Modelling Ecosystems in Information Systems – A Typology Approach

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Abstract. Ecosystems as a modern concept of interorganisational networks are often discussed in current information systems research. There is a lot of investigation in the field of behaviouristic information system research. However, when designing ecosystems there is not much guidance and methodical support. In particular, modelling methods as a specific methodical support for ecosystem design are rare. Based on a literature review, this paper introduces specific types and characteristics of ecosystems. As a first step towards a comprehensive modelling framework, we use these types to propose views for the modelling of ecosystems. The framework organizes the modelling of ecosystems in three aspects: goal modelling, ecosystem modelling and platform modelling.

Keywords: ecosystems, platform, design, literature review, modelling

1 Introduction

Researchers in information systems propose networks of independent actors that they name as an "ecosystem" [1–3]. Ecosystems have become a popular research object and an often-used term for distributed networks of independent industrial partners and their technology. Even in practice and funding politics, ecosystems have become a design goal of innovative projects (e. g. [4]).

An uprising challenge is to design and engineer information technology (IT) artefacts that form ecosystems. However, in practice as well as in research the concept of ecosystems is often used without specifying why an implemented system is understood as an ecosystem and how this system achieves specific effects that are associated with the concept of ecosystems. Therefore, in each project, the expectations that are comprised in the idea of ecosystems have to be specified.

In economics, ecosystems are defined as evolutionary self-organizing cross-industrial systems of independent economic actors that are connected by value-added chains and behave similarly to naturalistic systems [5, 6]. General expectations towards ecosystems are postulated in a range of publications. These publications focus on the governance [7, 8], the business models and strategies of ecosystems [9–11], the architecture and properties of ecosystem components [12, 13] and the relationships between the participants of an ecosystem [14–16]. However, different term conjunctions describe specific types of ecosystems (e.g. software ecosystem, platform ecosystem, business ecosystems) that are bound to different ideas how these systems are structured and how they behave. Consequently, a construction of ecosystem architectures and a modelling of ecosystem-creating artefacts cannot be conducted without taking into account these different types of ecosystems. Moreover, the differences between them may lead to differences in the design implications of the underlying artefacts. However, prior research of ecosystems in information systems is primarily located in the field of behaviouristic research. Concrete guidance for artefact construction and modelling of ecosystem-building artefacts is rarely available. For example, ADOMAVICIUS ET AL. propose an IT ecosystem model to evaluate IT landscapes, but lesser describe design models for the engineering of ecosystems [17]. Some papers investigate the properties of specific types, like software ecosystems [18, 19] or business ecosystems [20, 21] and create taxonomies. Yet, there is a little investigation on how different ecosystem concepts lead to different ecosystem-building artefacts and how we can represent them in an adequate architectural model. Though, there are some authors proposing modelling and visualization approaches [22–25]. They focus on specific dynamics or specific configurations of ecosystems. So far, the diversity of ideas about ecosystems is rarely considered when modelling ecosystems. A comprehensive framework which systematizes the modelling aspects of ecosystems is missing. We argue that a systematization of types of ecosystems in information systems helps to derive these modelling aspects. Therefore, we question which aspects must be considered when specifying ecosystem models with a design-oriented lens. Based on a literature review, we contribute by providing a comprehensive understanding of different ecosystem types and derive views for a modelling framework from their characteristics.

This paper is structured as follows: In section 2 we introduce our literature review and the research questions. In section 3 we systematize seven types of ecosystems as ideal-typical forms. For these types, we explain common characteristics. In section 4, as an initial step towards a modelling framework, this paper concludes with a proposal for an ecosystem modelling that is based on the different types of ecosystems.

2 Literature Review

The literature study was conducted using a top-journal oriented literature analysis [26] based on the German VHB Jourqual ranking, which contains all journals that are also in the AIS senior scholars basket. We selected all publications with the ranking of A and A+. Even if an initial focus on top-rated journals restricts the view to dominant understanding of ecosystems, it is one possible point of origin to identify the predominant discussed archetypes. Additionally, we included the most important IS conferences (ICIS, ECIS, AMCIS, PACIS, ACIS). This ensures that recent changes in understandings of ecosystems are also considered. Furthermore, the conference "Wirtschaftsinformatik" as well as the journal "Business & Information Systems Engineering" (BISE) is included to consider design-oriented information systems. *"ecosystem*"* was used as search term. We applied ot to the title, the abstract and the keywords. We used Thomson Reuters WebOfScience and AIS Electronic Library, because these databases index the publications of the named rankings and conferences. Based on the abstracts we selected the publications which directly discuss ecosystems. We rated all papers as relevant except those that focus on ecosystems in the sense of an environmental or biological view. We conducted an analysis of the ecosystems definitions in the remaining papers. In order to conduct the literature study, we have formulated two research questions:

(I) Which types of ecosystems are discussed in information systems research?

