CONCEPTUALIZING INFORMATION SYSTEMS AS BIOLOGICAL ECOSYSTEMS - A ”NEW” VOCABULARY FOR SPEAKING OF INFORMATION SYSTEMS

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Biological ecosystems and related concepts are well known and have been used for a long time, also outside of the ecology context. In this conceptual paper, we explore the use of biological ecosystem concepts as a new lens to understand and analyze information systems. We propose that applying a frame of reference from a different discipline enriches information systems analysis in several ways, firstly through broadening the perspective of information systems, secondly by offering connections to phenomena and areas that were previously outside of the scope of the information system, and lastly through offering a new viewpoint on actors, roles and functions within an information system. Further research is needed to deepen our understanding of the information system ecosystem and apply this approach to other business activities.

Keywords:
biological ecosystem,
ecosystem,
information system,
information system ecosystem,
socio-technical system

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1 Introduction

Digital transformation represents a new chapter in the human-technology relationship, disrupting traditional structures, logics and models (McAfee & Brynjolfsson, 2017). One example of such changed logics and models are internet enabled platforms where companies leverage digital technologies and collaborate in order to create and deliver an increased value proposition (Cusumano et al., 2019; Libert et al., 2016; Parker et al., 2016). Such platforms are often described as digitally enabled ecosystems inhabited by people, organizations and resources (Parker et al., 2016; Fehrer et al., 2018). At the core of platform business models are information systems.

As information systems are very much a prerequisite and backbone of the ongoing digital transformation of organizations and society, their role and the way we think about them have not been excluded from being challenged, on the contrary. This has initiated a call from the information systems research community for a new or extended vocabulary in order to gain a richer understanding (Nischak et al., 2017; Benedict, 2018; Guggenberger et al., 2020). Alongside of the digital transformation, however not dependent on it, a discussion about ecosystems as a framework of understanding complex phenomena has emerged. This is very much related to an increased conversation on ecosystems from a biology and ecology perspective as climate issues have become more and more visible and critical. Ecosystem is about seeing wholeness and the term was originally coined by the English botanist Arthur G. Tansley (e.g., Tansley, 1935; Tansley, 1939) after suggestions from A. R. Clapham (Willis, 1997, p. 268). The concept of ecosystem has subsequently been developed and applied also in other fields outside of ecology. According to Adner (2017, p. 40) ecosystems can be explained as "the alignment structure of the multilateral set of partners that need to interact in order to focal value propositions to materialize". The use of the ecosystem concept within information systems research has increased over the years and several authors have stressed the ambiguity of the concept seeking to provide theoretical synthesis in order to increase relevance (Nischak et al., 2017; Benedict, 2018; Guggenberger et al., 2020).

The purpose of this paper is to explore the concept of information systems through the lens of biological ecosystems, in order to gain a richer picture of information systems as well as to contribute to the understanding of how biological ecosystems can be used as a blueprint to understand complex phenomena. We explore how concepts from biological ecosystems can be applied to the analysis of information systems, focusing on concepts describing ecosystem actors, environment and presumptions. Our proposed contribution is conceptual. More specifically, we aim at offering an alternative view; "to see something that has been identified in a new way", called *revising* by MacInnis (2011, p 138). MacInnis uses the metaphor of a person turning a kaleidoscope to reveal new perspectives to describe conceptual work of this type: we use a different frame of reference and view on a previously identified phenomenon. To do this, MacInnis suggests researchers can make use of novel metaphors – in our case biological ecosystem metaphors – and to seek new vantage points from other disciplines. Our work can also be understood through a design science lens. March and Smith (1995) state that constructs or concepts are one possible type of output or artifact from design science. The authors emphasize the importance and impact of terminology as tools for describing and thinking in a field. Hevner et al. (2004) outline seven guidelines for the design science research process. In line with these guidelines and within the scope of this article, we present a novel conceptualization, argue the relevance and contribution of our proposed vocabulary, offer a descriptive evaluation of it, and suggest steps for further research.

