich region, we executed the initial collection of ecosystem data identifying, assessing, and using Internet data sources and creating business ecosystem visualizations (see Section 7.4).

For the three teams we identified for the modeling process, we propose the following as presented by Faber et al. (2018d): A mobility ecosystem editorial team, which is firmly connected to the tool-support, is financially supported by a public organization interested in supporting the business ecosystem in focus. The ecosystem editorial team develops, maintains, and markets the tool-support for both public and private (for-profit) ecosystem visualizations, and eventually provides consulting services towards ecosystem members or policy recommendations towards city authorities. Therefore, the team gathers requirements and feedback of the other groups to deliver target visualizations. This group is also responsible for collecting publicly available data to be used as a data sources to be visualized taking over the responsibilities of the modeler team. In the case of a data collection by the crowd, i.e. the crowd acting as a modeler, the ecosystem editorial team is responsible for the quality of the data and must ensure that the maintained and visualized ecosystem information is accurate. The public organization funding the initiative acts as a gatekeeper.

The potential management stakeholders consuming the mobility business ecosystem visualizations could be smart city online communities, i.e. consumer-based focus groups as users of mobility services, provide for a 'crowd-type' community that might be driven by interest in customization of services, environment or resource efficiency. For this type of group, visualizations can support identifying regional coverage of offered services or uncovered service demands. Additional data analysis techniques potentially allow quantifying citizen requests for better service coverage and stimulating innovation.

6.4. Summary

In this chapter, we described the two main components of the design artifact developed in this thesis. It results presented address the first phase, *building*, of the design science research (Hevner et al., 2004). The chapter is divided into three parts:

1. the iterative process addressing the collaboration aspects of business ecosystem modeling,
2. the implementation of the concept developed in the previous chapter, and
3. potential use cases we identified through early interactions with ecosystem stakeholders.

First, the process to collaboratively model and visualize was presented including the description of the five phases and six activities, the roles involved in the different activities, and the artifacts created and used. The process is based on two processes we identified in scientific literature and is conducted iteratively. Thus, continuously business ecosystem information is collected capturing the changes of the business ecosystem, tailored visualizations are provided, and feedback is collected to adapt the business ecosystem model, the data sources in use and the visualization layouts. The roles described are taken from group modeling and adapted to business ecosystem-related activities. We identified three groups of actors, the ecosystem editorial team, providing the visualizations, the modeler team, collecting the business ecosystem information, collecting feedback, and adapting the model, and management stakeholder, using the visualization for their ecosystem-related tasks and providing feedback about the current usefulness of the visualized data and visualizations.

Second, the prototypical implementation of the tool-support concept presented in Chapter 5 is described. First, the knowledge management system and its features, which is used as a modeling environment, is presented. This is followed by the implementation of the BEEx prototype, a web-based application comprising of four views and four business ecosystem visualizations. All views including the navigation and provided features are discussed and illustrated with figures.

Finally, two use cases for a tool-supported collaborative modeling and visualizing process are described: the firm-internal use case, in which the visualization are only accessible for employees and only employees (or dedicated consultants) are involved in the modeling process, and the publicly accessible tool to model and visualize the business ecosystem of a specific market or technology. Both cases were identified within the discussion rounds.

CHAPTER 7

Evaluation

7.1. Evaluation approach

The two complementary aspects in the center of design science research are *building* and *evaluating* artifacts designed to meet the identified business need (Hevner et al., 2004). In the previous chapters, we elaborated on how we built the tool-supported process to collaboratively model and visualize business ecosystems. The framework presents our design artifact. It incorporates the results of the preliminary evaluation of the initial prototype serving as a minimum valuable product.

This chapter addresses the evaluation of the design artifact as second design science aspect. We conducted multiple kinds of evaluation aiming at a demonstration of the usefulness of the design artifact. We envision to provide insights for the next design process iteration which we propose as future work refining the design artifact further.

A variety of evaluation approaches exist in design-science research. Hevner et al. (2004) describe five design evaluation methods:

1. *observational*, in case and field studies,
2. *analytical*, through static analysis, architecture analysis, optimization, and dynamic analysis,
3. *experimental*, with a controlled experiment or a simulation,
4. *testing*, as functional (black box) or structural (white box) testing, and
5. *descriptive*, in form of an informed argument or scenarios.

For the evaluation of our design artifact, we selected the observational and experimental design evaluation method. We conducted two case studies and a series of interviews, to study the artifact in depth in business environments (Hevner et al., 2004). We followed the case study design as presented by Yin (2014) and discuss the results of both case studies in Section 7.2 and the results of the interview series in Section 7.3. The highlights of the two case studies including the lessons learned were presented by Faber et al. (2018b). We applied the artifact to model and visualize the Munich smart city mobility business ecosystem using Internet data sources and eventually providing the visualizations publicly. The results of this evaluation are described in Section 7.4 as presented by Faber et al. (2018d). The three evaluation methods are visualized in Figure 7.1.

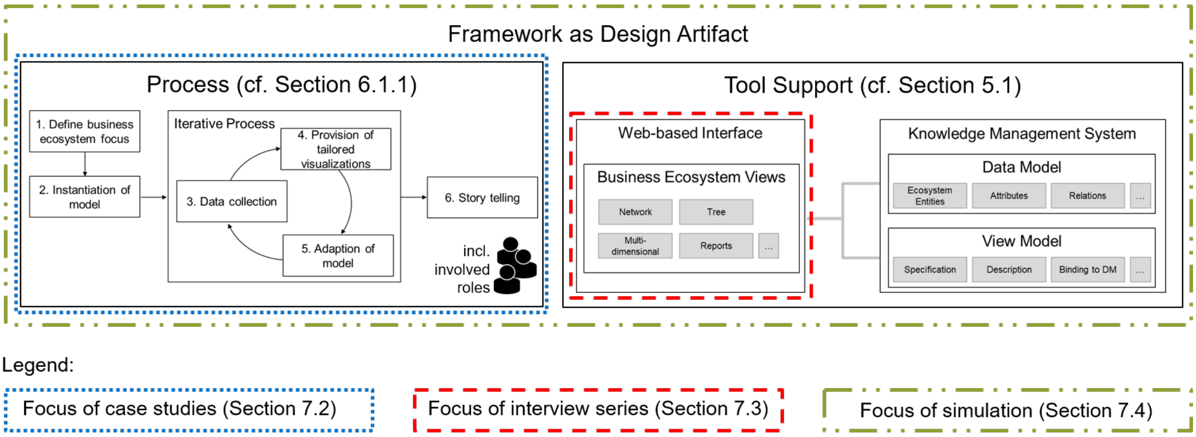


Figure 7.1.: The three evaluation methods a presented in this chapter

7.2. Evaluation of the tool-supported process in two practical environments

Conducting case studies allows researchers to obtain an in-depth appreciation of the application of a design artifact – in our case the tool-supported collaborative modeling process to visualize business ecosystems – in a real-life context (Runeson and Höst, 2009; Crowe et al., 2011). Thus, to evaluate our design artifact in practical environments, we carried out two case studies. Both studies address the first use case as described in Section 6.3.1: firm-internal business ecosystem modeling and visualizing.

For both studies, the results are described without giving detailed information about the ecosystem entities, relations or categories. Pictures included in this section have been modified by us to meet the anonymization requirements of the case study partners.

7.2.1. Case study design and setting

For the set up of the case studies, we draw on steps for a multiple-case studies design as suggested by Yin (2014) and performed our study in seven subsequent steps as illustrated in Figure 7.2. In this section, we justify the design of our study and describe how it was realized.

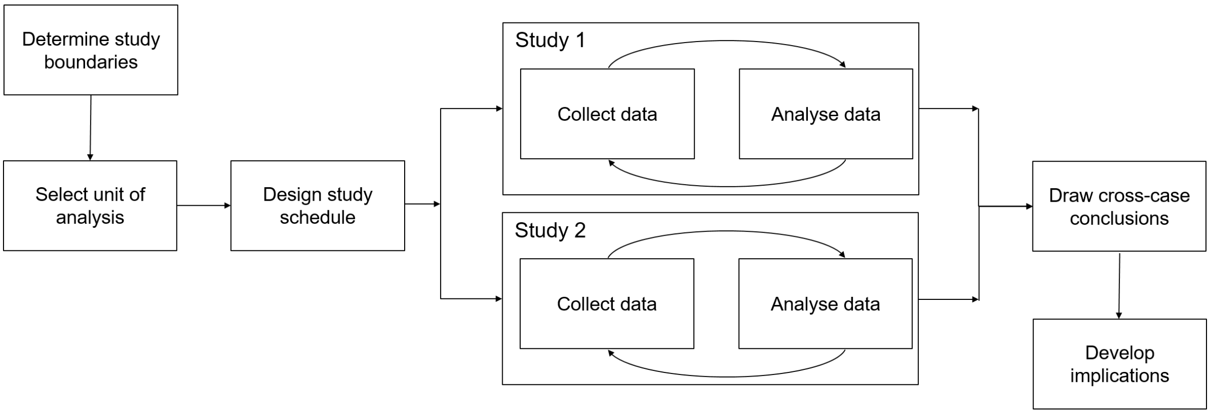


Figure 7.2.: Multiple-case studies design steps (adapted from Yin (2014))

Determine study boundaries. The aim of conducting the studies was to evaluate the process as presented in Section 6.1 including the associated roles. In addition, an instantiation of the tool-support, which includes the web-based application with visualizations tailored to the study participants' needs and the knowledge management system (cf. Section 6.2) should be provided to the study partner organizations. Thus, we wanted to apply and observe our artifact in practical environments to evaluate its usefulness. Since we wanted to observe not only the process but also the instantiation of the prototype, we searched for study participants with no comparable tool already in use.

Select unit of analysis. We identified two independent organizations, both with no business ecosystem model in place and interested in analyzing a specific ecosystem through visualizations as case study partners. The first organization is an automotive company, headquartered in Europe with approximately 120,000 employees. The second organization is a publishing company, headquartered in Europe with about 16,000 employees.

We identified the first organization as a suitable unit of analysis through previous interactions with respective representatives, who already participated in the interview rounds of the preliminary prototype. The second organization was identified through a cooperative research project funded by the German Federal Ministry of Education and Research (BMBF).

The automotive company defined the smart city mobility business ecosystem around innovative mobility services as their business ecosystem of interest. The publishing company determined their own company's business ecosystem including (potential) business partners, competitors, and interesting start-ups as study focus with an emphasis on publishing-related IT services and key stakeholders relevant to their business.

Design study schedule. Before the studies were started, meetings were held with the company representatives to present the prototype as described in the previous chapter. In these meetings, the business ecosystem focus for both studies was defined. Afterward, a dedicated workshop to explain the tool-support – knowledge management system plus web-based application – was conducted with each study partner, explaining the concept of business ecosystem data and view models and the adaption of both in run-time.

After the studies started, several workshops were conducted in the period from December 2017 to August 2018. For both studies, discussions about the general study schedule (begin and end) happened before the study period, whereas the workshops and meetings with the study participants were scheduled on an ad-hoc basis.

Data collection. We used a "mixed methods" approach to collect data following Benbasat et al. (1987). Data on the course of study was collected through

1. documentation,
2. archival records, and
3. direct observation.

At the beginning of the studies, a dedicated Workspace within the knowledge management system was set up for both organizations. The Workspaces were used by the company representatives involved in the studies to model their business ecosystem in focus, and each study participant received a dedicated user identity. Due to the versioning feature of the knowledge management system, the systems documents changes and thus allowed us to observe the activities of all involved study participants during the entire study period. In case of changes of the models in between workshops, these were transparent to us.

Both companies provided us access to existing company material related to the selected business ecosystem, which contributed to a shared understanding of the ecosystem. In later stages of the studies, this material was used as data source.

Within both studies, we conducted several workshops with the study participants with a high degree of interaction and made direct observations of the study process. Each workshop was documented in the form of a report.

Data analysis. The collected data on the study implementation was evaluated regarding the process effectiveness and instantiation of the tool-support. To assess the iterative phase of the process, which aims at capturing the evolution characteristics of the business ecosystem modeled, we analyzed how the ecosystem data model and ecosystem view model were instantiated and how they evolved following. In addition, we investigated the participation according to respective roles the study participants occupied compared to the roles we defined previously. Finally, the visualizations provided within the web-based application instantiation have been evaluated.

To achieve this, the direct observation records and the models created or adapted within each session were examined right after the meetings. All other documentation was analyzed at regular intervals. For both studies, final workshops with a larger group of stakeholders – including for both the respective gatekeeper – were conducted in which the status-quo of the created business ecosystem model and also resulting visualization were used to 'tell a story' about the business ecosystems. We used these last workshops as indicators of how the study participants perceived the study and the results obtained.

The final two study process activities (see Figure 7.2) are included in dedicated subsections at the end of this section: cross-contextual conclusion (see Section 7.2.4) and implications development (see Section 7.2.5).

As our focus was on the initiation of the tool-supported process, the iteration of process activities three to five of collecting data, providing visualizations, and adapting the model according to collected feedback (cf. Figure 6.1) were only conducted a limited number of times for both studies.

7.2.2. Study I: Modeling and visualizing an innovation mobility business ecosystem at a large automotive company

The study in cooperation with an automotive company was conducted over a time span of five months (December 2017 to April 2018). Throughout the entire study, overall five representatives were involved, whereby two of these five representatives were active in the modeling workshops. The three additional stakeholders were included in major decisions and the closing workshop. The study consisted of eleven workshops each lasting between 60 and 120 minutes. All workshops happened on the enterprise premise using laptops, a whiteboard, and pen and paper.

Business ecosystem in focus

The definition of the business ecosystem focus was set before the first modeling workshop. Purpose of this study was to model and visualize the smart city business ecosystem of innovative mobility services. Applying the process should contribute to a better understanding of

- which cities are providing innovative mobility services within their mobility service landscape,
- which service might be interesting for a city to offer which currently allocates fewer mobility services,
- which service provider offers which mobility services,
- how well is each service provider interconnected with which city,
- which mobility related projects are carried out in which cities, and
- which organizations are project participants.

Before the study was conducted, the business ecosystem was superficially analyzed by the organization's representatives. Information about the business ecosystem was collected by several stakeholders and documented in an unstructured form. The information was not processed any further, tracking about who included which information and who accessed it in a later stage was not conducted, and no visualizations were used to further analyze the collected information.

Course of the study

Within the first three modeling sessions (December 2017 and January 2018), the initial ecosystem data model was created. As the knowledge management system provides the feature of supporting the evolution of models, the data model was continuously updated and adapted during the study execution.

In the following two months, two company representatives implemented the already within the company collected data in the system and enriched it with additional ecosystem information. They used company external data sources such as newspaper articles, news feeds, and free of charge online databases. The data collection process step was carried out manually by the two enterprise representatives and not supported by us. During this phase, four modeling workshops were conducted within which we answered questions about the usage of the knowledge management system. Besides, inconsistencies of the models were addressed and solved.

Simultaneously, in three workshops in February and March, the ecosystem view model was created and the initial visualization types defined: three force layout views. In a dedicated workshop, the building blocks (marks, scales, and signals) of each visualization were defined using pen, paper, and whiteboards. After creating the view model, we created the web-based application incorporating the tailored views. The tool was presented and discussed in the following workshops end of March. After collecting the feedback, the visualizations were adapted and further discussed in two workshops in April.

The closing workshop happened at the end of April. Besides the gatekeeper, the two modelers, and us, two additional enterprise stakeholders participated. The results of the previous modeling workshops were presented, and feedback regarding the view model was incorporated immediately.

Business ecosystem data and view model

The knowledge management system was used to implement the business ecosystem data and view models. After the first data model creation workshop, the data model consisted of six EntityTypes and eight AttributeDefinitions. In the following session, the data model grew to ultimately eight EntityTypes and 26 AttributeDefinitions, a more significant increase on the attribute level than on the entity level.