(II) Which implications for design-oriented modelling of ecosystems arise from the characteristics of these types?

We excluded papers that did not discuss the characteristics of ecosystems. Finally, we identified 163 papers. Table 1 gives an overview of the number of papers for each year. We have done a full-text analysis for papers that directly discuss the concept of ecosystems. For papers that apply the concept of ecosystems (e. g. ecosystems in payment) or analyse a specific property, we analysed the sections where the concept of ecosystems is explained. Subsequent, we identified dominant types of ecosystems which are mentioned more than one time by different authors. Specific types were assigned to a more abstract type (e.g. mobile platform ecosystems to platform ecosystems). After identifying the types, we inductively identified characteristics during the text analysis. We used two primary characteristics two describe two dimensions in which we assigned the different types of ecosystems. We derived *implications for modelling* ecosystems from these characteristics. These implications for modeling provide guidance to create the modelling framework with different modelling views.

Table 1. Overview of publications discussing ecosystems in IS journals and conferences

Publicat.	*2000*	*02*	*03*	*04*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*#*
AMCIS	1		1					3	2	1	3	1	3	4	7	6	32
BISE										1	1				1		3
DKE						1											1
ECIS		1			1		1	1		1			5	5	7	8	30
ICIS							1	2	1	1	1	2	4	8	11		31
ISJ												1	1		1	1	4
ISR									2		1			1			4
JAIS												2		2			4
JIT					2			1	1			1	1	4			10
Strateg. IS				1							1				1		3
MISQ							2				1	2		3	2	1	11
PACIS							2		1	4	1	1	2	3	5	5	24
WI								1		1				3		1	6
# p. a.	**1**	**1**	**1**	**1**	**3**	**1**	**6**	**8**	**7**	**9**	**9**	**10**	**16**	**33**	**35**	**22**	**163**

3 Systematization of Ecosystems in Information Systems

In the following, we describe the identified types and assign them to two specific dimensions. Based on the identified types we synthesize a systematization for ecosystems which is outlined in figure 1. We observed different concepts in ecosystems and different characteristics that can be assigned to each type. Two principal characteristics are discussed in a broad range of papers: the social entities in the ecosystems and the platform as a focal component. From this, we derived two dimensions of ecosystem design: system types and platform focus. We assigned the different types of ecosystems to these dimensions. Furthermore, for each type, we annotated additional characteristics that are emphasized in the literature and discuss them below. These represent different dynamics that are expected in ecosystems.

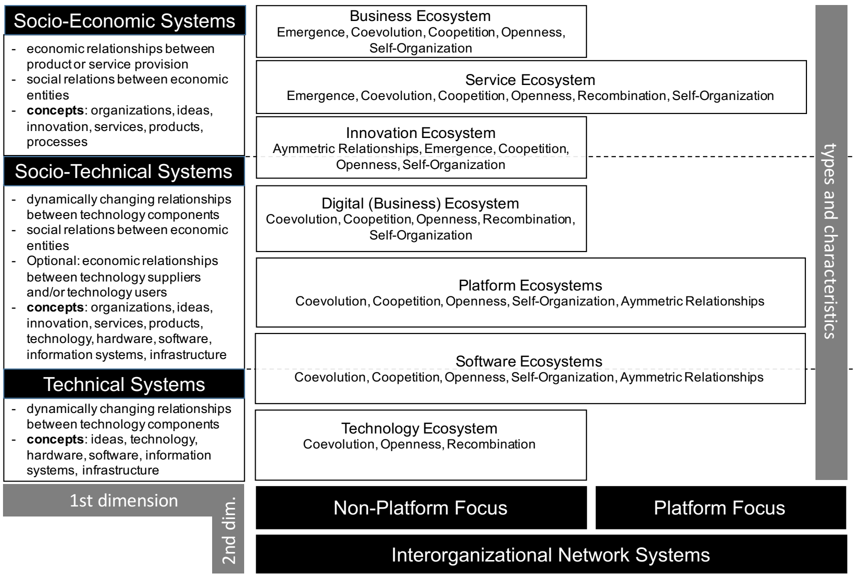

Figure 1. Systematization of ecosystems research in information systems research

3.1 Predominant Types of Ecosystems

Business Ecosystem: Business ecosystems were initially described by MOORE and by ROTHSCHILD [5, 6]. They were established in the context of economic and organization sciences but occur also in the information systems literature. Business ecosystems are defined as networks of organizations that are formed around a central innovation [6], technology or company [27]. The main focus is to establish economic relationships between the different participants around a focal technology. The existing research focuses *on actors, the relationships between them* and the *(economic) effects*.