2 Ecosystems in business and information systems literature

Research has linked various aspects of biological and ecological theories to business contexts in various settings to compare, analyze and shed new light on current practices and business theories. Most frequently it has its ground in using the biological ecosystem as a metaphor or analogy to other contexts. Biological ecosystems and evolutionary perspectives in business studies have focused on innovation, entrepreneurial, knowledge, organizational, and industrial ecosystems (e.g., Ghazinoory et al., 2021; Kuckertz, 2019; Pilinkienė & Mačiulis, 2014; Blijleven et al., 2013). A heap of research has been made synthesizing innovation ecosystems and its analogy to biological ecosystems or ecology theories (Shaw and Allen, 2018; Geng and Côté, 2002). Mars et al. (2012) states that the ecosystem metaphor "is a useful tool for understanding and predicting the conditions that shape and influence organizational systems." (p. 279). Criticism towards using the term eco in innovation ecosystems has been voiced e.g. by Oh et al. (2016), where a flawed analogy to the biological ecosystem is debated. The dangers of using the analogy for innovation research is that the ecosystems are designed rather than evolved in this case, and include a variety of definitions and variations that may confuse. Ritala and

Almpanopoulou (2017) instead defend the analogy and discuss some of the critique by Oh et al. (2016) suggesting that the term may be needed in understanding theory and practice. McMullen (2018) did a thought-experiment by deconstructing certain concepts in business and compared it to biological terms to shed new light on hybrid organizations. Some research has also focused on how business innovation ecosystems co-evolve and the role innovation has in them (Breslin et al., 2021), or looked at symbiotic relationships (Yoon et al., 2022). In the digital realm where other rules reign, problematization and discussion of the view of ecosystems has occurred (Márton, 2022). Briscoe and De Wilde (2009) imply that a digital ecosystem is to be regarded as a digital counterpart of biological ecosystems. They describe digital ecosystems as software systems that are robust, scalable, and self-organizing to meet users' demand for digital services. Romero and Vernadat (2016) emphasize that an Executive Information System (EIS) contains a digital ecosystem where many information systems, sometimes hundreds, are included. There are several publications on ecosystems with a focus on information systems, information technology and information communication technology (ICT) (e.g. Anjum, 2023; Bash et al., 2008; Basole et al., 2015; Brummermann et al., 2011; Brummermann et al., 2012; Chamberlain & Said, 2022; Changjun & Hongbum, 2018; Diga & May, 2016; Karl et al., 2020; Schramm et al., 2012). While the ecosystem concept is commonly used, definitions vary greatly and are not established.

3 Information systems and biological ecosystems

3.1 Information systems as socio-technical systems and core concepts

Information systems collect, process, store and share information in order to support decision making and purposeful action in organizations. Information systems are frequently characterized as socio-technical systems consisting of technology and data (the technical sub-system), people and processes/tasks (the social sub-system); these separate components interact and together form a complex system (Figure 1). The socio-technical perspective enables a more nuanced understanding of both possibilities and problems surrounding organizational technology use. For example, investments into IT frequently fail. The reasons behind failure can be organizational or social rather than technical, or the reasons might be entanglements of technical and social reasons; socio-technical thinking is a useful framework for analysis in this context (Baxter and Sommerville, 2011). When working with complex real-world systems, using socio-technical approaches instead of traditional systems development methodologies is necessary (Wu et al., 2015). For actionable insights, socio-technical systems need to be modelled which has proven difficult due to e.g. the complexity of the systems, and the inter-disciplinary nature of socio-technical systems leading to a scattered research field. Consequently, methods for socio-technical analysis remain immature (ibid.) and central concepts underdeveloped (Millerand and Baker, 2010).

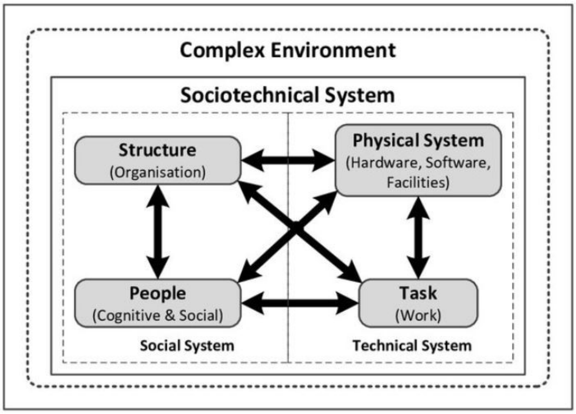

Figure 1: Sociotechnical system
Source: (Oosthuizen & Pretorious, 2016)