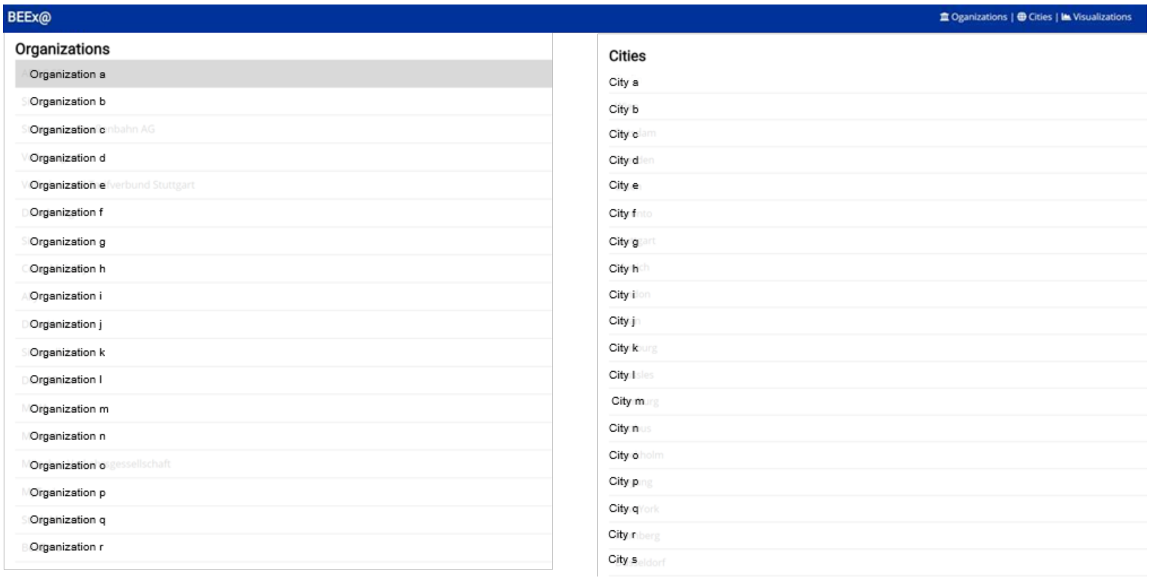
Cities, organizations (e.g., services providers such as automotive OEMs), mobility services, mobility related projects but also key stakeholder were modeled as ecosystem entities. Of special interest were mobility service providers offering car, bike or ride sharing services.

The ecosystem view model consisted of the three force layouts aligned upon during the workshops. For all three visualizations, the view model comprised the connection to the underlying ecosystem data and the specification. The view model was changed only on two occasions: first, during the study, to introduce hexagons as nodes, and second, during the closing workshop, implementing color coded relations to differentiate between various relation types.

Web-based application provided in the first study

The tool created within the study is similar to the BEEx prototype. In addition to the three visualizations as depicted in Figure 7.3, the web-based application comprises five views: a landing page, two list views, a view displaying details of all organizations and cities individually, and a view displaying the three available business ecosystem visualizations. For all views, a menu bar at the top of the page provides the option to navigate through the tool.

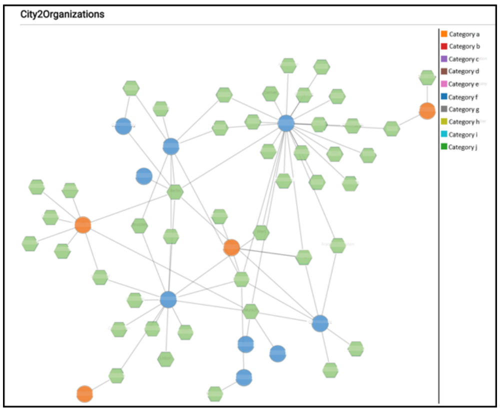
(a) Landing page



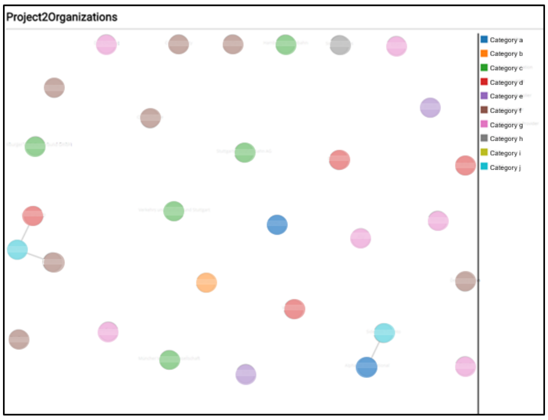
(b) List views

(c) Overview of visualizations

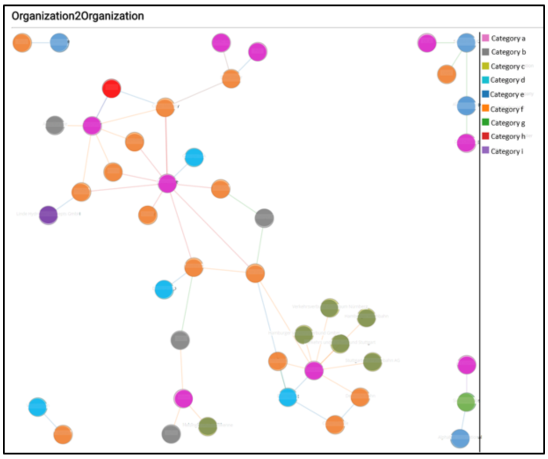
Figure 7.3.: Overview of available views of the tool-support provided for the automotive company



(a) Force layout visualization displaying cities and organizations and their relations: cities as hexagons and organization as circles



(b) Force layout visualization displaying projects, organizations, and their relations



(c) Force layout visualization displaying organizations and their relations

Figure 7.4.: Overview of available business ecosystem visualizations within the automotive company case study

The landing page (see Figure 7.3a) displays the prototype name, *BEEx@Company name*, a brief information about the business ecosystem in focus, *Discovering Insights in Mobility Projects*, and below three links: *Organizations*, navigating the user to the organization list view, *Cities*, navigating the user to the city list view, and *Visualizations*, navigating the user to the overview of available business ecosystem visualizations.

The two list views (see Figure 7.3b) present all organizations or cities in two separated table forms. When hovering over an ecosystem entity, the entity is highlighted. With a click on an entity, i.e. organization or city, the user is directed to the associated detail view.

The detail view looks similar to the detail view of the BEEx prototype. The organization/city name is displayed with a URL and a short description. Additional information is presented in boxes underneath, such as a list of cities in which an organization provides its mobility services, or projects an organization is actively participating in. Due to the necessary anonymization, this view is not displayed.

The last view (see Figure 7.3c) lists the three available business ecosystem visualizations. For all three visualizations, the study participants defined the view model including the specifications of the force layouts. The first visualization, *City2Organization* as depicted in Figure 7.4a, shows the network of cities and organizations addressing the first two points of interest for the business ecosystem modeling (i.e. which cities are providing innovative mobility services within their mobility service landscape, and which service might be interesting to offer for a city currently allocating fewer mobility services). The visualization was specified to display cities as hexagons and organizations as circles. For the second visualization, *Project2Organization* as displayed in Figure 7.4b, the network of projects and organizations is shown not differentiating the type of the nodes for projects and organizations. In the third force layout, *Organization2Organization* as visualized in Figure 7.4c, organizations and their relations are displayed. In this visualization, the relations are color-coded as well, a request by one company representative stated in the closing session, whereby a corresponding legend was not implemented in this session. For all three force layouts, the organization category is displayed using color-coded nodes as explained in the legends on the right sides of each visualization. All three visualizations provide interactive features. Clicking on a specific node directs the user to the respective detail view.

The instantiation of the web-based application with interactive business ecosystem visualizations and the modeling environment were provided to the participating organization for later use. The modeling environment of the knowledge management system was not accessible through the web-based application, as required by the practitioners. They aimed to strictly separate the business ecosystem visualizations from the knowledge management system. They envisioned a small team collaborating on the actual modeling and a broader group of company representatives to access the tool-support only consuming the visualizations and eventually providing feedback about necessary changes to the business ecosystem model.

Study particularities

The collected ecosystem data is lacking relations for the visualizations of the organization network and even more for the project-organization network. The study participants noticed the lacking ecosystem data during the modeling workshops but even though the visualizations promised to deliver insights about the business ecosystem, the necessary ecosystem data was unavailable during the study frame.

Through further iterations of the modeling process, additional data sources should be evaluated regarding the availability of this specific business ecosystem information. If this kind of information remains unavailable, the according visualizations might no longer attract attention and be removed from or replace within the tool.

7.2.3. Study II: Modeling and visualizing a company's business ecosystem

The second study was conducted with a publishing company. The study took place over seven months (February to August 2018). Overall, seven enterprise representatives participated in the study, with a core team of two study participants. Overall, ten workshops each lasting between 90 and 120 minutes were conducted, whereby nine workshops took place on the enterprise premise using laptops, a whiteboard, and pen and paper. One workshop was executed using a video conference system.

Business ecosystem in focus

Within the first workshop in February, the focus of the business ecosystem was defined as the company's business ecosystem. With the modeling and visualization of the ecosystem, a better understanding of

- which publishing related IT services are provided to which publisher,
- which other IT related services are consumed by these publishers,
- which key persons of the German publishing market work for which publisher, and
- which past or future roles these key persons have or will hold.

Before the study was conducted, the business ecosystem in focus was not analyzed according to the above issues. Information was not collected and therefore also not visualized in the way provided through the developed application.

Course of the study

In the first workshop, past activities as described above and relevant additional stakeholders to involve were discussed.

In the next two workshops, the ecosystem data model was defined, whereby the second workshop focused on enriching the model through the implementation of attribute definitions.

During a workshop in April, the ecosystem view model including the visualization building blocks were initially determined. The study participants chose two force layout visualizations: one for the service landscape and the other for the key person network.

At the beginning of May, the instantiation of the web-based application including these two visualizations was provided by us using the data implemented in the knowledge management system. Company internal data sources and news articles were used to collect relevant business ecosystem information. The data was entered mostly during the workshop sessions.

In the following workshops, in which the prototype was demonstrated each time, the business ecosystem model was iteratively adapted. Therefore, five additional company representatives were included in two workshops in May to discuss the usefulness of the prototype and to provide feedback. Two more workshops took place in July adapting the business ecosystem model further together with the study participants.

The final workshop was held in August. Besides the core team, three additional company representatives participated who were involved previously. The study results and potential next steps were discussed.

Business ecosystem data and view models

Similar to the first study, the knowledge management system was used to implement both the ecosystem data and view models. After the first data model creation workshop, three EntityTypes with seven AttributeDefinitions were defined. At the end of the study, the final data model consisted of nine EntityTypes. These EntityTypes included 24 AttributeDefinitions.

The ecosystem data model evolved during the modeling process, especially on the attribute level and during the initial phase of the project. For the data model, ecosystem entities such as key persons, publishers, and publishing groups were identified, including relation types such as the role of the person within the ecosystem and type of service. After the tool was provided, the data model on the entity level stayed the same.

The ecosystem view model consisted of the two entities defining the visualizations displayed in Figure 7.7. After the view model was aligned upon, only one specification changed: the relation type *Berichtswesen* was adapted as it is a directed relation. This relation type is not displayed as a straight line connecting two ecosystem entities but through an arrow. Both visualizations are force layouts targeting to tell different stories about the company's business ecosystem.

Web-based application provided to model and visualize the business ecosystem of a publishing company

Besides the two visualizations, the application comprises only one view: the landing page as visualized in Figure 7.5 displaying the prototype name, *BEEx@Company name*, brief information about the prototype purpose, *Discovering Insights in Business Ecosystems*, and below three links: *Personennetzwerk*, navigating the user to the visualization of the person network, *Service Landschaft*, navigating the user to the visualization of services provided within the business ecosystem, and *Modeler*, navigating the user to the knowledge management system with the dedicated Workspace for this study (see Figure 7.6).

In the first visualization (see Figure 7.7a), key individuals of the publishing area in Germany are

Figure 7.5.: Landing page of the prototype developed for the publishing company

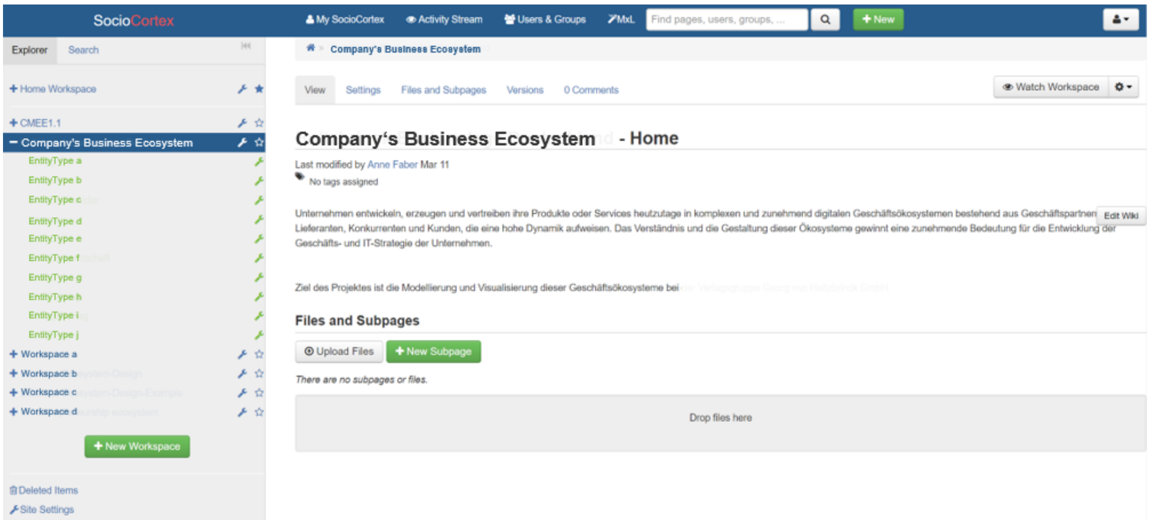
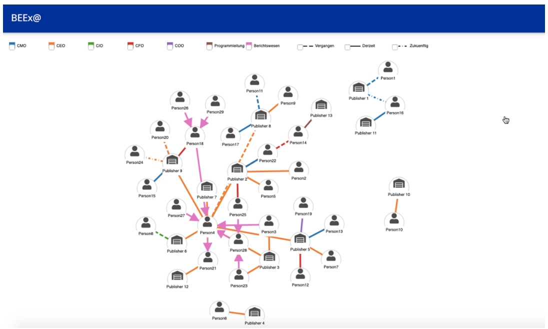


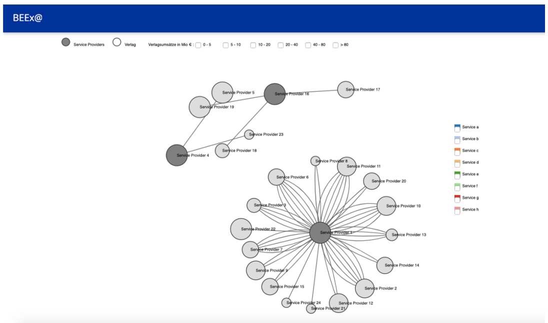
Figure 7.6.: Modeling environment within the knowledge management system for the publishing company

visualized with their professional relations to publishers. The links are color-coded according to the roles occupied by identified key stakeholders of the ecosystem. The color-coding is explained in the legend in the top left corner. In addition, the structure of the relations provides insight if the role is executed currently, has been performed in the past or will be performed in future. The legend of the structure is located in the top right corner. Both legends provide filter options to select a specific role of interest, like CEO, or status of employment, like current. When clicking on any entity, the user is directed to the knowledge management system and the according page of the respective entity in the Workspace.