Digital Ecosystem: A digital ecosystem is a business ecosystem, based on an organizational network in the context of a digital technology [10]. Digital ecosystems are *formed on the basis of digital objects (digital content, products, ideas, software, hardware, infrastructure)* that are interchanged and shared between *independent actors* [28, 29]. In this context, the term digital business ecosystem is also used, where the economic aspect in the sense of the business ecosystems is more emphasized [10, 21].

Innovation Ecosystem: Innovation ecosystems are networks of companies that share knowledge (skills and technology) to create innovation and to provide it to consumers [30]. In such ecosystems, the *shared set of skills and knowledge* forms the foundation for new business and entrepreneurial opportunities [31]. This kind of ecosystems can be considered as communities as well as business networks [32]. Both, the innovators as well as the innovations play an important role.

Platform Ecosystem: Platform ecosystems emerge around a focal platform [14]. The platform provides a combination of *hardware, software and infrastructure* as well as *organizational and social rules* that connect actors around the platform [7, 14]. A platform owner (platform sponsor/provider) controls the platform and consequently influences the ecosystem [33]. Through the establishment of platform ecosystems, additional offers for end users are created which the owner of the platform cannot or does not want to offer [34]. Platform ecosystems may emerge from existing products. This can happen also unintendedly [35]. By the provision of user-adequate *boundary resources*, the platform providers enable platform users to participate [13, 36].

Software Ecosystem: The software ecosystem emerges analogue to the platform ecosystem around a *software technology* (e.g. a browser) or *a combination of software and hardware* (e.g. a smartphone). The distinction between platform ecosystem and software ecosystem is blurred. TIWANA [7] uses the term "platform based software ecosystems" as an equivalent to "platform ecosystems". Actors in software ecosystems can contribute new software components and services [16]. A distinction is possible using the contribution of hardware in the ecosystem as a criterion. Software solutions of actors play the central role in software ecosystems [19]. There are existing literature reviews on software ecosystems from the perspective of software engineering [18, 37].

Technology Ecosystem (IT/ICT Ecosystem): Technology ecosystems describe a *set of information technologies* that share a certain common context of usage and are connected to each other. The technologies mutually interfere with each other and are able to play different roles in the context of the ecosystem (products, applications, components, infrastructure) [17, 38]. Actors do not play a key role and are not a component of the ecosystem. Technology ecosystems focusing on *the relation of technology* [17].

Service Ecosystem: Service ecosystems are shaped by an *exchange of services* within the ecosystem. Due to this exchange of services, the integration of resources as well as a common creation of value by the different connected actors is realized [39].

Implication for Modelling: Allow modelling of technical concepts (software, hardware), conceptual non-materialistic concepts (ideas) and business concepts. Provide modelling facilities for boundary resources.

3.2 First Dimension: System Types

The first dimension describes the differentiation between socio-economic systems, socio-technical systems and technical systems. These differentiation results from the different types of ecosystems that represent specific views to an ecosystem (business view, technology view etc.).

We perceive socio-economic systems as systems which comprise social relationships and economic decision-making entities with specific operating characteristics [40]. Business ecosystems, innovation ecosystems and service ecosystems are considered as socio-economic systems by scholars because their focus is on the relationships between the actors and their value-creating concepts which may be products, services or knowledge (ideas). As socio-technical systems, we understand systems that comprise decision-making social entities like humans or enterprises as well as technical-components [41, 42]. Socio-technical systems can be understood as a result of the interdependence of technical systems and social systems [43]. Digital ecosystems, platform ecosystems and software ecosystems are socio-technical systems that comprise social actors and technical components that have reciprocal relationships. Innovation ecosystems can be socio-technical systems if they focus on technological innovations as system components and can be socio-economical systems if ideas and concepts are in the focus. Technical systems comprise only technical components as entities with reciprocal relationships. However, these types of systems may be subsystems in a social context, but the technical relationships and units are emphasized [44]. For each of the system types, the emphasized concepts are named in figure 1.

Implication for Modelling: Model the social actor's needs, organizations, socio-technical structures and behaviour as well as technical components and technological relationships on different modelling layers [43].