For example, when discussing the People component of socio-technical systems, the concept user is an established term to describe the individual who is making use of the system. The user concept has, however, been criticized e.g. for being narrow and simplistic, and for creating an artificial separation between users and developers (Lamb & Kling, 2003; Millerand & Baker, 2010). Within the Work System Framework, instead of 'users', the concepts of participants and customers are used to describe the people working with the system (Alter, 2004). Participants encompass those individuals who perform at least part of the target business process, and customers are people who receive benefit from the products or services produced. In another twist, Actor-Network theory makes use of the concepts actor and actant to denote both human and non-human elements participating in a network (Hanseth et al., 2004). In other words, by using different concepts and definitions for the people involved with the information system, we can examine the same phenomena from different viewpoints and gain new understanding. Hence, in section 4 of this paper we explore how concepts derived from biological ecosystems can be applied to information systems in order to gain novel insight. In the following section we overview a selection of biological ecosystem concepts.

3.2 Biological ecosystems and core concepts

In biology, an ecosystem includes all living things with their habitat within an area. An ecosystem has properties of self-organization, scalability, and sustainability. An ecosystem is self-regulating and consists of independent actors with selfish interests acting in an overall functioning environment. In addition to its internal integrity, an ecosystem can be affected by external factors. The word ecosystem consists of the two concepts ecology and system. Ecology, a nomenclature, includes an interaction between what lives, i.e., the biotic, and the non-living, i.e., the abiotic. A system is several parts that are connected to each other and that together form an ordered whole. In summary, the biological ecosystem consists of a biotic component, containing Organism and Function, and an abiotic component, containing Presumption and Habitat. The two components have interaction both between and within, furthermore they occupy a physical space (e.g., NE, 2023; Adner, 2017; Dhillon et al., 2013; Guggenberger et al., 2020; Nischak et al., 2017; Transley, 1939; Willis, 1997). There are different ways to describe the next order of principles in the biological ecosystem, one way is shown in figure 2. To clarify the meanings and content of an ecosystem, the Baltic Sea ecosystem is presented below.

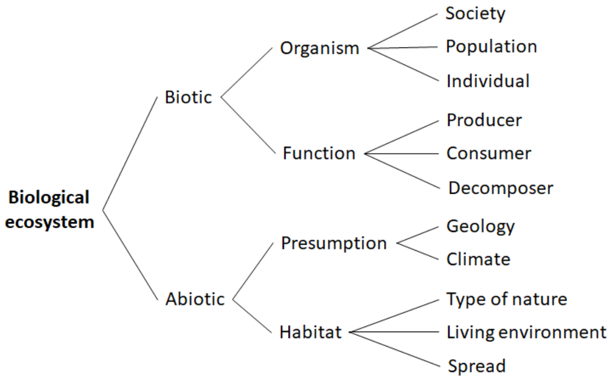

Figure 2: Principles of a biological ecosystems top three levels

The notion Biotic means living and can be divided into society, population and individual. A society contains all populations of different living species within a geographic area. In our example the society is all living species inhabiting the Baltic Sea. A population is a group of individuals belonging to the same species, living in the same area and interacting with each other. An example of a population in the Baltic Sea is a shoal of Baltic cods. An individual is the individual animal, for example an individual Baltic cod.

Organisms in an ecosystem can perform the functions or roles of producer, consumer and decomposer. These functions are key enablers for the circulation of energy within the ecosystem. A producer can, e.g., by using photosynthesis, transform energy into food, both for themselves, and for other organisms. In the Baltic Sea ecosystem, planktonic algae act as primary producers (John Nurminen Foundation, n.d.). Consumers are the animals and fungi that cannot produce their own food. The Baltic cod is a consumer in the Baltic Sea ecosystem. Decomposers break down dead plants and animals, and release energy back into circulation. Main decomposers in the Baltic Sea are various aerobic and anaerobic bacteria (Furman et al., n.d.).

Abiotic means nonliving and is dependent on Geology and Climate. In the Baltic Sea ecosystem, the abiotic are for example seabed, water and seacoast. Geology deals with the outer covering of the planet earth (the Lithosphere i.e., the earth's crust with the upper mantle). This casing covers soils and how they are composed and structured, to which over time is added development. Here it is possible to present stones, bedrock, sand and mud to mention a few.