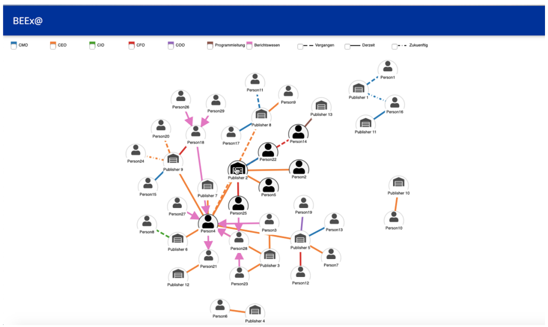
The first visualization (see Figure 7.7b) displays publishing-related IT services provided within the industry. Dark grey nodes display service providers and lighter nodes publishers. The services provided are listed in the legend on the right. The visualization offers the interactive feature of showing the color-coded relations when hovering over any node. The node size of the publishing companies is according to their last years business turnover as explained in the legend in the top right corner, whereas the size of the service providers is fixed. Again, both the turnover and the provided service legend provide filter option to select only publishers with a



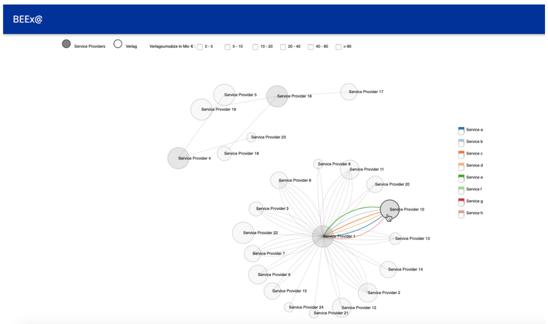
(a) Force layout visualization of key stakeholders working for publishing companies in Germany: relations are color coded according to the role executed



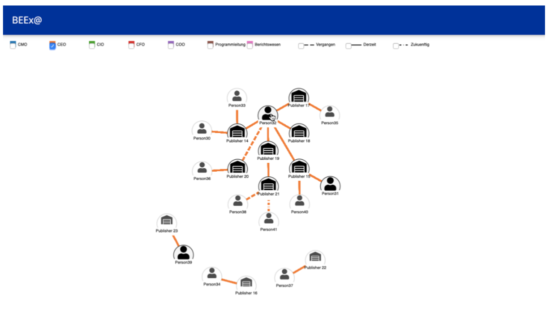
(b) Force layout displaying service providers active in the publishing business area and publishing companies consuming these services



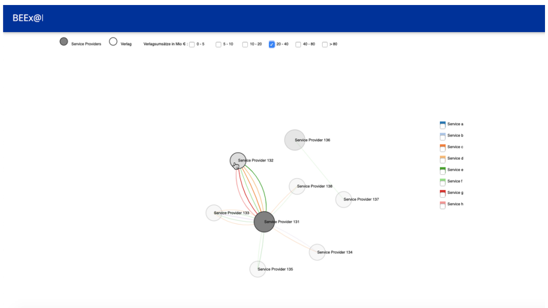
(c) Force layout with highlighted key stakeholders and publishing companies



(d) Force layout with colored service relations



(e) Force layout with applied role filter



(f) Force layout with applied turnover filter and colored service relations

Figure 7.7.: Overview of available business ecosystem visualizations and their interactive features within the publishing company case study

specific turnover or display only chosen services. When clicking on any node, the user is directed to the respective page of the entity in the knowledge management system.

Study particularities

Similar to the first study, the instantiation of the web-based application with interactive business ecosystem visualizations and the modeling environment were provided to the participating organization for later use.

In this study, the knowledge management system was linked in the instantiation of the application. The study participants aimed to enable a broader group of company representatives to work in the modeling environment. That is why some of the visualizations provided in the initial prototype as discussed in the previous chapter were not provided. The focus was not purely on the visualizations but the knowledge management of ecosystem-related information.

The visualizations provide somewhat independent aspects of the business ecosystem in focus, and navigation between these visualizations was not implemented. Especially the collection of IT services provided by competitors was perceived as burdensome by the study participants. Compared to the first study, the study participants of the publishing company contributed less between the workshops.

7.2.4. Cross-case conclusions: findings and lessons learned

Even though in both studies different topics and ecosystem models have been instantiated, we can draw some cross-case conclusions. Following Patton (2001) who defined lessons learned as the knowledge which is derived from the screening of a situation and which can be applied in similar cases in the future, we will present our findings and lessons learned of both studies.

Availability of ecosystem information. For both studies the collection of ecosystem information turned out to be more challenging than expected by the study participants. Especially in the first study with the automotive company, a reason why the force layout visualization for organizations and their involvement in projects was rather neglected and the focus oriented towards the other two visualizations. The challenge of the data collection related to business ecosystem information is not new (Basole et al., 2015). A possible solution could be to use Internet data sources as an initial starting point for ecosystem modeling as we present in Section 7.4. Providing a visualization can guide ecosystem stakeholders towards ecosystem information which is currently insufficient or completely missing.

Evolution of the data model. We noticed for both case studies, that the data model evolved rather on the AttributeType Level than on the EntityType Level. That means, the entities visualized remained nearly untouched whereby for all entities the attributes changed during the modeling process. This could be due to the user being accustomed to the provided visualization and thus is less willing to change it. A change of the attribute, which might also include adding or deleting an attribute, does not lead to changes of the force layout view. Furthermore, as the attributes can be defined as mandatory attributes or not, the user is free in adding attributes for specific entities that are not available for others.

Another possible reason is that for the study participants the entities were easier to identify than the relevant attributes.

Expertise of modeling participants. Comparing both studies we noticed that the existing modeling knowledge of the workshop participants has a significant influence on the achieved results. The modelers involved in the first study were less experienced with modeling activities. One consequence was more time spent on the ecosystem data and view model creation and thus receiving the implemented interactive visualizations at a later point within the study time frame. To address this, an additional workshop before the actual study period focusing on how to create a model is recommended. Our pre-study workshop solely concentrated on explaining the tool-support and the data and view models in use (cf. Section 6.2) but not on analyzing the study participants prior modeling experience.

Maintaining motivation during the modeling process. Especially in the first study we noticed a decrease in motivation during the data and view model creation phase. As described above, the study participants – including the facilitator – were unfamiliar with modeling activities. Thus, reaching the fourth process activity, i.e. provision of tailored visualizations, took longer than expected by the company representatives. As the expected outcome of the study was an instance of the tool-support, the availability and use of the tool including tailored interactive visualizations was expected earlier.

Importance to provide visualizations. The findings as mentioned above led to the conclusion, that the visualizations play a crucial role in the perceived success of the modeling process. We noticed within both studies that as soon as the interactive visualizations were provided with the additional feature of adopting changes to the data model and the data collected in run-time contributed heavily to the motivation of the participants to collect and implement data.

Story telling. As for both studies the focus was on the instantiation of the business ecosystem model, the provided visualizations can be considered as preliminary visualizations of the respective ecosystems. Within the studies, this process step was instead used to present the results of the study to the gatekeeper. After further iterations of the repetitive process activities – data collection, provision of visualizations, and adaption of model – the 'story telling' can be used to answer the ecosystem-related questions, such as *which cities are providing innovative mobility services within their mobility service land-scape?* or *which publishing related IT services are provided to which publisher?*.

Collaborative modeling. In both studies, several stakeholders were included in the modeling process. During the workshops, all participants contributed as modelers. Between the workshops, the overall contribution decreased, and only key team members, those we identified as facilitators, continued collecting and implementing data. Changes of the model were only implemented during the workshops, which might be due to the still somewhat unfamiliar knowledge management system in use and the application provided. We observed a lively discussion during the workshops, implying the relevance of managing the business ecosystem model in focus.

We identified four roles clearly within both studies: the facilitator, the modeler, the recorder and the gatekeeper as described in Section 6.1.3. As we conducted this process of instantiating a business ecosystem model for the first time, a process coach was missing for both studies.

7.2.5. Summary and implications

The focus of the two case studies we conducted was the evaluation of the modeling process including the roles as described in Section 6.1.3. The results of both studies indicate that the process we developed is suitable to instantiate a business ecosystem model including various stakeholders of the company.

For additional case studies, the study time frame should be set in a way that multiple iterations of the data collection, visualization provisioning, and adaptation of the model can be conducted. In addition, a longer time frame would allow to evaluate how the the business ecosystem model is adapted according to changes of the ecosystem.

Involving ecosystem stakeholders in the modeling process facilitates the creation of tailored visualizations that support these stakeholders in their ecosystem-specific decisions. Within both studies, the ecosystem stakeholders as study participants were empowered to define the business ecosystem data and view models according to their requirements. With growing knowledge of the analyzed business ecosystem and the provision of tailored visualizations, the participants were able to identify missing ecosystem-related information and adapt the business ecosystem model accordingly.

7.3. Evaluation of the prototype

To enable the collaborative modeling of the business ecosystem, the usage of the knowledge management system is significant. With the basic collaboration and content management features, it provides the necessary features to support collaboration (cf. Figure 6.1).

Since the evaluation of the prototype was not the main focus of the case studies but rather the process, we conducted a series of five interviews to evaluate the prototype as discussed in Section 6.2. The prototype remained unchanged within this time frame and instantiations of the prototype as developed in the previously presented studies were not included in the interview series.

Similar to the evaluation of the preliminary prototype (cf. Section 5.3.3), we demonstrated the BEEx prototype to multiple practitioners with diverse backgrounds. The purpose of the web-based application is to provide an easy-to-use interface for business ecosystem stakeholders to explore their ecosystem using tailored interactive visualizations. The demonstration was followed by a semi-structured interview addressing the usefulness of the prototype in their business area to identify concrete use cases. Our aim was to determine use cases besides the mobility business ecosystem or aspects of this ecosystem we did not address yet. In addition, we explicitly asked for feedback regarding the strength and weaknesses of the prototype and potential improvements for future development.

7.3.1. Interview series setting

The five in-depth semi-structured interviews were conducted between March 2017 and February 2019. All interviews consisted of two phases: in the first phase, the prototype was presented demonstrating all implemented views and interactive features. Besides, the underlying data set was explained. Questions of the interviewees regarding the prototype were answered. This phase lasted about 15 minutes. In the second phase, the interview partners were given the opportunity to try out the prototype themselves and were asked for feedback towards their perception of the usefulness of the prototype, and possible use cases related to their business activities. This phase lasted between 30 and 105 minutes. Four of these interviews were conducted using video conference software. The last one happened in person. Before each interview, the link to access the prototype was shared.

Participant details

In the following, we briefly describe the business areas of the company and the roles the interviewees occupied.

Mobility related service provider. We conducted two interviews with two independent mobility service providers. Both have their headquarters in Germany and offer mobility services possible due to the digitization of mobility.

The first interview was conducted in March 2017 with the managing director and senior partnership manager. The company is a start-up with an active competitor analysis in place.

The second interview was conducted in April 2017 with a senior advisor for corporate strategy and a representative of the business development and partner management department.

Logistics. In December 2017, we interviewed a German logistics company operating worldwide. The interviewees were two employees, one representative of the change management department and a program manager.

Recruitment agency. To discuss a possible use case within the recruiting service business, we interviewed a client engagement manager of a recruitment agency with headquarter in the United Kingdom. The interview happened in March 2018.

Associated research institute. We performed an interview with three research associates all active in projects related to business transformations and ecosystems. The interview participants work at an associated research institute with its headquarter in Germany[1].

[1]The research institute is not located in Munich.

7.3.2. Feedback collected through the interview series

The feedback collected is split into two parts: feedback addressing weaknesses and strength of the prototype including suggestions for future development and identified use cases close to the work activities of the interviewees.

Feedback addressing weaknesses and strength of the prototype. All interviewees stated that the prototype is intuitive to use. As a strength of the prototype, the fact that it is a web-based application was mentioned, as no additional software installation is needed.

Especially the last interview provided valuable feedback regarding the weaknesses and strength of the prototype. The strength was identified through the provision of multiple layouts, all targeting different aspects of the business ecosystem visualized. According to the interviewees' experience, the visualizations can contribute to a better understanding of how well an organization is positioned within the business ecosystem in focus and where expertise is eventually lacking.

But also possible improvements for future development – especially improvements of the visualizations – were discussed within the interviews. The interviewees pointed out that as improvements of specific visualizations, another view could be used instead, emphasizing the necessity to provide multiple visualizations. We summarize the feedback targeted at the four prototype visualizations in the following.

Force layout. As an additional feature, the possibility to zoom in on aspects of the business ecosystem was named. Clusters of the business ecosystem could be enlarged. Also, the size of the nodes could represent the number of relations to indicate highly connected ecosystem entities.

Chord diagram. To filter for specific relation types was named as a promising future development. In addition, the categories of the ecosystem entities could be displayed on an additional outer ring of the chord diagram.

Treemap. The number of relations could also be included in the visualization specification to provide additional relevant ecosystem information. Currently, only the size of an ecosystem category is visualized not considering the impact of specific ecosystem entities which could be eventually misleading. If not the number of relations is taken into consideration for the square size of the ecosystem entity, the amount of turnover could be used for organizations to provide more insights.

Adjacency matrix. To focus on the main contributors of the business ecosystem visualized, the sorting of ecosystem entities according to the number of relations was suggested. In the first rows and columns, the ecosystem entities with the highest number of relations would be visualized.

Vital feedback targeting the visualizations in general was the inconsistency of the used color coding of the different relationship types between the visualizations.

Identified use cases. All interviewees identified more concrete use cases within their business field, and some were able to name data sources to collect relevant business ecosystem information.

For the two interviews with mobility-related organizations, their specific cases were discussed: The start-up identified a tool usage beneficial to show visualizations of the mobility business ecosystem to demonstrate their unique selling proposition to potential investors or future business partners. It was discussed how to customize the visualizations providing detailed information about competitors and their products within the mobility business ecosystem.

The second mobility-related company described the visualizations as helpful in demonstrating software usage dependencies within the company's business system. Especially at the business unit level, the understanding of the ecosystem of companies with which other units collaborate to provide and use mobility related services was described as missing or incomplete.

The representatives of the logistic company discussed the application of the tool-support to their 100 most valuable customer network. Ecosystem information about the customers is already available but not their interrelations. The expected findings could be used to make ecosystem-related decisions strengthening the ecosystem and therefore positively influencing their own logistics business. This business ecosystem can be considered as rather static with only a few entities entering and leaving the ecosystem.

For the client engagement manager of the recruiting agency the visualizations of business relations between freelancers and companies they already work with were named as potentially beneficial. Also, visualizing connections between these freelancers could contribute to better suggestions of freelancer teams for project collaborations. As data sources, information available in social networks aiming at maintaining existing business contacts and establishing new business connections were named. These data sources are already used to collect information about the freelancers.

The three research associates suggested to use the prototype to visualize innovative product business ecosystems, e.g., for smart homes. The components of a smart home could provide the organization categories to classify the organizations according to their contribution to the smart home. A second use case discussed was similar to one mentioned in the interview round conducted with the preliminary prototype: the knowledge management within an organization on the business unit level. To visualize the expertise of teams but also individuals and the collaborations within past projects could contribute to an improved resource allocation in the future.

7.3.3. Critical reflection of the interview series

The interview series focused exclusively on the prototype and left out an evaluation of the collaborative process. For this reason, the identification of necessary stakeholders for the successful modeling and visualization of the proposed use cases was not discussed. It also excluded the knowledge management system.

The small number of interviewees and their selection limits the generalization of evaluation results. To receive feedback on the prototype, we selected interview partners where we could imagine the usage of the prototype for their business activities. The evaluation of the applicability cannot, therefore, be generalized on the basis of the interviews. For this reason, the interviews were more focused on identifying concrete use cases of the prototype close to the everyday professional life of the interviewees.

As the prototype was only tested by the interviewees, the positive feedback regarding an application for their daily business could be biased. The actual usage, e.g., in the form of a case study, requires more effort and resources.

7.4. Applying the framework to model and visualize a smart city mobility business ecosystem

To further evaluate the framework, we applied it to model and visualize a smart city mobility business ecosystem. According to Hevner et al. (2004), this kind of evaluation can be classified as experimental evaluation carrying out a form of simulation: How can the framework be applied to provide interactive visualizations of a specific business ecosystem to incentivize ecosystem stakeholder to contribute with their ecosystem specific knowledge.

The emphasise during this evaluation is on the data collection as no company internal data sources can be used. Publicly accessible data sources comprising relevant business ecosystem information have to be identified, assessed, and the data extracted.

The proposed process (cf. Figure 6.1) was executed by us. In the following, we will describe the results of each process step and the visualizations created. The data collection process step is divided into sub-steps, namely the identification, assessment, and usage of Internet data sources.