3.3 Second Dimension: Platform Focus

A second dimension is the distinction between platform focused and non-platform focused types of research. Ecosystems with non-platform focus do not exclude platforms but emphasize the actors and components around the focal platform. Regarding this characteristic, we observed that in several types, platforms are generally defined as focal components of ecosystems that provide a clear ruleset and boundary resources [36] to access the ecosystems. Therefore, a stream of research focuses on the design of platforms [7, 11, 13, 14, 34, 36, 39, 45]. In these papers, explicit characteristics of the focal components are described. In contrast, some researchers are not focusing directly on the characteristics of platforms even if they often name a central platform [10, 21, 22, 29, 46–48]. Thus, it can be argued, that the authors, who name those types of ecosystems, emphasize the socio-economic or socio-technical relationships in the platform environment (e. g. common goals of ecosystem participants). There are also authors who mention platforms despite their view is more abstract [28]. For example, an innovation ecosystem may emerge around an existing network of companies and may have a platform, but the focus is on the characteristics of entrepreneurs [31]. Other authors also combine a platform focus with the analysis of the actors [16, 49]. Thus, every type can be used as a subject of research in studies which does not focus on the platforms but on the environment.

Implication for modelling: Differentiate between platform modelling and ecosystems modelling.

3.4 Characteristics of Ecosystems

In table 2 we describe the different characteristics of ecosystems that were gathered in the literature review. For each characteristic, we identify implications for modelling of ecosystems. These are used to derive views for modelling in section 4.

Table 2. Characteristics and implications for modelling

Characteristic	*Description*	*Implication for Modeling*
Asymmetric relationships	- asymmetry (unilateral dependency) between platform owner and ecosystem participants - focal authority controls the ecosystem - control of the ecosystem with direct and indirect measures [7, 33, 50]	Model governance measures, direct influences measures and power relationships.
Emergence and Generativity	- unpredictable development of the whole ecosystem for all actors - generativity as a property to allow unanticipated changes[7, 24] - unanticipated relationships may develop over time, environment is turbulent, emergence as the characteristic which means the systems structure and behaviour is not predictable [20, 39, 46].	Provide an extension mechanism for new modelling elements to consider unpredicted actors, social-structures and technologies.
Coevolution	- actors cause effects on other actors as well as on the ecosystem as a whole [39, 51] - adaption of individual system components result from changes of other components [6] - constant screening of the environment by each actor due to ongoing evolution = continuous reinterpretation [7, 39]	Model temporal ecosystem development, mutual dependencies, mutual information flows and technology interaction.
Cooperative behavior	- integration of actor-oriented resources to create shared value [39] - contribution of knowledge, content and technological solutions to all actors [7, 52–54] - symbiotic relationships [10], social rules [39] and a common view [7], mutual trust [21, 52]	Model the business models and their combination by different partners.
Competitive behavior	- performance- and value-oriented behaviour between different ecosystem actors [5] - evolutionary-like competition [14] ("predators and prey" [6]), replacement and suppression of actors [46], egocentric behaviour [21] - two-sided markets [16, 49, 53, 55]	Model economic relationships and mutual competition relationships.
Coopetition	- the simultaneous presence of competitive and cooperative behaviour [6, 56].	Integration of cooperation and competition modelling
Openness	- number of system components (actors and technology) is dynamic - new components may enter the ecosystems, other components may leave it [11, 39, 57] - different levels of openness are possible - interoperability is a base of openness [28, 33]	Describe openness measures in the platform architecture, assign levels of openness to technical components.

Recombination	- similar to recombination in nature, ecosystem components (e.g. ideas, services and products) are combined to new components [47, 58] - resource integration leads to innovation, innovations are used in further innovation cycles [39]	Realize a component oriented modelling and allow business interface modelling.
Self-organization	- direct control of ecosystem actors is impossible - actors possess freedom of action within the governance limits and may act independent [7, 39] - self-regulation [51] of relationships between actors, adaption to the environment [22, 58] and unsolicited transition of the ecosystem [54]	Model individual goals and restrictions for each actor.

4 A Proposal for an Ecosystem Modelling Framework

Ecosystems as networks of independent actors cannot be designed directly [7, 59]. Using a design-oriented lens, a focal component, the platform and its boundary resources play the dominant role when engineering ecosystems [13]. The most authors, even those who discuss business ecosystems, mention a focal platform. Therefore, a modelling framework for ecosystems should comprise the aspect of platform modelling. In figure 2 we outline a basic dependency model that describes the relationship of the ecosystem and the concrete platform design measures. We use it to derive modelling aspects. The dynamics that occur in ecosystems are directly influenced by governance measures and a platform architecture [7]. This creates a solution space which should be modelled. The initial spark for the set-up of an ecosystem comes from the business environment and the intention to enable ecosystems dynamics [24, 59]. The intentions to create an ecosystem may differ, therefore a modelling approach should consider the modelling of the basic design objectives (aspect 1). The second aspect focuses on the direct system modelling of the platform (solution space: platform strategy and design). The third aspect focus on modelling of the relationships between the participants of the ecosystems, the relationships and the effects that occur in the ecosystem.

