An operationalizable definition and method for research on innovation ecosystems

Olli Kytömäki
KTH Royal Institute of Technology Stockholm, Sweden
olliky@kth.se

Abstract

The concept of innovation ecosystem has attracted much research in strategy and innovation fields in recent years. The expansion of literature without common definitions or methodology has caused ambiguity about what innovation ecosystems are about. Recently, several authors have criticized the conceptual and methodological rigor in innovation ecosystems research and called for research focusing on the systemic nature of innovation ecosystems.

This paper builds on these critical accounts by providing an operationalizable definition of innovation ecosystem: *a system of actors that contribute towards a common system-level innovation goal.* Based on this definition, the paper provides a methodological approach that quantifies qualitative data and then analyses that quantitative data by social network analysis. This method is used for multi-level, multi-layer ecosystem analysis. The definition and methodology are operationalized in a study of innovation ecosystem in the real estate sector.

Keywords: innovation ecosystem; social network analysis; real estate; digitalization; innovation; facility management; construction

Introduction

Research on innovation ecosystems has grown rapidly in recent years. This surge of interest is probably because firms' innovation efforts are increasingly depended on other actors in a fast-changing environment and a perceived inadequacy of other concepts to provide sufficient explanation for the logic of change in these environments (Moore 1993). This surge has led to a plurality of concepts about business and innovation ecosystems, which has made comparison of ecosystem studies challenging.

Recently, several authors have engaged in a debate about the lack of conceptual and methodological rigor in ecosystems research, calling for more clarity and coherence (Oh et al. 2016; Ritala and Almpanopoulou 2017). This has been followed by review articles on the use of ecosystem concepts (Tsujimoto et al. 2018; Scaringella and Radziwon 2018; Granstrand and Holgersson 2019), as well as work on further theoretical grounding of the ecosystem concepts (Jacobides et al. 2018; Adner 2017). Yet, there is no commonly accepted definition of innovation ecosystem and methodological questions related to ecosystem research have received less attention (Phillips and Ritala 2019).

One promising avenue for conceptually and methodologically rigorous ecosystem research is to view ecosystems as complex adaptive systems (Roundy et al. 2018; Ritala and Gustafsson 2018; Phillips and Ritala 2019). Through complex systems perspective, it is argued, that ecosystems can be "more fully understood" (Roundy et al. 2018), and that this perspective is to overcome the methodological challenges related to narrowly framed research designs (Phillips and Ritala 2019).

This paper builds on the "complex adaptive systems agenda" on innovation ecosystem research by providing an operationalizable definition and methodology for research on innovation ecosystems. The provided definition - *a system of actors that contribute towards a common system-level innovation goal* – sets the focus on the systemic nature of ecosystems. It addresses the distinction between actor-level and system-level attributes, such as innovation goals, as well as recognition of multiple ecosystem layers that are dependent on the system-level attributes.

Further, this paper provides a methodological approach for identifying actor-level and system-level attributes, such as actors, actor ties and innovation goals. Here, the boundary criteria for the innovation ecosystem is actor's contribution towards a system-level goal. The methodology also describes how different ecosystem layers can be identified based on the system-level goals. The paper proposes a methodology that combine explorative qualitative data collection methods and quantitative social network analysis. The definition and methodology are operationalized in a study on innovation ecosystem, that aims for digital development in the real estate sector.

Thus, the paper contributes to the debates on rigor on innovation ecosystem research by complementing the complex adaptive systems perspective. Particularly, this paper contributes by highlighting the methodological questions related to analysis on actor-system -analysis and analysis of different ecosystem layers. Finally, the implications of systems perspective for innovation ecosystem research are discussed.