7.4.1. Define business ecosystem focus

The business ecosystem in focus is the smart city mobility business ecosystem with a regional focus on Munich. As the funding of the TUM LLCM project indicates, there is a great interest in the Munich region to find innovative solutions for urban mobility problems through the use of information technologies such as an open, provider independent digital mobility platform[2]. Thereby, business ecosystem visualizations can eventually contribute to a better understanding of the evolution process of a mobility business ecosystems for (semi-)governmental institutions developing public policies or for companies making strategic decisions about business and technology partnerships. In addition, for the context of mobility business ecosystems, a shared-use visual analytic system similar to the tool-support we developed that informs and configures shared platforms and infrastructures is potentially valuable for the entire ecosystem (Constan-

[2] The first case study together with the automotive company (cf. Section 7.2.2) did not have a local focus on Munich, but included several cities in the created business ecosystem model.

tinides et al., 2018). Studies addressing a usage for business ecosystem-aware management in smart city contexts are currently lacking.

7.4.2. Instantiation of the mobility business ecosystem model

As a starting point for both business ecosystem data and view models, we used the models of the prototype presented in Section 6.2.2: Within the initial data model, the organizations are among others automotive OEMs, their suppliers, public institutions, and mobility-related projects. The AttributeTypes in the organization are company name, abbreviation, logo, URL, short description, headquarter, CEO, category, and legal form. Additionally, the relations describe different types of interaction between organizations, which are cooperation, (partially) ownership, funding, supplying, in talks with, and interested in. Each relation is modeled with a date and the source. The view model comprises the two elements of data binding and specifications for the four visualizations as pictured in Figure 6.6.

7.4.3. Data collection

We used Internet data sources for the data collection process step. To ensure the selection of suitable data sources, we included an individual ecosystem stakeholder representative in the assessment of the sources. As a possible user and beneficiary of the created mobility business ecosystem visualizations, we identified a publicly funded institution located in Munich, established to support local collaboration and start-ups. One strategic objective of this institution is strengthening the mobility ecosystem by organizing mobility networking events and initiating and supporting innovative mobility projects in close cooperation between research and industry through co-funding. Mission and objectives of the institution provided an initial set of requirements for the definition of quality criteria for the data collection. We conducted two semi-structured interviews in December 2016 and March 2017 as described by Narazani (2017).

The overall data collection process we followed is visualized in the grey box in Figure 7.8 and includes the three steps: identification, assessment and selection, and data extraction.

Identification of Internet data sources

For the identification of Internet data sources that provide information about the mobility ecosystem, we conducted an online search and interviewed the identified ecosystem stakeholder in December 2016. The interview focused on the importance of specific ecosystem organization categories and types of relations which we used to identify suitable search terms.

During the online search, different search terms were used within two search engines to ensure a broad variety of sources. They ranged from rather granular search terms like “connected car database”, “mobilität startup datenbank” (mobility startup database), or “blog über mobilität” (blog about mobility) to basic queries such as “company database” or “automotive database”.

The identified Internet data sources can be divided along three categories:

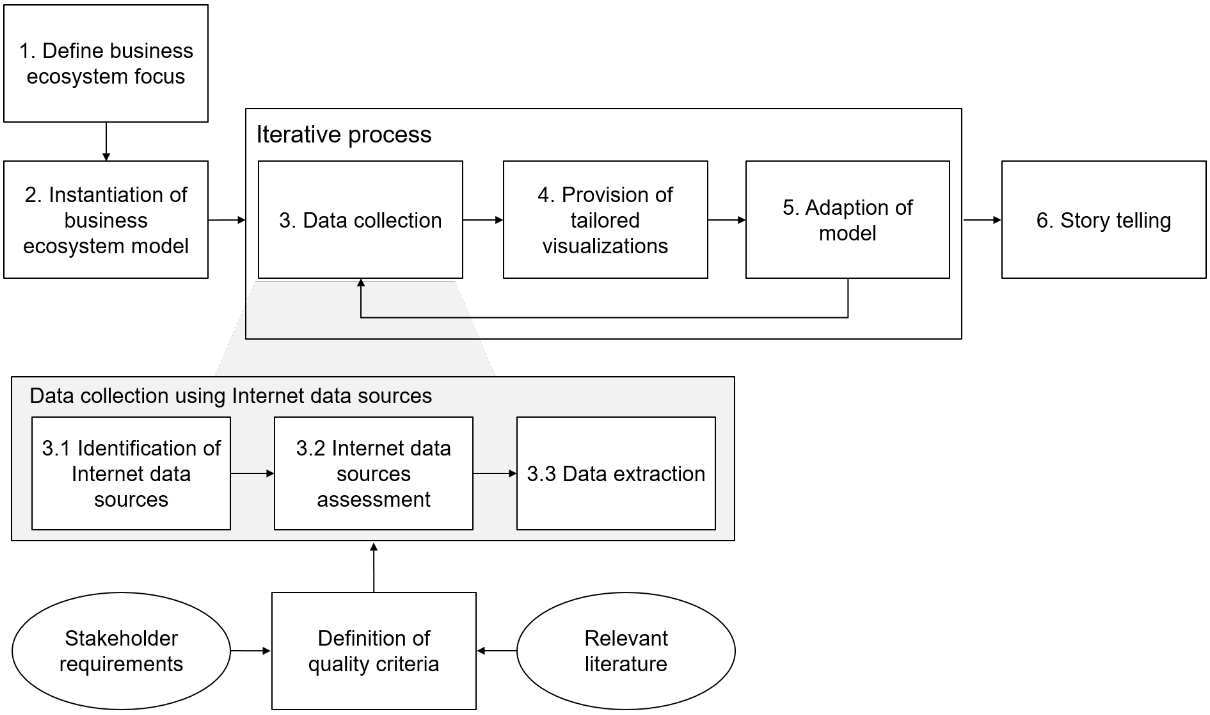


Figure 7.8.: Process steps for data collection using Internet data sources including quality criteria defined through stakeholder requirements and relevant literature

Databases. The first category concerns databases comprising entities that offer products and services related to mobility. Depending on the focus of the database, the information provided ranges from a sole company name or a superficial categorization to more detailed information about each entity such as information about the headquarter location, the current CEO or a general description of the field of activity. This category also comprises databases of established (publicly funded) networking organizations situated in the region of Munich or Bavaria that do not necessarily focus on mobility issues; one such example is Bayern International[3]. In general, these databases offer access to their data either open source, meaning the data is freely accessible and reusable without an additional authorization step, open source with enforced registration (without charge), or as proprietary data sources, which require registration, authorization, and charge fees (Stróżyna et al., 2016).

News feeds, blog posts, and web articles. The second category comprises news feeds, blog posts, or web articles, which describe recent developments of the mobility ecosystem. The blogs can target only mobility-related topics or address this topic as one among others in dedicated articles or posts. These sources can be categorized regarding their accessibility analogous to the ones mentioned above: open source, open source with registration or proprietary data sources.

Web presences. The third category covers information published online by mobility ecosystem stakeholders about themselves as part of their public web presence or in publicly accessible

[3] https://www.bayern-international.de/en/

reports. Such information can range from public statements regarding their recent business development, and strategic corporate decisions, to listings of suppliers or collaboration partners. Within this category of Internet data sources, information is accessible without restriction or enforced registration.

Internet data source assessment and selection

All potential useful Internet data sources identified in the previous step were analyzed using six criteria derived from related literature on qualitative evaluation of data sources (Stróżyna et al., 2016; Naumann et al., 1998; Wang et al., 1995; Batini et al., 2009) as listed in Table 7.1.

Table 7.1.: Qualitative evaluation of Internet data sources

Criteria	**Description**
Data access	We focused on openly available Internet data sources.
Platform focus	The data source should at least contain data that is relevant for a mobility business ecosystem within the scope of the smart city project.
Geographic focus	The content of the source should contain data that is relevant for the local mobility ecosystem.
Data scope	Defining what kind of data is covered regarding – entities, with attributes such as name, legal type, headquarter, CEO or description, and – relations, with attributes such as type of relation, involved partners or date (in case of a funding).
Data extraction	How easy can the relevant data be extracted from the source.
Data validity	Meaning if the source can be trusted.
Language	We selected only Internet data sources providing information in either German or English.

The resulting twelve Internet data sources were prioritized and preliminary data (247 entities and 300 relations) was extracted. We evaluated both the data sources and the already collected data within the second 60-minute interview with the same stakeholder in March 2017. One finding was the lack of relationships between ecosystem entities. To address this, we searched especially for Internet data sources that contain the corresponding information.

In total, we selected 15 databases plus all available company websites. The databases are listed in Appendix D.

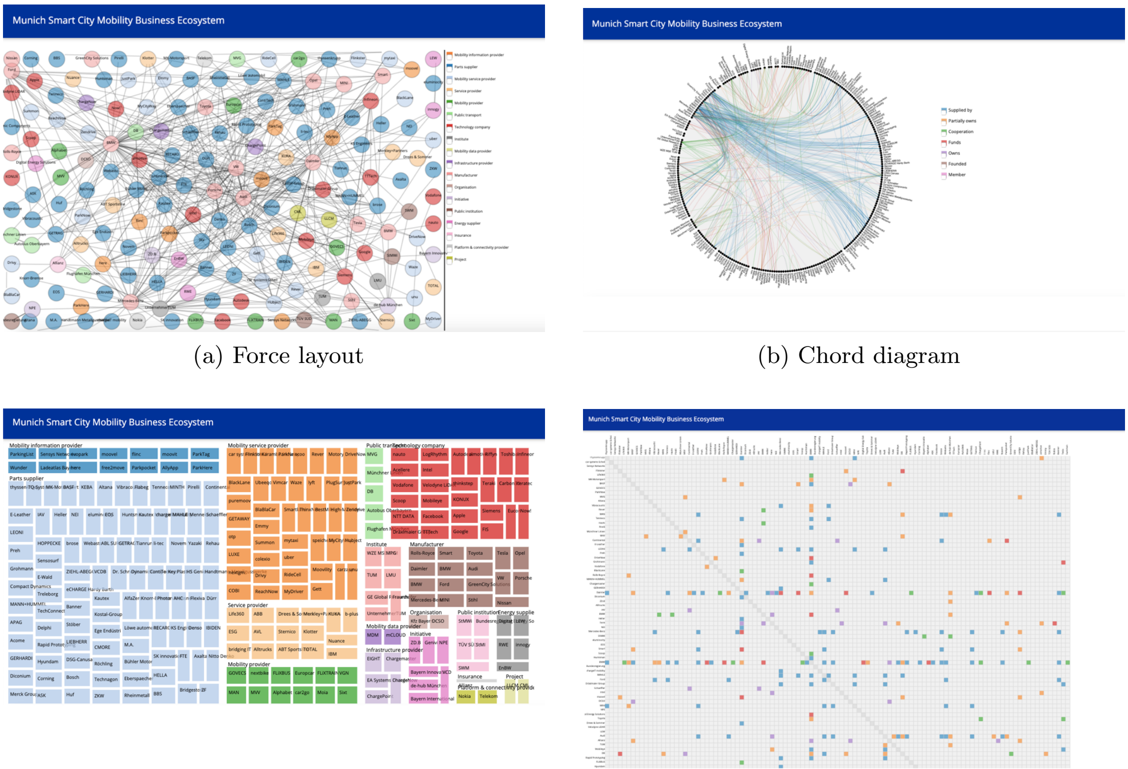
Data extraction

Depending on the data source, the data extraction process varies. Often the Internet data sources provide download features for their data, or a data subset, in a compressed form, e.g., as comma-separated values (csv) or Excel tables (xlsx). As a preliminary ecosystem data model is created prior to the data gathering process step, the data downloaded from databases has to be adapted to the model.

In addition to the used data sources, we manually extracted data from blogs, news feeds, and company public web sites. Overall, we collected information about 271 ecosystem entities and 498 relations between them.

7.4.4. Provision of mobility business ecosystem visualizations

To visualize the collected ecosystem data, we used the visualizations as provided in the BEEx prototype as visualized in Figure 7.9: a force layout, a chord diagram, a treemap, and an adjacency matrix.



(a) Force layout

(b) Chord diagram

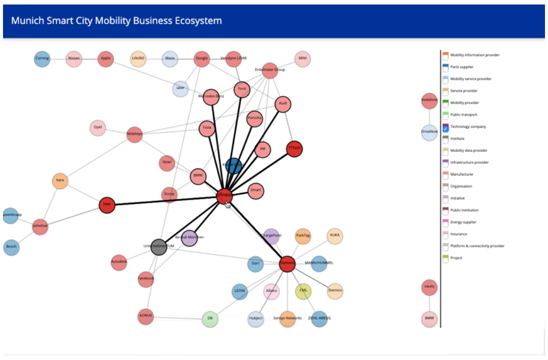
(c) Treemap

(d) Adjacency matrix

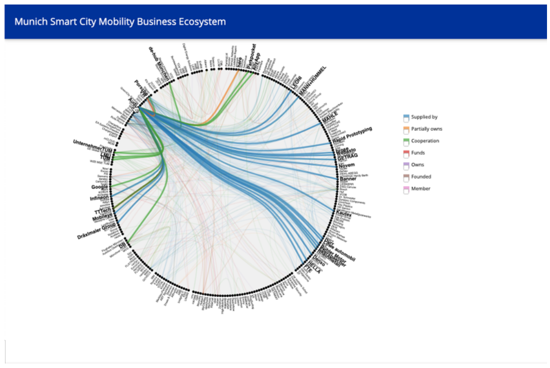
Figure 7.9.: Visualizations of the smart city mobility business ecosystem of our case study using Internet data sources

7.4.5. Adaption of the business ecosystem model

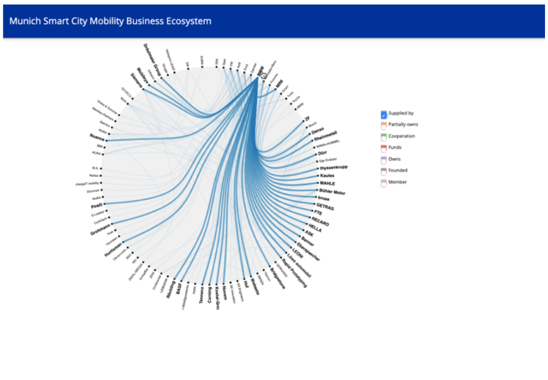
Due to the amount of data collected, especially the force layout as provided within BEEx was only of limited use. Therefore, we adapted the specification of the visualization in the view



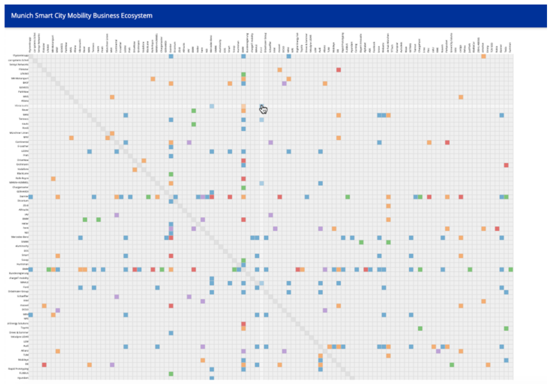
(a) Force layout with filter applied and a highlighted ecosystem entity



(b) Chord diagram with a highlighted ecosystem entity



(c) Chord diagram with an applied filter and a highlighted ecosystem entity



(d) Adjacency matrix with a highlighted ecosystem entity

Figure 7.10.: Interactive features of the visualizations of the smart city mobility business ecosystem

model by including filter options. For the force layout, the organization categories are available for selection (see Figure 7.10a). For the chord diagram, the relation type can be selected and only ecosystem entities with the respective relation type are visualized (see Figure 7.10c). Both reduces the number of visualized ecosystem entities.

7.4.6. Story telling

Within the final process step, 'tell a story', we used the visualizations to extract knowledge about the smart city mobility business ecosystem as we modeled it. The "stimulated knowledge flows" (Rehm et al., 2017) through each visualizations are described in Table 7.2 as presented by Faber et al. (2018e).