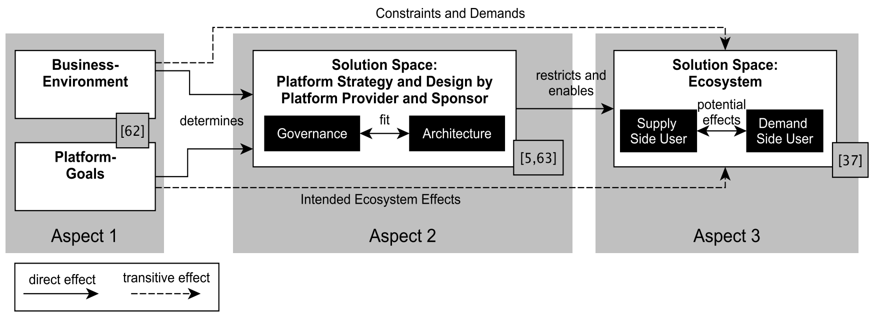

Figure 2. Dependency model for ecosystems, based on [7, 33, 59, 60]

In figure 3, we outline a basic modelling framework for ecosystems with different model types. The model aims to support ecosystem construction by separating different aspects of ecosystem specification. The first aspect, the goal modelling, describes two types of goal models and a restriction model: The internal goal model describes the motivation of the platform sponsor to set-up an ecosystem while the environmental goal model specifies the objectives for the participants in the ecosystems.

In contrast, the restriction model explicates the constraints and negative effects that may hamper the goal achievement. The modelling of the ecosystem comprises the modelling of ecosystem participants, the relationships between the participants (socio-economic layer), the value-creating concepts (ideas/products/services, socio-technical layer) that are combined in the ecosystem and the basic technological components and their relationships (technical layer). Supplementary to these structural aspects, the modelling approach considers the dynamics that occur in the ecosystem. For example, it should be modelled to which relationships describe coevolutionary effects. The definition of these dynamics could be specified by the concrete business processes that occur between specific types of actors. For example, to get a more detailed view to coevolution between two partners it should be specified how they combine specific ideas, products or services. The technology-layer focuses on how the business processes are integrated. The platform model describes the boundary resources as well as the technological architecture and the governance measures for ecosystem participants. In this aspect, the measures, that enable concrete ecosystem dynamics, should be modelled. They have direct influence on possible business models and the technology.

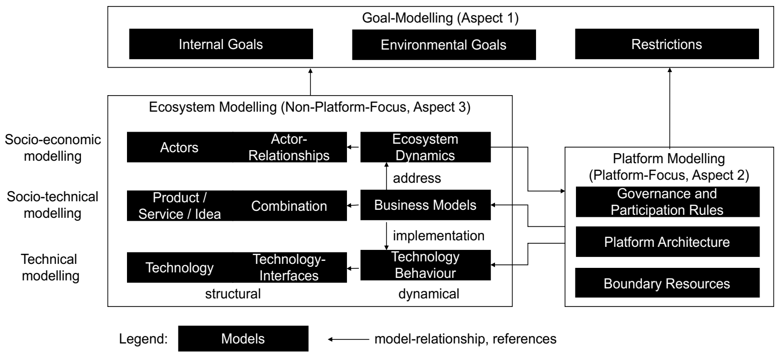

Figure 3. Proposal for conceptual modelling framework for ecosystems

5 Conclusion

This paper analyses how ecosystems are currently understood in information systems research. It systematizes seven dominant types of ecosystems and outlines a modelling framework. However, in our literature review, we found that seven types are often used synonymously. The use of a specific type is associated stronger with an emphasis on specific characteristics than a clear typology of ecosystems. Applying a design-oriented lens, platform ecosystems are dominant in information systems research. Nevertheless, when engineering ecosystems the use of the types may help to specify different design dimensions. Furthermore, the identified characteristics may help to formulate evaluation criteria for designed artefacts. The outlined modelling approach for ecosystems can be used for research to create a view-based architecture framework for ecosystems and may also provide a basis for architectural modelling. For this purpose, existing enterprise architecture frameworks should be considered. Existing modelling methods should be analysed for their ability to be used in ecosystems modelling. An evaluation of the proposed modelling framework is planned for further research. However, a methodical support for modelling is needed. In particular, there is a need for guidance how specific architectural measures can be obtained from the goals in aspect 1.

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