Climate controls the weather and is a combination of physical average atmospheric conditions over a longer period for a geographic area. This includes, e.g. humidity, temperature and wind. The climate is naturally affected by e.g., the sun's radiation and the tilt of the earth's axis. It is also affected by human activities such as emissions of greenhouse gases and deforestation. A warmer climate leads, among other things, to increased water levels, stronger storms, and changing seasons.

A nature type has common flora and fauna within a geographically defined area. Examples of Swedish nature types are deciduous forest, coniferous forest, and mountains. The Baltic cod lives in brackish water. The biological habitat is the sum of the external circumstances that an individual needs in order to survive. The habitat for the Baltic cod is overfertilized, contains environmental toxins and suffers from overfishing of e.g., Baltic Herring. Spread is the geographical area within which a species is found; the Baltic cod exists only in the Baltic Sea.

4 Information systems as ecosystems

Considering the concepts of information systems and biological ecosystems side by side, some similarities emerge. Both information systems and biological ecosystems are inherently complex and challenging to understand. Information systems consist of multiple layers of technology, people and social structures, and biological ecosystems consist of multiple species and environmental factors. Changes in any of the separate components of the biological ecosystem or the information system impacts all parts of the system. Furthermore, the flow, exchange and transformation of energy is the focal function of an ecosystem - the flow, exchange and transformation (or refining) of data is central to the information system. Some concepts originating from biological ecosystems are already used in discussing information systems, especially holistic, behavioral concepts such as feedback loops, equifinality and adaptability. Even so, some authors suggest that the information systems discipline has done too little to understand the system nature of information systems, and in practice too often focusing on the technology as a tool (Alter, 2004). We suggest the use of ecosystems concepts by adapting terminology describing organisms, functions, presumptions and habitats as outlined in figure 2 to the information system. As a practical illustration we describe the concepts in the context of how the Ladok system is used by Linnaeus university in Sweden. Ladok (2023) is a Swedish national system that provides 40 Swedish universities with support in the study administrative work and is used by students, teachers and administrators. Ladok is used to store information about students' attendance, results and other data (Ladok, 2023).

The division made within ecosystems theory between biotic and abiotic subsystems bears a resemblance to the division often made within socio-technical systems and its social and technical subsystems, the biotic component corresponding to the social, and abiotic corresponding to the technical subsystem. Taking the analogy further, we explore the use of the biotic components organism and function and the abiotic components presumption and habitat to describe and understand an information system (Figure 3). Doing this, a new, enriched picture of the information system emerges, distinct from and complementary to previous socio-technical and system modelling approaches. We propose using the term organism in order to depict the character and nature of stakeholders/actors that use, contribute, as well as benefit from the data provided by the information system. When viewing Ladok through this lens, we can identify individual stakeholders, such as university teachers using the system to enter grades; intra-organizational stakeholders such as different faculty departments and educational programs using the system in order to achieve organizational goals; inter-organizational stakeholders such as funding and accreditation bodies using data from the system in order to validate and ensure quality.