Table 7.2.: Visualization layouts and knowledge extracted

Layout	Stimulated Knowledge
Force layout	– The keystone players of the ecosystem are automotive OEMs. – The clusters are located around the OEMs.
Chord diagram	– Automotive OEMs show a high interest in mobility service providers with funding and cooperation relations. – Mobility information and mobility service providers – as two innovative groups of ecosystem entities – are connected through collaborations indicating a complementary orientation.
Treemap	– The organization category with the largest number of organizations is *part supplier*, including tier 1 to 3 part supplier, illustrating the dependencies of a large number of SME companies from automotive OEMs. – The second largest group are mobility service providers.
Adjacency matrix	– The dominant relation type of the mobility business ecosystem is "supplied by". – Automotive OEMs comprise the largest amount of relations as they are still a focal part of the mobility business ecosystem. – Automotive OEMs largely trust the competencies of the same suppliers but invest in competing companies/startups.

7.4.7. Smart city mobility business ecosystem model

In the following, the final business ecosystem data and view models are described in detail to provide a starting point for similar initiatives. These initiatives might use the provided information to identify attributes and categories of ecosystem entities and their relations of their primary interest or to enlarge the existing lists with additional attributes and types to complete their view of the ecosystem in focus.

Smart city mobility business ecosystem data model

The ecosystem data model comprises each a EntityType for the ecosystem entities, the organization categories, the relations, and the relation types. The differentiation of organization and relation types allows applying color coding in the visualizations and thus a deeper analysis of the ecosystem using the visualizations.

First, to describe the ecosystem entities, we identified seven attributes as presented in Table 7.3. Not all information is available for each ecosystem entity, e.g., due to a missing web presence of a recently initiated project. Nevertheless, collecting this information allows further analysis of the ecosystem in a later stage.

Table 7.3.: List of attributes describing the smart city mobility business ecosystem entities

Attribute	Description
Name	Full name of the ecosystem entity. In case of an organization the full company name including the legal form.
Abbreviation	Initials used for the ecosystem entity.
Description	Detailed information about the ecosystem entity in form of text. The entity's web page or free online encyclopedias can be used as data sources.
Headquarter	Address of the head office of the ecosystem entity.
Logo	Graphically designed symbol to identify the ecosystem entity.
Legal form	Definition of the ecosystem entity by the legal system of the head quarter's country.
URL	The Uniform Resource Locator (URL) directing to the ecosystem entity's web presence.

Second, we identified sixteen organization categories, which are described in Table 7.4. In our initial attempt to use visualizations for a better understanding of the mobility business ecosystem (cf. Section 3.1.2) some of the listed organization types were already explained and applied. To provide a comprehensive table of all organization categories identified by us, these are also described in the following table. Also, the organization category *new competitors of affected industries* is now described in more detail through several categories.

Table 7.4.: List of organization categories participating in the smart city mobility business ecosystem

Organization category	Description	Organization type
(Mobility) Data providers	Entities bundling and providing (mobility) data to third parties.	Service provider
Add-on services	Additional service providers, such as mobility focused consultants or advertisement agencies, but also car tuners.	Service provider
Automotive OEMs	Original equipment manufacturer with the focus on car production.	Service provider
Energy suppliers	Companies involved in the production and sales of energy, including fuel extraction, manufacturing, refining, and distribution.	Service provider
Infrastructure providers	Companies offering charging infrastructure for electric cars.	Service provider

Continued

Organization category	Description	Organization type
Institutes and initiatives	Public organizations targeting research, innovation, technology, and knowledge transfer within a specific region or industry field. Often actively engaged in networking activities.	Service provider
Insurances	Companies offering protection from financial loss.	Service provider
Mobility providers	Companies offering mobility in the form of classic rental car services.	Service provider
Parts suppliers	Companies producing automotive components, ranging from electric systems, interior equipment to car paint, which they supply to automotive OEMs.	Service provider
Platform & connectivity providers	Companies providing a platform enabling a two-sided market of developers and users to develop, provide and consume applications. In addition, service providers offering telephone and network services for customers to exchange information electronically.	Service provider
Public institutions	Public institution responsible for funding and regulations with high influence in the market, but also research institutions.	Service provider
Public transports	Companies offering public transportation with buses, trains, trams or metro trains.	Service provider
Technology companies	Companies focusing on the development and manufacturing of technology or providing technology as a service.	Service provider
Mobility information providers	Companies enabling mobility as a service by providing traveling information incorporating different modes of transportation. Often a strong link to mobility service providers exists due to the necessary interfaces between both services.	Service solution
Mobility service providers	Companies offering mobility solutions that enable customers to consume mobility as a service, such as car sharing, bike sharing or ride sharing.	Service solution
Projects	A temporary (rather than permanent) undertaking that is carefully planned to achieve a particular aim. Can be carried out individually or collaboratively.	Service solution

Considering mobility service providers or transportation network companies (TNCs) addressing the demand for mobility as a service (MaaS), we distinguished in our data model between *service providers* covering all "traditional" organization types on one hand, and *service solutions*, represented by mobility information providers, mobility service providers, and projects on the other hand. With this distinction, the ecosystem can be analyzed regarding its realization or shortfall adjusting to 'digitized mobility' from a user-centered perspective addressing the need for MaaS (cf. Section 3.1.2).

Third, the relations between ecosystem entities are described using attributes as listed in Table 7.5. Especially, when incorporating ecosystem stakeholders outside of the editorial team in the modeling process, it is relevant to collect the data sources describing where the information is originating from. This information can support the ecosystem editorial team to decide about the quality of ecosystem information implemented.

Table 7.5.: List of attributes describing the relations between ecosystem entity

Attribute	**Description**
Name	Describing name of the relation.
Source of information	Link to the data source describing the specific relation modeled.
Status	The distinction between current, past, and future relations to address changes in the ecosystem.

Finally, as relations between these diverse entities within the mobility business ecosystem, we identified six relation types. These types are described in detail in Table 7.6. Thereby, only the relation type 'cooperation' is an undirected relation whereas all other relation types describe directed relations, i.e. with a source and a target.

Table 7.6.: List of relation types between entities in the smart city mobility business ecosystem

Relation types	**Description**
Cooperation	Entities collaborating, e.g., to provide shared services or products. The cooperation can be temporary or a long-term strategic one.
Funds	Granting of funds between two entities, usually during the start-up phase of one entity or in the form of project funding.
Membership	Entity is part of an initiative, institution or project.
Ownership	One entity having exclusive rights over another entity due to a legal belonging.
Partial ownership	Several entities sharing the rights of another entity. The shares can be equal but also proportionate.
Supplied	One entity provides its service or product to another entity, which consumes it for its own service or product.

Smart city mobility business ecosystem view model

The collected ecosystem data is visualized using the four visualization layouts of the BEEx prototype depicted in Figure 7.9.

As described in Section 6.2.2, the business ecosystem view model incorporates two elements: the link between the data model and the visualizations, and the specification of the visualizations. Using a declarative language, we can describe the specification in detail by discussing the building blocks data, marks, scales, signals, and legends (see Table 7.7).

Table 7.7.: Visualization building blocks

Visualization building blocks	Description
Force layout	
Data	All data visualized is documented in an object composed of nodes and links. The ecosystem entities are represented by nodes consisting of attributes, whereas relations between entities are documented as links connecting these nodes with a source, target, and type attribute. The attributes describing the entities are ID, abbreviation, category, description, headquarter, logo, legal form, and URL.
Marks	The entity nodes are displayed as circles. Each node displays the company's abbreviation as text. The links represented as straight lines always connecting two entities.
Scales	The node color is set according to the ecosystem entity categorization. Each category is rendered with a particular color. The link line is identical for all types of relations.
Signals	When hovering over a diagram node, it is highlighted by an extension of the node size. Additionally, the mouse pointer changes to emphasize that each node is clickable leading to a dedicated side presenting more descriptive attributes. The filter option can be set to visualize only one or more specific organization categories.
Legend	The color of the icons, i.e. the organization categories, are displayed including the option to select specific categories to be visualized using a filter.
Treemap	
Data	The entities of the ecosystem are documented in a hierarchical data structure. Each element contains a reference to an ID, name, and parent, where applicable.
Marks	Each ecosystem entity is represented as a rectangle in the according category. In each rectangle, the abbreviation of the entity is displayed and the text font is defined.
Scales	The color of the rectangle is chosen depending on the entity's category.

Continued

Visualization building blocks	**Description**
Signals	When hovering over a rectangle of the diagram, this rectangle is highlighted by a brighter tone of the respective rectangle color and by a bold type company name. Additionally, the mouse pointer changes to emphasize that each node is clickable leading to the dedicated company side.
Chord diagram	
Data	The data documenting the business ecosystem entities is stored as described in the clustered treemap layout. This data is transformed to be visualized as arcs around the circle. Additional to this data and its transformation, an array documents the relations between the ecosystem entities. Each array entry thereby consists of a source, target, and the type of relation.
Marks	To achieve a circular layout, the coordinates are mapped from a Cartesian to a polar description. The text size of the company name is defined.
Scales	To support the distinguishability of the different kind of links between ecosystem entities, each type of relation is visualized with a respective color.
Signals	When hovering over an entity on the arc of the circle this entity is highlighted by a bold type company name. Also, all relations of this entity are highlighted by a bold type curve whereas the remaining relations are grayed out. All entities are highlighted by a bold type company name which are connected to the selected entity. The mouse pointer changes to emphasize that each node is clickable leading to the dedicated company side. The filter option can be set to visualize only one or more specific relation types.
Legend	The mapping between the color of relations and the relation types is displayed including the option to select specific relation types to be visualized using a filter.
Adjacency matrix	
Data	The visualized data is documented identical to the force layout. An object consists of nodes and links. To achieve clusters inside the matrix, during the data transformation, the entities are sorted and grouped.
Marks	All cells of two entities not connected via a relation are colored gray. Additionally, the text font of the first column and first row, displaying the entities' names, are defined.
Scales	In case a relation is available for two ecosystem entities, this cell is colored according to the type of relation.

Continued

Visualization building blocks	Description
Signals	When clicking on a node label, i.e. an entity name in the first row or column of the matrix, the according row and column is highlighted by a darker gray color of all empty cells.
Legend	The mapping between the color of relations and the relation types is displayed.

7.4.8. Critical reflection on the simulation and the achieve results

Within this simulation, the visualizations were made publicly accessible, but no activities were started to involve ecosystem stakeholders in the next iterations of the process. Through the inclusion of additional stakeholders, we envision to identify other data sources than the ones already in use and relevant to the continuous modeling process. The only actively involved modelers were the research team.

The presented results of this section indicate that the developed framework can be applied to model and visualize a business ecosystem of a market or technology using Internet data sources.

For this evaluation method, the roles of the collaborative process and their adaptation to the use case of providing ecosystem visualizations publicly to incentivize the ecosystem crowd to contribute to the modeling process with their ecosystem specific knowledge have not been evaluated.

The visualizations in Figure 7.9 have reached their limits with the number of entities and relations. Especially in the case of the force layouts, an analysis of the ecosystem is not possible without filters. One way to improve this is to use different node sizes of the ecosystem entities based on the number of their relationships.

We only used sources that were accessible free-of-charge. We believe that for individual initiatives using fee-based data sources might be a beneficial addition, as such sources might also actively inform registered users about changes in the data.

The ecosystem data was collected manually in time-consuming work. We believe that especially for databases comprising blogs and news feeds about the ecosystem in focus, the (semi-) automated extraction is an appropriate enhancement. Automation of this process could not only save valuable resources but could also enable (almost) real-time availability of the data and hence create possibilities for more advanced analyses of changes within the ecosystem. For instance, artificial intelligence (AI) mechanisms could be useful for distinct ecosystem actors such as financial analysts. A first attempt in this direction is described by Braun et al. (2018).

7.5. Summary of evaluation results

In this section, we presented the results of the evaluation of the developed framework. We presented three different evaluation methods as visualized in Figure 7.1, namely

- two case studies to evaluate the process in two practical environments,
- an interview series of five interviews with potential users of the prototype, and
- applying the framework to provide business ecosystem visualizations to the public as a form of simulation.

In Section 7.2, we used case studies to evaluate the framework in two practical environments while focusing on the proposed collaborative process and the according roles. Within this modeling process the tailored business ecosystem visualizations are provided as fourth process activity. This poses a challenge, especially in the instantiation of the process. Through further iterations of the process activities of data collection, provision of visualizations, and adaptations of the business ecosystem model, this challenge might be solved. Nevertheless, the results indicate that a business ecosystem model can be created incorporating various business ecosystem stakeholders in a collaborative process enabled to define both the data model and the view model to meet their requirements. Through the continuous adaptability of both models, stakeholders with growing experience in ecosystem analysis can modify the models and, through the iterative nature of the process, obtain visualizations that support them in their ecosystem-specific questions and decisions.

Within an interview series we focused on the perceived usefulness of the developed prototype to collect feedback regarding the strength and weaknesses of the tool-support and potential additional use cases (see Section 7.3). Even though, the interviews remained on a superficial level, since the interviewees only tried out the prototype but did not actually use it with their own data and visualizations, the interviews provided some interesting impulses for the further development of the prototype, especially regarding the visualizations. The fact that the prototype is available as a web-based application caught the interest of practitioners as no additional software has to be installed. Each interview partner identified a concrete use case for the tool usage ranging from the network of most valuable customers to the freelancing business network. In a next step, additional case studies should be initiated targeting these use cases and instantiating the business ecosystem model.

Finally, in Section 7.4, we applied the framework in a simulation to gain insights in a specific business ecosystem relevant for more than one organization. For our simulation, we selected the Munich smart city mobility business ecosystem as an extension of the TUM LLCM project business ecosystem. Instead of using simulated data as discussed by Hevner et al. (2004), we used Internet data sources we identified and assessed for its practicality to be used for visualizations of this specific business ecosystem.

CHAPTER 8

Conclusion

In this closing chapter, we summarize the results presented in this thesis by recapitulating on the research questions guiding the research, providing a critical reflection about the approach followed and the results achieved, and proposing future work enabled through the contributions of this thesis.

8.1. Summary

In Chapter 1, we motivated the thesis by describing the growing relevance of business ecosystems for the overall health of most enterprises nowadays and the related challenges business ecosystem stakeholders face when analyzing the business ecosystem of their interest. Based on this problem description, we derived seven research question which guided this thesis and presented the research design we followed to answer these research questions. The chapter closed with a description of the thesis' contribution and the outline of the following chapters.

To provide a common understanding of the research field, the foundations of business ecosystem research were described in Chapter 2. Using the results of a systematic mapping study, we discussed proposed definitions and described characteristics of a business ecosystem in scientific literature presented by researchers. We outlined in more detail the dimensions and roles (cf. Section 2.2), the stages of evolution (cf. Section 2.3), and the different types of business ecosystem we identified (cf. Section 2.4).

To identify the relevance of business ecosystem analysis in practice, we explained the initial starting point of this thesis in Chapter 3. In Section 3.1, we described the TUM LLCM project, which aimed at establishing a mobility business ecosystem in Munich by bringing company representatives, start-ups, developers, and end users together. We used the project environment and the close interaction with mobility business ecosystem stakeholders to discuss their perception of the relevance of the mobility business ecosystem and particular challenges. Following a visual approach presented by Iyer and Basole (2016), we built preliminary visualizations of this ecosystem to analyze how they can help to better understand the mobility business ecosystem (cf. Section 3.1.2). To broaden our understanding of the current practices applied and the perceived challenges of ecosystem stakeholder actively analyzing and modeling the business ecosystem of their interest, we conducted an online survey and reported on the results in Section 3.2. Even though visualizations seem to contribute to a better understanding of the ecosystem, they are not yet applied by most of the practitioners surveyed. In addition, a perceived challenge by the survey participants was the lack of or unsupported cooperation and collaboration between colleagues analyzing the ecosystem of interest.

The identified challenges motivated our search for related work addressing the visualization of business ecosystems. In Chapter 4, we presented scientific papers that report on approaches and tools to model and visualize business ecosystems and presented their results. In Section 4.2, we outlined approaches designed to visualize business ecosystem data and in Section 4.3, we described already existing tools providing interactive business ecosystem visualizations. To conclude this chapter with a description of the identified research gap (cf. Section 4.5), we briefly reflected on existing commercial tools and their application to business ecosystem analysis in Section 4.4. The research gap derived is the lack of a collaborative tool-supported process to model and visualize business ecosystems with various foci by including different ecosystem stakeholders. The envisioned process should allow to include various data sources and knowledge of ecosystem experts, to collect requirements towards the visualizations provided, and to incorporate these in a web-based application with multiple tailored interactive visualizations.

To develop a tool-support for ecosystem stakeholders and their related modeling activities, we used the tool requirements presented in related work and the insights we gained through the discussion rounds with the mobility business ecosystem stakeholders. Overall, we derived ten requirements (cf. Section 5.2) for the tool-support comprising of a web-based application for the interactive visualizations and a knowledge management system that support especially the collaboration of ecosystem stakeholder and evolution of the underlying business ecosystem model (cf. Section 5.1). To collect early feedback from potential users, we followed the iterative design cycles presented by Hevner (2007) and developed and evaluated a preliminary version of a web-based application (cf. Section 5.3). We incorporated the collected feedback in the next iteration of the design cycle resulting in a prototype (BEEx) as an implementation of the conceptually designed tool-support.

In Chapter 6, we presented the design artifact develop in this thesis – the collaborative process and the tool-support – in detail. First, the collaborative process was described in Section 6.1 including the roles we adapted from group modeling to business ecosystem modeling. Second, the tool-support was discussed in Section 6.2. We presented a knowledge management system resting on a Hybrid Wiki meta-model and its basic collaboration and content management features in Section 6.2.1. The business ecosystem model and visualizations incorporated in the BEEx prototype were described in Section 6.2. The chapter ended with a description of possible use cases for the tool-supported process presented.

After the description of the design artifact, we discussed the evaluation results as the second important aspect of design science research (Hevner et al., 2004) in Chapter 7. We applied three evaluation methods. First, we evaluated the process in two practical environments through two case studies (cf. Section 7.2). Within both studies, we applied the process, used the knowledge management system, and instantiated a version of the BEEx prototype tailored to the requirements of the involved ecosystem stakeholders. Second, to evaluate the usefulness of the BEEx prototype, we conducted five interviews with potential tool users asking for their feedback and possible use cases related to their field of business activities (cf. Section 7.3). Finally, we followed the process using publicly accessible data sources to visualize the Munich smart city mobility business ecosystem in Section 7.4. The resulting business ecosystem model is described to serve as a blueprint for similar projects.

As the final part of this summary, we recapitulate briefly on the research questions defined in the first chapter.

> ***Research question 1:*** What business ecosystem concepts are discussed in the scientific literature?

To answer the first research question, we presented definitions and characteristics of business ecosystems provided in scientific research in Chapter 2. To give the reader a solid understanding of the business ecosystem concept, we elaborated on the characteristics, roles, evolutionary stages, and types of business ecosystems. The interested reader is guided through the years of business ecosystem publications and to additional work for further reading on these aspects.

For this thesis, we follow the definition of James F. Moore (1996) describing a business ecosystem as an economic community of interacting organizations and individuals. These organizations include (semi-)governmental institutions and potential future business partners but also competitors.

> ***Research question 2:*** What challenges do practitioners face when completing ecosystem-related tasks?

We used discussion rounds with mobility business ecosystem stakeholders as a starting point to understand which tasks and challenges these stakeholders complete and perceive. Two aspects named were the identification of relevant business ecosystem entities and stakeholders and the possibilities of visualizing ecosystem information (cf. Section 3.1.1).

In the online survey, discussed in Section 3.2, we asked explicitly how business representatives currently model the business ecosystem of their interest, which visualizations are already used, and which challenges they perceive. As the main challenge, we identified the time-consuming processing of collected and documented information.

> ***Research question 3:*** What business ecosystem modeling approaches and visualization tools have been presented in scientific literature?

Within the systematic mapping study, we searched for scientific records addressing business ecosystem visualizations. We identified two approaches which visualize business ecosystem data, a data-driven approach to understand business ecosystem dynamics (cf. Section 4.2.1) and the visual approach to understand ecosystems (cf. Section 4.2.3). We applied the latter already in an early phase of the research to evaluate how visualizations help to understand the mobility ecosystem and present the results in Section 3.1.2.

In addition, we identified three tools providing multiple interactive (business ecosystem) visualizations in one user interface each: dotlink360 (cf. Section 4.3.1), visual analytics for supply network management (cf. Section 4.3.2), and ecoxight (cf. Section 4.3.3). All three tools have been evaluated through various methods, including interviews, discussions with focus groups, laboratory experiments, and user studies.

> ***Research question 4:*** What are tool requirements to visualize business ecosystems?

We derived ten requirements for a tool-support consisting of a web-based application incorporating interactive business ecosystem visualizations and the knowledge management system for implementing the business ecosystem model. We address the collaborative (Requirement 9) and evolutionary (Requirement 8) features necessary to support ecosystem stakeholder in modeling the changing business ecosystem of their interest collaboratively.

For the requirements of the web-based application, we draw on requirements explicitly proposed by similar tools in scientific research, such as providing interactive visualization features (Requirement 1) in multiple views (Requirement 4) incorporated in an easy-to-use interface (Requirement 5).

> ***Research question 5:*** How can business ecosystems be collaboratively modeled considering necessary activities, roles, and artifacts?

Combining two approaches from literature, we present a process consisting of six activities to model and visualize business ecosystems. The process, as described in Section 6.1 can be applied to various business ecosystems as the focus is defined within the first process activity. The business ecosystem is modeled using an ecosystem data model and view model, which are instantiated within the second activity. These models define which information about the ecosystem should be collected and how this information should be visualized. During the third activity, business ecosystem data is collected, followed by the provision of tailored visualizations as defined in the view model. Gathering feedback of the involved business ecosystem stakeholder leads to the adaption of the business ecosystem, both in respect to the data and view model. These last activities are conducted iteratively, to capture changes in the business ecosystem and provide useful visualizations. Finally, the created business ecosystem visualizations are used to 'tell a story' about the respective ecosystem.

Following the process as proposed empowers the ecosystem stakeholders involved in the modeling process to adapt both models according to changes in the business ecosystem or the requirements towards the visualizations.

We transferred roles proposed for group modeling (Richardson and Andersen, 1995) to their specific tasks and responsibilities within the business ecosystem modeling process.

> ***Research question 6:*** How can a tool supporting the modeling process be designed?

We describe the conceptual design of the tool in Chapter 5 and the prototypical implementation in Chapter 6. Two parts define the conceptual design: a web-based application comprising the interactive business ecosystem visualizations with an intuitive user interface and a knowledge management system resting on a Hybrid Wiki approach allowing multiple ecosystem stakeholders to collaboratively instantiate and continuously adapt the business ecosystem model (cf. Figure 5.1).

The prototypical implementation including four interactive business ecosystem visualizations – an adjacency matrix, a force layout, a treemap, and a chord diagram – are presented in Section 6.2. For all visualizations, the implemented interactive features are described and depicted.

> ***Research question 7:*** How can a business ecosystem be modeled and visualized using Internet data sources?

In Section 7.4, we describe how Internet data sources can be identified, assessed, and used to visualize business ecosystems. We applied it to the Munich smart city mobility business ecosystem. Overall, we used 15 Internet data sources to visualize 271 ecosystem entities and 498 relations.

We describe the respective business ecosystem model by providing detailed information about the ecosystem data model, i.e. entities, categories, and relation types, and the ecosystem view model, i.e. the specification of all four visualizations.

8.2. Limitations

Recapitulating on this thesis, we found limitations of the applied approaches, the functionalities of the developed design artifact, and the evaluation methods. In this section, the main limitations are described.

8.2.1. Limitations of the systematic mapping study

We conducted a systematic mapping study (cf. Section 1.3.1) which aimed "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" (Wendler, 2012, p.1318). For this mapping study, we used the search string *business ecosystem* in six databases (cf. Table 1.1).

Additional search strings, such as *business network*, *business clusters* or *networked ecosystems* could have led to results that are missed out now. Also, search strings targeting specific business ecosystem characteristics, such as roles, evolutionary stages or ecosystem types could have generated a broader picture of these characteristics.

A second limitation of the systematic mapping study is the number of databases – ACM, IEEE, Science Direct, Scopus, Springer Link, and Web of Science – which we picked due to its coverage of scientific literature on computer science, information systems, and management theory. A broader selection of databases and research areas could have led to the identification of additional records not covered within these databases and the following forward and backward search. One potential additional database is the AIS eLibrary.

8.2.2. Limitations of the research methodology

For the development of the design artifact, we applied the design science framework (Hevner et al., 2004). This research methodology is common in information system research and often applied as it provides a structured approach with seven design principles for the *building* and *evaluating* of design artifacts (cf. Section 1.3.2).

Frank (2006) discussed four flaws and misconceptions the seven principles suffer from:

1. *lack of accounting for possible future worlds*, as Hevner et al. focus on problems which already exist and are perceived as relevant in practice to ensure research relevance leading to a focus on reproduction rather than on innovation,
2. *insufficient conception of a scientific foundation*, not reflecting on "basic ontological and epistemological assumptions" (p.30) which leads to the lack of a solid foundation for integration or configuration of the developed artifact,
3. *mechanistic world view*, as Hevner et al. assume that there are precise definitions of requirements and that there is a space of possible solutions, leaving out "the fact that requirements are contingent" (p.31) and not always such a space can be produced, and
4. *lack of appropriate concepts for describing the IT artifact*, as "Hevner et al. are not too familiar with information systems design" (p.31) using terminology "not appropriate for designing information systems" (p.31).

Two of these flaws are indeed visible in this thesis as the motivation originates from a problem description of practitioners. Through the online survey, the perceived challenges of practitioners are analyzing in more depth. This indicates a lack of accounting for possible future worlds and focusing less on innovation. In addition, the requirements as defined in Chapter 5 are contingent of the scientific papers used as a baseline and our perception of how the challenges of the practitioners can be addressed.

8.2.3. Limitations of the online survey

We designed and conducted the online survey at an early stage of the research project to use the survey results later within the artifact design phase. Even though we did this with the highest possible accuracy and conscientiousness, we recognize some limitations in retrospect.

The number of survey participants – 52 completed surveys – limits the generalizability of the survey results presented. Also, the survey targeted mainly German enterprises. As an additional limitation, the usage of the survey tool must be stated. As participants completed the survey remotely, full transparency within the response process is not provided. Offering participants with predefined answer options might have led to a biased result as participants face specific choices instead of open questions, which we tried to counteract with the free text answer option "other" whenever feasible. Also, a shared understanding of analyzing business ecosystems among all participants might be missing. Finally, the questions defined by us address a business ecosystem consisting of organizations and institutions and do not adequately model key decision makers of the ecosystem.

8.2.4. Functional limitations of the prototype

Using explicitly stated requirements of business ecosystem visualization tools in scientific literature and insights we gained through the discussion rounds with ecosystem stakeholders of the mobility business ecosystem, we identified ten requirements. The requirements and a brief description of how we addressed these are listed in Table 8.1.

Table 8.1.: List of requirements identified (cf. Chapter 5) and how these were addressed

No.	Requirement	Addressed through
Req 1	Provision of visualization displaying the relation.	Three of the four visualizations display existing relations between ecosystem entities in form of undirected or directed connections (cf. Section 6.2.3.1).
Req 2	Provision of interactive visualization features.	All visualizations provide interactive features such as hovering and clicking (cf. Section 6.2.3.1 and Figure 6.7).
Req 3	Provide temporal insights.	Temporal insights are only provided through snapshots of the visualizations and manual comparison.
Req 4	Provide multiple views.	Overall, the BEEx prototype provides four interactive visualizations: an adjacency matrix, a force layout, a treemap, and a chord diagram (cf. Section 6.2.3.1 and Figure 6.6).
Req 5	Provide an easy-to-use interface.	BEEx followed best practice UI design patterns for web-based applications such as the navigation through a tab (cf. Section 6.2.3 and Figure 6.5).
Req 6	Support usage of semi- and non-structured data.	Feature provided within the used knowledge management system (cf. Section 6.2.1 and Figure 6.3).
Req 7	No predefined structure of content.	Feature provided within the used knowledge management system (cf. Section 6.2.1).
Req 8	Adaptability of data and view model.	Feature provided within the used knowledge management system (cf. Section 6.2.1).
Req 9	Collaborative content creation.	Feature provided within the used knowledge management system (cf. Section 6.2.1).
Req 10	Binding of data and view model.	Feature provided within the used knowledge management system (cf. Section 6.2.1 and Figure 6.4).

The requirements Req 6 to Req 10, addressing among others the collaborative and adaption features, were provided through the knowledge management system we used which rests on the

Hybrid Wiki approach as described in Section 6.2.1. It has been successfully used in different use cases and domains and its limitations are described in the Ph.D. theses of Reschenhofer (2017) and Neubert (2012) in detail.

One requirement, Req 3, was not fully met with the presented version of the prototype as no temporal visualization was implemented. The user can only compare temporal evolution by self-initiated snapshots of the visualizations. Even though the knowledge management system we used provides the feature to model temporal information, the visualization of such information is challenging. Possible ways of providing temporal insights are provided by Basole et al. (2013) and Basole et al. (2018) as depicted in Figure 4.5b and Figure 4.7e.

Another functional limitation of the prototype is the missing navigation between the multiple views. If a user wants to navigate from the force layout to the chord layout, this is only possible via the visualization overview (see Figure 6.5d). This limits the triangulated insights a user can gain through the use of multiple views. Instead, users clicking on a node are directed to the detail view of the respective ecosystem entity.

As shown in the third evaluation method, visualizing the Munich smart city mobility business ecosystem with 271 entities and 498 relations modeled takes the visualizations to the limits of their usability. To address this, we implemented additional filters to enable users to visualize only specific organization categories. Nevertheless, compared to the visualizations of the identified business ecosystem visualization tools (cf. Section 4.3), the visualizations provided in the BEEx prototype leave room for improvements.

8.2.5. Limitations of the evaluations

Even though the limitations of the evaluations and the results are already described in Chapter 7, we briefly summarize the main limitations of the three evaluations applied here.

As first evaluation, we reported from two case studies we conducted with two companies over the time frame from December 2016 to August 2018. The study time frame can be considered as rather short, leading to some limitations.

- The iterative process activities of collecting business ecosystem information, providing tailored visualizations, and adapting the business ecosystem model according to collected feedback have been carried out only a few times. The 'story telling' as last process activity just happened once to present the overall study results.

  Having multiple iterations of the process would have led to more communication and thus potentially more involvement of the management stakeholders. In addition, the business ecosystem model eventually would have changed more drastically compared to the described changes.

- All provided visualizations within both studies were force layouts, lacking insights about which visualization would help specific business representatives in their ecosystem-specific tasks.

As we only collaborated with two companies, the results are not generalizable. Including more industry partners and conducting long-term user studies could have contributed to a more comprehensive evaluation of the process developed.

The interview series was conducted to specifically evaluate the prototypical implementation of the web-based application BEEx. With this interview series, we aimed at evaluating how useful the interviewees perceive the prototype for visualizing business ecosystems and at identifying potential use cases close to the business activities of the interview partners. The first limitation is the small number of interviews as we only conducted five interviews with overall ten interviewees. Four of the five companies the interview partners work for are German companies, which again limits the generalizability of the evaluation results. We selected interview partners based on their potential interest in a tool-support similar to the one provided by the prototype to identify future use cases. In addition, the interviewees only tested the prototype comprising the visualizations of the TUM LLCM project business ecosystem over a short period before or during the interview. Thus, the positive feedback and the identified use cases must be valued taking these aspects into account.

Within the last evaluation, we modeled and visualized the Munich smart city mobility business ecosystem using Internet data sources. Overall, the study took more than one year. Nevertheless, the resulting visualizations were never evaluated with ecosystem stakeholders and potential future modelers contributing with their ecosystem-specific knowledge.