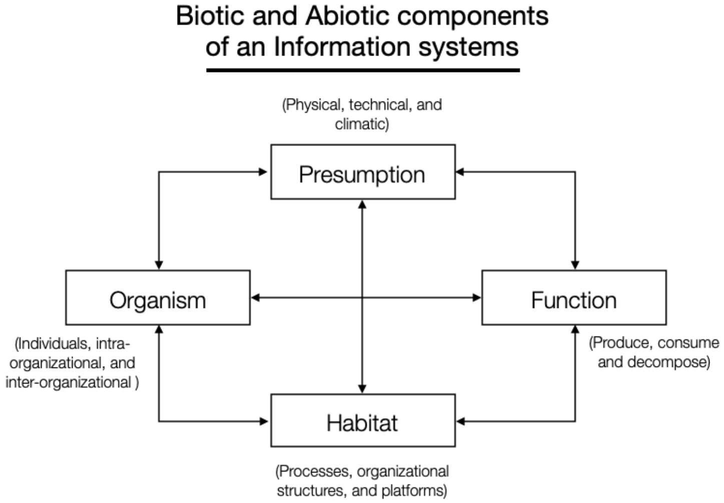

Figure 3: Components of the biotic and abiotic subsystems

The function component is defined as the activity areas or roles enabling the flow of data within the information system and consists of the activity roles: producer, consumer and decomposer. The activity role of producer depicts and concerns how data is put into the system; the activity role of consumer depicts how data is extracted from the system and presented; the activity role of decomposer depicts how existing data is refined, mined, combined and analyzed in ways that enable new understanding. The different stakeholders identified within the organism component each, concurrently or at different times, could hold the different roles of producer, consumer or decomposer of data. For example, an individual teacher is both a producer of data when registering course grades, and a consumer of data when accessing student course registrations ahead of an upcoming course. The biotic components of an information system provide a greater understanding of the who (organism) and why (functions) of information systems. Turning to the abiotic subsystem, here we investigate the conditions under which the information system operates. The presumption component consists of geology and climate and depict physical, technical and climactic aspects affecting the flow and use of data in the information system. Geology of the information system refers to the tangible infrastructural and technical aspects necessary for the information system to function, such as network infrastructure, hardware and software. Climate, on the other hand, refers to both tangible aspects (e.g. boundaries set by government, industry and organizational regulations and guidelines), as well as intangible aspects (e.g. strategies and culture on both an organizational and national level).

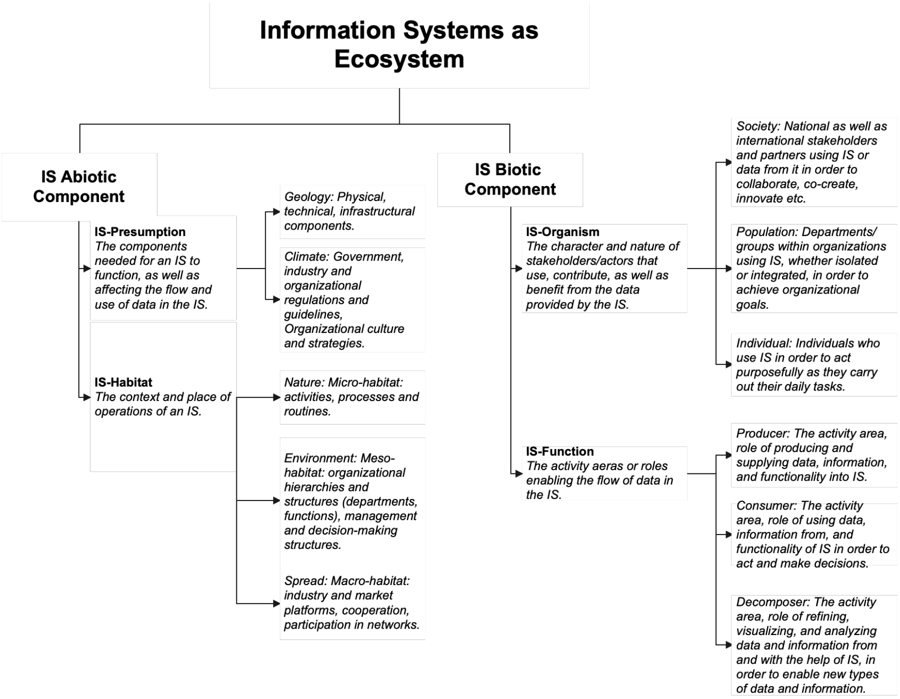

Figure 4: Principles of information system as an ecosystem, top three levels

The habitat component depicts the environments which constitute the context and place of operations of an information system. Firstly, there is the micro-habitat (type of nature) which constitutes organizational processes, routines, and activities where the information system is intended to provide support and be used. Information systems are typically used with the purpose to enforce, improve, or automate processes, related to the previously mentioned functions of producing, consuming, and decomposing data. In the Ladok example, there are the processes related to gathering and storing student credit data. A practical consideration is that processes with the same goal might be enacted differently at different faculties of the university, or at geographically separate campuses. Secondly, there is the meso-habitat (living environment), which constitutes organizational and decision-making structures and hierarchies, as well as interactions between different information systems. At the meso-habitat level the focal point of information systems is the support of, and alignment, with organizational or company-wide functions, strategies, and goals. Thirdly there is the macro-habitat (spread), which constitutes industry and market platforms, participation in networks etc. It is very much the external context in which information systems support the expanded organization, enabling cooperation, coopetition, and a sustainable competitive position. In our example, the Linnaeus university is a member of the Baltic University Program, a collaboration between 90 universities in the Baltic Sea region requiring the exchange of data between information systems to for example fulfil reporting requirements. The abiotic components provide a greater understanding of the what and where (habitat) as well as the how (presumptions) of an information system. They enable a rich picture of both the context and outcome of information systems, as well as the nature and character of needed infrastructure.