All three evaluation methods can be categorized as qualitative rather than quantitative evaluation. Even though insights and useful feedback were collected, the evaluation lacks the general significance of using the developed design artifact for collaborative modeling and visualizing of business ecosystems.

In addition, no laboratory experiment – for example conducted by Basole et al. (2018) – was conducted to evaluate the interaction of users with the prototype. A laboratory experiment could have contributed to a better understanding about how easy to use the prototype is for users, how the user is able to navigate between the visualizations or which visualizations work for which specific ecosystem-related tasks (similar to the analysis for visual support for business ecosystem by Basole et al. (2016)).

8.3. Outlook and further research

The final section of this thesis is dedicated to future research opportunities we identified especially at the end of our research. These research opportunities build upon this thesis' contribution. The limitations discussed in the previous sections all provide candidates for potential future research, such as an additional literature review using search terms as discussed above, the improvement of the business ecosystem visualization of BEEx, a long time user study or a laboratory experiment as additional evaluation. For this section though, we focus on other research opportunities with one exception as we did not meet one tool requirement identified.

8.3.1. Provide temporal insights

As already discussed as a limitation in the previous section, the implementation and provision of temporal insights is a promising enhancement of the existing prototype. Similar to the tools presented in the related work chapter, the evolution of specific keystone organizations and their establishment of relations is particularly interesting for ecosystem stakeholders.

For the modeling process presented in this thesis, future related research could address how to model the evolution and for which kind of ecosystem information it would be accessible and potentially suitable. Different visualization layouts for the representation of temporal insights could be tested in laboratory experiments and field studies.

8.3.2. Combining the firm-internal tool usage with publicly accessible data sources

To simplify the instantiation of the business ecosystem model and to have an early incentive for company representatives to contribute with their ecosystem-specific knowledge, for the first iteration(s) of the process, publicly accessible Internet data sources seem promising. After the business ecosystem focus is defined in the first process activity and the initial business ecosystem model is set, Internet data sources can be used to achieve a critical mass of collected ecosystem information, which are then visualized. The approach discussed for the Munich smart city mobility business ecosystem could be used as a blueprint to be applied to the business ecosystem of interest. As the visualization of this information alone can lead to new insights into the ecosystem, company representatives could be more easily motivated to contribute to the process.

Thus, a future use case in a practical environment including Internet data sources provides an interesting research opportunity. We envision the study participant group to grow larger compared to the two case studies we conducted and the business ecosystem model to evolve more drastically.

8.3.3. Include the crowd into the modeling process

For the public accessible tool to model and visualize business ecosystem, we envision the inclusion of the ecosystem crowd as interesting future research. This would include whom to address with these visualizations, how to ensure the quality of the collected business ecosystem information, and the evolution of the business ecosystem model.

We have already formulated questions to be discussed as presented by Faber et al. (2019a):

1. Is it reasonable to assume that professionals will provide knowledge about their business ecosystem and engage in modeling business ecosystem structures to populate models of a shared, community-wide system/service?
2. How can data be obtained about the entities to be modeled, such as start-ups, firms, public entities, and their relationships with each other? So far, an editorial team has collected

such information. Can this process be transformed into a more wide-reaching community, maybe supported by open or closed professional social networks – or in cases of smart cities, crowd-based approaches?

3. How can further data be included in an automated way, e.g., by linking peripheral data from IoT systems in smart cities or from business databases (such as Crunchbase)? How can this be accomplished without compromising intellectual property rights or data privacy rights of the legal entities and persons about whom data is collected?
4. How could/should data governance be designed to ensure liabilities are with the appropriate stakeholders of such as system?
5. What types of additional analyses, e.g., stemming from computational social science, could prove reasonable to enhance visualization towards recommendations or simulations?

8.3.4. Further use cases for BEEx

We used the interview series to identify potential future use cases for the prototype with practitioners (cf. Section 7.3). Conducting case studies for these use cases, such as the network of 100 most valuable customers or the network of freelancers, are future research opportunities. Learning from previously identified case study limitations, the studies could be conducted as long term studies to evaluate the process and prototype in more depth.

The mobility business ecosystem use case was extensively discussed in this thesis as we interacted with related ecosystem stakeholders, implemented the preliminary and final prototype using the business ecosystem of the mobility project, and finally applied the framework to the Munich smart city mobility business ecosystem. Thus, an application to another technology or market, such as the Blockchain ecosystem or the Berlin or Munich start-up ecosystem, are promising future research opportunities.

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Abbreviations

AI Artificial Intelligence

API Application Programming Interface

BE Business Ecosystem

BEEx Business Ecosystem Explorer

BMBF Bundesministerium für Bildung und Forschung

CMEE Connected Mobility Ecosystem Explorer

IoT Internet of Things

IS Information System

MaaS Mobility as a Service

OEM Original Equipment Manufacturer

Req Requirement

R&D Research & Development

SME Small and Medium Enterprise

StMWi Bayerisches Staatsministerium für Wirtschaft, Landesentwicklung und Energie

TUM Technical University of Munich

TUM LLCM TUM Living Lab Connected Mobility

URL Uniform Resource Locator

APPENDIX A

Concept Mapping Matrix

The following table is the completed concept mapping matrix created during the systematic mapping study. The marker *X* in a cell indicates that the record in this line addresses the respective characteristic.

Below the double line the results of the forward and backward citation search as proposed by Webster and Watson (2002) are listed.

Citation	**Definition**	**Roles**	**Phases**	**Types**	**Visualization**	**Application**	**Example**
Moore (1993)	X		X				
Vuori (2005)					X	X	
Peltoniemi (2006)	X	X					
Corallo (2007)	X	X					
Ford and Garnsey (2007)							X
Fragidis et al. (2007a)	X			X	X	X	
Fragidis et al. (2007b)				X	X	X	
Liu and Chen (2008)	X	X				X	X
Xie et al. (2008)		X				X	X
Basole (2008)					X		X
Li (2009)	X			X	X	X	X
Isckia (2009)	X	X				X	X
Jansen et al. (2009)				X	X		
Li et al. (2009)		X		X			X

Continued

Citation	Definition	Roles	Phases	Types	Visualization	Application	Example
Tan et al. (2009)	X	X	X	X	X	X	X
Adner and Kapoor (2010)				X	X		X
van den Berk et al. (2010)	X	X		X			
Briscoe (2010)	X						
Hou et al. (2010)	X	X	X				
Kim et al. (2010)		X			X	X	X
Koseki et al. (2010)		X			X	X	
Popp (2010)	X	X		X	X		X
Stanley and Briscoe (2010)	X			X			
Zhang and Fan (2010)	X	X	X				
Basole and Karla (2011)	X	X		X	X	X	X
Gueguen and Isckia (2011)		X			X		X
Kang et al. (2011)	X	X		X	X	X	
Tobbin (2011)		X				X	
Zhang and Liang (2011)	X	X				X	
Basole et al. (2012a)					X	X	
Chou and Huang (2012)	X	X					X
Harland and Wüst (2012)	X		X			X	
Mäkinen and Dedehayir (2012)	X	X		X	X		X
Mazhelis et al. (2012)		X		X	X	X	
Purdy et al. (2012)		X		X			
Shang and Shi (2012)	X	X					
Zahra and Nambisan (2012)	X	X		X			
Heikkilä and Kuivaniemi (2012)	X					X	
Basole et al. (2013)					X		X
Lyu et al. (2013)			X				X
Rong et al. (2013b)				X	X		X
Rong et al. (2013a)			X			X	
Yue (2013)							X
Couzineau-Zegwaard et al. (2013)	X					X	
Basole (2014)					X	X	
Bodde and Taiber (2014)		X		X	X		X
Chesbrough et al. (2014)			X				X
Giesecke (2014)		X				X	
Harland et al. (2014)	X	X					X
Hu et al. (2014)	X	X	X				X
Immonen et al. (2014)						X	
Lu et al. (2014)		X	X			X	
Pilinkienė and Mačiulis (2014)	X	X		X			

Continued

Citation	**Definition**	**Roles**	**Phases**	**Types**	**Visualization**	**Application**	**Example**
Rong and Shi (2014)	X	X	X	X	X	X	X
Yoo et al. (2014)		X			X	X	
Zhang (2014)							X
Annanperä et al. (2015)				X			X
Basole et al. (2015)	X				X	X	X
Bosch-Sijtsema and Bosch (2015)		X					
Holmström Olsson and Bosch (2015)	X	X					
Hyrynsalmi et al. (2015)	X	X		X		X	
Koivisto et al. (2015)					X	X	
Nuseibah and Wolff (2015)	X	X				X	
Overholm (2015)						X	
Peltola and Mäkinen (2015)		X				X	
Rong et al. (2015a)	X		X				X
Rong et al. (2015b)			X			X	
Toivanen et al. (2015)			X	X	X		
Weber and Hine (2015)	X	X					X
Annanperä et al. (2016)						X	
Attour and Barbaroux (2016)			X			X	
Basole et al. (2016)					X	X	
Galateanu and Avasilcai (2016)		X					X
Guo and Bouwman (2016)		X					X
Ikeda et al. (2016)						X	
Iyer and Basole (2016)				X	X		
Jiang et al. (2016)		X			X	X	
Majava et al. (2016)		X				X	X
Peltola et al. (2016)		X				X	
Visnjic et al. (2016)				X		X	
Bai and Guo (2017)				X	X		
Faber (2017)	X	X			X		
Hernandez-Mendez et al. (2017)					X	X	
Holmström Olsson and Bosch (2017)				X		X	
Järvi and Kortelainen (2017)	X	X		X	X		
Kuo and Zhang (2017)							X
Lee et al. (2017)	X	X	X	X			
Lozano (2017)		X				X	
Mäntymäki and Salmela (2017)	X						
Ma et al. (2017)		X				X	
Miri-Lavassani (2017)					X		X
Papert and Pflaum (2017)		X		X	X		

Continued

Citation	Definition	Roles	Phases	Types	Visualization	Application	Example
Radonjic-Simic et al. (2017)		X				X	
Rong et al. (2017)		X	X				X
Stanczyk (2017)	X	X	X				
Teece (2017)			X	X		X	
Tellier (2017)		X	X				X
Rehm et al. (2017)				X	X	X	
Aldea et al. (2018)				X	X		X
Bosch and Holmström Olsson (2018)	X					X	
Scaringella and Radziwon (2018)	X	X	X	X			
Dereń et al. (2018)	X						
Faber et al. (2018a)	X			X	X		
Faber et al. (2018c)						X	
Joo and Marakhimov (2018)		X				X	
Kangas et al. (2018)		X			X	X	
Gomes et al. (2018)	X	X		X			
Li et al. (2018)	X						
Perfetto and Vargas-Sánchez (2018)		X				X	
Rong et al. (2018a)			X				
Rong et al. (2018b)						X	
Rong et al. (2018c)	X	X					X
Sako (2018)	X			X			
Sun et al. (2018)	X	X			X		X
Teece (2018)	X		X				
Winter et al. (2018)				X		X	
Yang et al. (2018)				X		X	
Zhang and Wang (2018)			X				X
Moore (1996)	X	X	X			X	X
Moore (1998)		X					
Iansiti and Levien (2002)	X	X	X				X
Iansiti and Levien (2004a)	X	X	X	X	X		X
Iansiti and Levien (2004b)	X	X					X
Peltoniemi and Vuori (2004)	X			X			
den Hartigh and van Asseldonk (2004)	X						
Adner (2006)				X			X
Moore (2006)	X	X					
Gueguen et al. (2006)	X						X
Iansiti and Richards (2006)		X		X			
Iyer et al. (2006)				X	X		X
Anggraeni et al. (2007)	X	X	X				

Continued

Citation	**Definition**	**Roles**	**Phases**	**Types**	**Visualization**	**Application**	**Example**
Mars et al. (2012)	X	X	X				
Gawer and Cusumano (2014)				X			X
Valkokari (2015)	X	X		X			
Adner (2017)	X					X	X
Basole et al. (2018)					X		

APPENDIX B

List of Identified Business Ecosystem Definitions

During the systematic mapping study we overall identified 61 records providing a business ecosystem definition, i.e. with a marker in the column *definition* of the concept mapping matrix. Of these 61 records, 30 definitions target business ecosystems in general without focusing on a specific type. These definitions are listed below.

Author(s) & Year	Respective definition
Moore (1993, p.76)	A business ecosystem [...] crosses a variety of Industries [...], companies coevolve capabilities around a new innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations. [...] Like its biological counterpart, gradually moves from a random collection of elements to a more structured community. [...] Every business ecosystem develops in four distinct stages: birth, expansion, leadership, and self-renewal – or, if not self-renewal, death. [...] While the center may shift over time, the role of the leader is valued by the rest of the community. Such leadership enables all ecosystem members to invest towards a shared future in which they anticipate profiting together [...] Like its biological counterpart, gradually moves from a random collection of elements to a more structured community.
Moore (1996, p.26)	An economic community supported by a foundation of interacting organizations and individuals – the organisms of the business world. This economic community produces goods and services of

Continued

Author(s) & Year	Respective definition
	value to customers, who are themselves members of the ecosystem. The member organizations also include suppliers, lead producers, competitors, and other stakeholders. Over time, they co-evolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies. Those companies holding leadership roles may change over time, but the function of ecosystem leader is valued by the community because it enables members to move toward shared visions to align their investments and to find mutually supportive roles.
Iansiti and Levien (2004a, p.35)	(Similar to the definition from (Iansiti and Levien, 2002, pp.20)) Like biological ecosystems, business ecosystems are formed by large, loosely connected networks of entities. Like species in biological systems, firms interact with each other in complex ways, and the health and performance of each firm is dependent on the health and performance of the whole. Firms and species are therefore simultaneously influenced by their internal capabilities and by the complex interactions with the rest of the ecosystem. [...]
Iansiti and Levien (2004a, p.40)	[L]ike their biological counterpart, business ecosystems are characterized by a large number of loosely interconnected participants who depend on each other for their mutual effectiveness and survival.
Iansiti and Levien (2004a, p.46)	To assess the health of business ecosystems [...], we propose examining three aspects [...], inspired by our biological metaphor and expressed in terms of our ecosystem analogy: productivity, robustness, and niche creation.
Iansiti and Levien (2004b, p.1)	[E]ach member of a business ecosystem ultimately shares the fate of the network as a whole, regardless of that member's apparent strength. [...] They have done this by creating "platforms"-services, tools, or technologies-that other members of the ecosystem can use to enhance their own performance.
Peltoniemi and Vuori (2004, p.13)	A dynamic structure which consists of an interconnected population of organizations. These organizations can be small firms, large corporations, universities, research centres, public sector organizations, and other parties which influence the system [...] If we follow the principles of complexity business ecosystem should be self-sustaining. This means that no government interventions would be needed in order to survive in local or global markets. Business ecosystem develops through self-organization, emergence and coevolution, which help it to acquire adaptability. In a business ecosystem there is both competition and cooperation present simultaneously.
den Hartigh and van Asseldonk (2004, p.23)	A network of suppliers and customers around a core technology, who depend on each other for their success and survival.