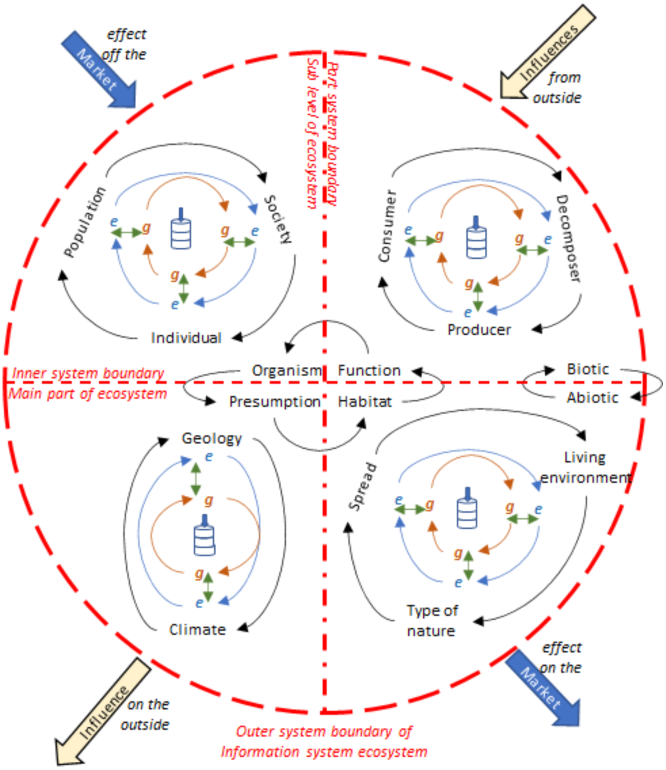

Figure 5: Three levels of circulation in information system ecosystem

When analyzing any system, a holistic view and investigating interdependence of the components are central (Figure 5). For example, while the organism component is useful to identify internal and external stakeholders, further insight is gained when considering how different stakeholders engage with the information system through the function component (producing, consuming and decomposing data). A deeper level of understanding is then gained when analyzing connections and interactions between sub-systems or components of the system at hand. The information system ecosystem has a system boundary providing an interface with an external environment. This environment affects and is affected by the ecosystem. The ecosystem with its biotic and abiotic components constitutes a constant, ongoing circulation, iteration, and/or feedback of data in and between all levels in an information system ecosystem. Data then becomes the heart of an information systems ecosystem. In figure 5 the example of Ladok is used to illustrate this complexity. The dashed line depicts outer, inner, and sub level boundaries. Furthermore, "e" stands for education and "g" for Ladok as a grading application.

5 Conclusion

We believe the biological ecosystem concepts give new insights as compared to traditional information systems analysis concepts. Ecosystem analysis goes beyond processes, taking into consideration also structures and hierarchies. For example, the concept Habitat gives a novel lens to analyze the boundary conditions impacting an information system, and by its division into three levels broadens the scope of the scrutiny both within the organization and beyond it. Further, in traditional systems analysis, tools such as data flow diagrams are used to model how data moves in the system, giving a necessary technical blueprint for how to build the system. The Function concepts, on the other hand, look at how and which data is needed in the socio-technical system for e.g. decision making, at the sources of the data, and at the usage of the data. The flow of data to and from stakeholders becomes a central focal point in the analysis, as all components of the system are analyzed in relation to the flow of data. We gain new understanding of the varied relations between stakeholders and data. Roles are not understood through the work tasks performed by the individual, or position in the organizational hierarchy, but as roles in relation to data. Using the biological ecosystem as a model forces a questioning of traditional information system concepts. It also means an extended and richer system perspective which is beneficial for the view of information systems. The ecosystem concepts give researchers and practitioners a new lens to use when studying, planning, designing or troubleshooting an information system.

In future research, we intend to further explore the notion of the information system ecosystem, and to carry out a more systematic evaluation of the framework, e.g. as a case study. As an additional evaluation of the proposed approach, a thorough review of and comparison to alternative information systems analysis frameworks and models is proposed. Finally, we intend to explore the use of the suggested framework in other business contexts, e.g. marketing.

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