Continued

Author(s) & Year	Respective definition
Peltoniemi (2006, p.2)	A business ecosystem consists of a large number of participants, which can be business firms and other organizations. They are interconnected in the sense that they have an effect on each other. Interconnectedness enables various interactions between the members. These interactions can be both competitive and cooperative. Together with interconnectedness they lead a shared fate among the organizations. The members are dependent on each other, and the failures of firms can result in failures of other firms.
Moore (2006, pp.31)	A new organization form besides market and hierarchy. Be conceived as a network of interdependent niches that in turn are occupied by organizations.
Gueguen et al. (2006, pp.15)	A standard, norm or know-how is used by several companies. This will allow them to develop one ore more central competencies. [...] Companies using these competencies form a strategic community of destiny based on the principles of coevolution. [...] One or more companies will play the role of the leader. [...] The leader company will have to develop a shared vision for other members of the business ecosystem. [...] Founded on the basis of critical, built-in contributions, the leader's power will make it possible to orient evolution in the central competencies. [...] The position of the leader is evolutive and its behaviour is primordial in the evolution of the business ecosystem. [...] The key players that make up the business ecosystem are heterogeneous [..., therefore] come from different industries and have a specific activity. There is thus a convergence of industries. [...] There is not necessarily exclusive membership of a single business ecosystem. [...] Business ecosystems are driven by significant competitive dynamics at the intra-ecosystem level [..., whereas] the competitive logic [...] exists at the inter-ecosystem level. [...] A business ecosystem associates cooperation and competition, and thus corresponds to the logic of coopetition. [...] [T]he business ecosystem could be seen as a set of relationships [...] between heterogeneous key players guided by the promotion of a common resource [...] and an ideology that leads to the development of shared competencies.
Fragidis et al. (2007a, pp.400)	[B]usiness ecosystems concentrate large populations of different kinds of business entities. They transcend industry and supply chain boundaries and assemble a variety of organizations that can complement each other and synergistically produce composite products. Interdependence and symbiotic relationships are inherent attributes in business ecosystems; as a result, the participants

Continued

Author(s) & Year	Respective definition
	counter a mutual fate and co-evolve with each other. But in parallel, members compete with each other for the acquirement of resources and the attraction of customers.
Liu and Chen (2008, pp.1198)	Major Characteristics of Business Ecosystem[s:] Multiple Agents[,] Adaptability[,] Self-Organization and Hetero-Organization[,] Opening[, and] Diversity.
Li (2009, p.380)	[B]usiness ecosystems have a loose network of [actors, consists of] a platform [..., and actors] evolve.
Isckia (2009, p.333)	An ecosystem is a business community that brings together firms from various interdependent industries. [...] These business communities are usually structured around one leader striving to share its commercial philosophy or its technological standard. [... T]he objective is the ecosystem's overall performance rather than that of a single actor.
Zhang and Fan (2010, p.3)	Business Ecosystem is an open, dynamic and selforganizing system based on the interactions of entities that evolve over time.
Mäkinen and Dedehayir (2012, p.1)	Business ecosystems describes the network of firms, which collectively produce a holistic, integrated technological system that creates value for customers. [...] [The] ecosystem of firms [...] center their collective efforts on a product, service, or technology, and [...] transcends a single industry.
Shang and Shi (2012, p.573)	[A business ecosystem is] a community consisting of different levels of interdependent organizations, who are loosely interconnected and generate co-evolution between partners and their business environment.
Zahra and Nambisan (2012, p.219)	Referred to as 'business ecosystems', the networks are the product of a long and evolutionary process that defines relationships among industry players.
Heikkilä and Kuivaniemi (2012, p.19)	Similar to a biological ecosystem, a business ecosystem is formed by large, loosely coupled networks of entities. These entities such as firms, organizations, entrepreneurs, etc. interact with each other and the health and performance of each actor is dependent on the health and performance of the whole. That is, the actors are simultaneously influenced by their own capabilities and their interaction ties with the other players in the ecosystem.
Mars et al. (2012, p.274)	Organizational ecosystems are comprised of diverse actors and organizations, which often enter into relationships and participate in exchanges based on a wide range of intentions. Organizational ecosystems in general are not anchored in pre-determined goals and

Continued

Author(s) & Year	Respective definition
	agendas, although the individual organizations within do purposefully develop and pursue agendas. [...] Instead, information and resource flows connect organizations within organizational ecosystems in spite of the presence of diverse and sometimes even competing goals and agendas.
Couzineau-Zegwaard et al. (2013, p.4)	In business ecosystem, organized groups of actors are formed and design their actions according to each other. These actors [...] come to induce cooperation and build coalitions social skills. To achieve their ends, these actors mobilize various forms of capital: social (networks), physical (resources) and symbolic (cultural). When ecosystems are being established, institutional entrepreneurs provide the vision to build coalitions able to structure the field. Once the fields are stabilized, installed actors strive to maintain their power and privileges at the same time they are trying to define the place of their challengers.
Rong and Shi (2014, p.50)	A business ecosystem is a community consisting of different levels of interdependent organizations which generates co-evolution between partners and their business environment.
Basole et al. (2015, p.1)	Business ecosystems consist of a heterogeneous and continuously evolving set of individuals and firms that are interconnected through a complex, global network of relationships. These firms come from a variety of market segments, each providing unique value propositions.
Nuseibah and Wolff (2015, p.501)	[A] business ecosystem is an idea used to describe the whole of the factors, in nature and in business, that contribute to the success or failure of a business. [...] Complex in structure, a business ecosystem is made up of many parts, including partnering businesses and organizations, competitors within the same field, laws and government, as well as employees, contractors, resources and environmental conditions.
Adner (2017, p.2)	[The ecosystem is defined by] the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize.
Faber (2017, p.1)	Business ecosystem (BE) describes the holistic environment of a company covering current and potential future business partners, customers, suppliers, competitors, regulatory institutions, and innovative start-ups. It exhibits a high dynamic as continuously entities enter and leave the ecosystem.
Stanczyk (2017, p.270)	The business ecosystem is a metaphor taken directly from the ecology theory, in which the flow and circulation of energy are emphasized. This metaphor has a cognitive function and makes it easier to study an organization operating in the space of an evolving

Continued

Author(s) & Year	Respective definition
	population. Therefore, an ecosystem is a system that is energetically open, able to run (auto regulate) and gradually to change (evolving).
Bosch and Holmström Olsson (2018, p.1)	Business ecosystems are dynamic and constantly evolving with actors, roles, and interdependencies changing as a result of collaborative and competitive forces.
Dereń et al. (2018, p.1)	Ecosystem is a concept from ecology that has been borrowed to describe the dynamic relations between a given organization and other organizations functioning in its business environment. Traditionally, the organization has been perceived as an element of a sector or industry that attempts to adopt trends and phenomena in its environment by analyzing and studying them. Failure to adapt to these changes signifies the organization's crisis, which in extreme cases may lead to its collapse. However, the understanding of an organization as an active entity in the ecosystem shows other possibilities for the organization's functioning. The organization not only adapts to changes in the environment, but actively shapes them. Depending on its role and position in the ecosystem, the organization shapes it independently or together with other ecosystem's participants.
Teece (2018, p.151)	A business ecosystem is a group of interdependent organizations collectively providing goods and services to their customers. Shared standards and interfaces are inherent features of platform-based ecosystems. They permit the members of the ecosystem to innovate independently while competing collectively against other firms and/or ecosystems in the relevant market.
Sako (2018, p.21)	A business ecosystem is a collection of business and other actors with resources operating as an interdependent system. Business ecosystems differ from clusters in sustainability, self-governance, and capacity to evolve over time.

APPENDIX C

Online Survey

Questionnaire the participants were invited to complete. For the survey the online survey software questback was used.

Fragebogen

1 Startseite

Business Ecosystem Analysis

Dear Sir or Madam,

thank you for participating in this survey.

My name is Anne Faber and I am an informatics PhD student at TU Munich. You can find more information about me and my research project here.

The anonymized results will be part of my PhD research project to better understand the current status of business ecosystem analysis within companies.

Completing the survey will take about 15 - 20 minutes. You can leave the questionnaire at any time.

In case you have questions regarding the survey, please do not hesitate to contact me at anne.faber@tum.de.

Please feel free to forward the questionnaire to interested colleagues.

Kind regards,

Anne Faber

2 Participant Details

The company I work for is a(n)

- Automotive OEM
- Mobility Service Provider / Mobility Platform Provider
- IT Provider
- Parts Supplier
- Insurance Provider
- Energy Provider
- Public Institution
- other

The number of employees is

- 1 - 100
- 101 - 1.000
- 1.001 - 30.000
- > 30.000

My current job position can be described as

- Enterprise Architect
- Market (Intelligence) Analyst
- Market Research Analyst
- Business Value Analyst
- Competitor Analyst
- Innovation Manager
- other

I carry out my job as an external consultant

- Yes
- No

3 Business Ecosystem Analysis

In the following, the term **business ecosystem** describes the holistic environment of a company **covering current and potential future**

- business partners,
- customers,
- suppliers,
- competitors,
- regulatory institutions, and
- innovative start-ups.

The company I work for is active in analyzing its Business Ecosystem

- Yes
- No

4.1 Division of Labour

In the following, the term **business ecosystem** describes the holistic environment of a company **covering current and potential future** business partners, customers, suppliers, competitors, regulatory institutions, and innovative start-ups.

Within the business ecosystem analysis, I am responsible for
(multiple answers possible)

- ☐ data and information collection
- ☐ information processing
- ☐ reporting to higher management levels
- ☐ using (processed) information for strategic decisions
- ☐ responsibilities not clearly defined
- ☐ other ____

I perform my business ecosystem related task(s)

- ○ full-time
- ○ part-time, on a daily basis
- ○ part-time, on a weekly basis
- ○ part-time, on a monthly basis
- ○ other ____

For the business ecosystem analysis, I work

- ○ alone, no other responsible colleagues known
- ○ collaboratively in a team and the responsibilites are clearly defined
- ○ not alone, but work is rather uncoordinated between me and other colleagues
- ○ other ____

5.1 Data and Information Collection

In the following, the term **business ecosystem** describes the holistic environment of a company **covering current and potential future** business partners, customers, suppliers, competitors, regulatory institutions, and innovative start-ups.

The information about the business ecosystem is collected
(multiple answers possible)

- ☐ actively, by searching for relevant information
- ☐ passively, by collecting information only by chance

I collect business ecosystem related information about the
(multiple answers possible)

- ☐ current development of the market and exitsing business relations
- ☐ future development of the market and business relations within the next 5 years
- ☐ future development of the market and business relations exceeding the next 5 years

For the business ecosystem analysis, the following format of data is used
(multiple answers possible)

- ☐ printed information, e.g., brochures
- ☐ digital information, e.g., news feed

Information is collected using

(multiple answers possible)

- ☐ internal company information sources
- ☐ regional newspaper
- ☐ national newspaper
- ☐ (trade) journals
- ☐ trade fair information
- ☐ national online news portals
- ☐ international online news portals
- ☐ national free of charge databases
- ☐ national fee-based databases
- ☐ international free of charge databases
- ☐ international fee-based databases
- ☐ online search engines
- ☐ other ____________

The 3 main data sources for the information collection are

Source 1 ____________

Source 2 ____________

Source 3 ____________

Within the business ecosystem analysis, I am interested in information about

(multiple answers possible)

- ☐ Competitors
- ☐ Business partners
- ☐ Start-ups
- ☐ Suppliers
- ☐ Public regulatory institutions
- ☐ Public research institutions
- ☐ other ____________

When collecting company related information I am interested in
(multiple answers possible)

- ☐ General description
- ☐ Business area
- ☐ Business turnover / financial information
- ☐ Business Model
- ☐ Strategic decisions
- ☐ Strategic partnerships
- ☐ CEO
- ☐ Striking employees
- ☐ Number of employees
- ☐ Stock information
- ☐ Headquarter / Locations
- ☐ other ______

6.1 Data documentation and processing

In the following, the term **business ecosystem** describes the holistic environment of a company **covering current and potential future** business partners, customers, suppliers, competitors, regulatory institutions, and innovative start-ups.

The collected information is documented
(multiple answers possible)

- ☐ with pen, paper and non-electronical document storage
- ☐ as digital documents in a (shared) file system, i.e., saving the documents without any processing
- ☐ transferred into a standard tool, e.g., MS Excel. The tool in use is ______
- ☐ transferred into a dedicated commerical tool, e.g., company CRM. The tool in use is ______
- ☐ transferred into a custom-developed tool providing business ecosystem related features, e.g. Tableau. The tool in use is ______
- ☐ other ______

The collected (and processed) information is reported upon by
(multiple answers possible)

- ☐ notifying colleagues ad hoc whenever information is available
- ☐ notifiying colleagues according to an agreed reporting schedule
- ☐ providing access to information, but no active notification
- ☐ no reporting or sharing of information conducted
- ☐ other ______

The results of the processed business ecosystem information are
(multiple answers possible)

- ☐ an updated and accessible database
- ☐ list of current potential future competiors, business partners and innovative start-ups
- ☐ (economic) figures / performance indicators
- ☐ visualizations
- ☐ collected data is not processed
- ☐ other ______

The following visualization types are already provided and in use
(multiple answers possible)

- ☐ no visualizations are provided or used
- ☐ a list of ecosystem entites with further attributes
- ☐ bar charts comparing different competitors / business partners / start-ups
- ☐ networks
- ☐ treemap visualizations
- ☐ matrices
- ☐ other

The following visualization types would be interesting
(multiple answers possible)

- ☐ a list of ecosystem entites with further attributes
- ☐ bar charts comparing different competitors / business partners / start-ups
- ☐ networks
- ☐ treemap visualizations
- ☐ matrices
- ☐ other

7.1 BE challenges and comments

In the following, the term **business ecosystem** describes the holistic environment of a company **covering current and potential future** business partners, customers, suppliers, competitors, regulatory institutions, and innovative start-ups.

For me, the main challenges of the business ecosystem analysis are
(multiple answers possible)

- ☐ too much information
- ☐ difficulties to distinguish between relevant and irrelevant information
- ☐ no adequat way to document the information available
- ☐ time-consuming processing of collected and documented information
- ☐ responsibilities within the organization unclear
- ☐ several business units involved, working rather uncoordinated
- ☐ creating visualizations
- ☐ no challenges perceived
- ☐ other

If you have further remarks regarding the business ecosystem analysis, please indicate them here:

8.1 Reasons for not being active in BE analysis

In the following, the term **business ecosystem** describes the holistic environment of a company **covering current and potential future** business partners, customers, suppliers, competitors, regulatory institutions, and innovative start-ups.

The reasons why the company I work for is not active in business ecosystem analysis are
(multiple answers possible)

- ☐ responsibilities within the company unclear
- ☐ information gathering not possible / too difficult
- ☐ information processing not possible / too difficult
- ☐ no free capacities
- ☐ not considered yet
- ☐ no relevance for the company
- ☐ other

Within the business ecosystem analysis, I would be interested in information about
(multiple answers possible)

- ☐ Competitors
- ☐ Business Partners
- ☐ Start-Ups
- ☐ Suppliers
- ☐ Public regulatory institutions
- ☐ Public research institutions
- ☐ other

Support within the following aspects of the business ecosystem analysis would be interesting for me:
(multiple answers possible)

- ☐ provision of relevant information
- ☐ tool support for the documentation of information
- ☐ tool support for the processing of information, e.g., providing a list of competitors / business partners / start-ups or calculated figures
- ☐ provision of information visualizations
- ☐ other

9 Endseite

Thank you very much for your participation. Your answers have been recorded.

Within my research project, I am currently developing a tool called *Ecosystem Explorer* to model and visualize business ecosystems in a collaborative way.

Feel free to try the prototype version of the Ecosystem Explorer: https://ecosystem-explorer.in.tum.de

In case you are interested in the results of this survey and the prototype developed please contact me at anne.faber@tum.de.

I am looking forward to your feedback, ideas, and suggestions.

APPENDIX D

Internet Data Sources

The table below lists the 15 data sources used for the modeling and visualizing of the smart city mobility business ecosystem.

Database Name	**URL**
Bayern innovativ - Cluster Automotive	https://www.bayern-innovativ.de/cluster-automotive
Bayern international	https://www.bayern-international.de/en/company-database/search/automotive-industry/
Core TechMonitor	https://core.se/de/techmonitor
CrunchBase	https://www.crunchbase.com/
Elektromobilität Bayern	http://www.elektromobilitaet-bayern.de/
Gründerszene	https://www.gruenderszene.de/
Schaufenster Elektromobilität Bayern	https://schaufenster-elektromobilitaet.org/de/content/ueber_das_programm/foerderung_schaufensterprogramm/foerderung_schaufensterprogramm_1.html
TechCrunch	https://techcrunch.com
VDV Datenbank	https://www.vdv.de/
Bloomberg	https://www.bloomberg.com
Wikipedia	https://en.wikipedia.org
eMobilität - der Blog	https://emobilitaetblog.de/
Kompass	https://de.kompass.com/
Firmendatenbank	http://www.firmendatenbank.de/

Continued

Database Name	**URL**
Firmen in Bayern	https://firmen-in-bayern.de