Research on innovation ecosystems

Business ecosystems and innovation ecosystems

The concepts of business ecosystems and innovation ecosystems have attracted both researchers and practitioners in the past two decades (Moore 1993; Jacobides et al. 2018; Adner and Kapoor 2010). This interest springs from the growing demand to understand complex business communities and networks, and to this need the ecosystem concept provides a framework for analysis. While the definitions of ecosystem concept have been varied, the overall advantage of the concept is that it is not limited to actor types, contractual arrangements or geography (Tsujimoto et al. 2018). Rather, the ecosystem concept captures a business logic, where multiple actors depend on each other's activities (Jacobides et al. 2018). In addition, the ecosystem literature provides further conceptualizations based on specific value focused activities: for example, knowledge ecosystems focus on knowledge creation activities, in which universities and public research organizations greatly influence the value creation (Clarysse et al. 2014); innovation ecosystems focus on value creation related to particular innovations or new value proposals (Adner and Kapoor 2010; Vasconcelos Gomes et al. 2018); and business ecosystems focus on value capture mechanisms.

Conceptual rigor in ecosystem research

One challenge for ecosystem research has been the lack of conceptual rigor (Valkokari 2015; Gulati et al. 2012; Tsujimoto et al. 2018; Ritala and Almpanopoulou 2017; Oh et al. 2016). First, several authors, both in industry and academia, have adopted ecosystems concepts that are conceptually close to other concepts focusing on organization's interorganizational operations (Adner 2017). This plurality of concepts offers optional tools for explaining phenomena, but makes it challenging to transfer the results and explanations from context to another. Another challenge related to the conceptual rigor, and a more significant one, is that ecosystem concepts are often used ambiguously. Many researchers use the ecosystem concept as an overarching term to refer to the business environment of the company, without specifying the concept. Perhaps it is so that the ecosystem as a word is very useful for such a purpose. In this regard, Oh et al. (2016) point out that one benefit of ecosystem concept is that it encourages for systems thinking about organizations' environments. Yet, Oh et al. (2016) and Ritala and Almpanopoulou (2017) see that research that aim at addressing structures of ecosystems or business logics in ecosystems, should strive for more rigorous and prudent use of ecosystem concepts, especially so as the use of ecosystem concepts continue to grow, both in industry and in academia.

Methodological rigor in ecosystem research

Another challenge for ecosystem research is methodological. Partly, this issue is related to the lack of conceptual rigor, but recently several authors have provided more specific criticism on methodology (Oh et al. 2016; Ritala and Gustafsson 2018; Phillips and Ritala 2019). Ritala and Gustafsson (2018), Oh et al. (2016) and Ritala and Almpanopoulou (2017) point out that studying interconnected systems that contain multitude of actors is difficult due to excessive data gathering requirements. Phillips and Ritala (2019) agree, and propose a methodological framework focused on mapping ecosystem boundaries, relationships and dynamics, which they see as the necessity for rigorous ecosystem research. They point out that the field lacks a coherent methodology and that complex adaptive systems perspective, although being in the minority within ecosystem research, would best suit the purpose of building such a research program.

Thus far empirical research on ecosystems has remained limited, as the ecosystem literature has mostly circled around ecosystem concepts (Ritala and Gustafsson 2018). The most commonly used method is case studies, where data collection is based on interviews, mapping or utilization of existing data sets, and analysis and theorization are based on either qualitative or quantitative analysis (e.g. Phillips and Srai 2018; Rong et al. 2015; Rohrbeck et al. 2009; Ritala et al. 2013; Chesbrough et al. 2014; Zhang and Liang 2011). Examples of case research that has primary focused on quantitative methods are Li (2013), who uses US patent data and Kapoor and Agarwal (2017), whose primary data source is application analyst firms. Case studies is a relevant method for ecosystems research, due to the necessity to explore the contextual factors related to the ecosystems, but due to lack of conceptual or methodological coherence, generalizations based on these efforts may be difficult to reach. Also, cases are by nature limited to certain parts of the ecosystem.

Recently, several authors have focused on studying the ecosystem as whole. Lu et al. (2014) provide an ecosystem level analysis by collecting data from interviews and by document analysis. They stress the need for an actor-based micro-level analysis for recognizing emergent macro-level phenomena. Other authors who have adopted the actor-based approach are for example Baggio and Del Chiappa (2014), Basole et al. (2015) and (Clarysse et al. 2014), who all have introduced social network analysis to ecosystems research (see also Basole 2014; Basole 2009; Basole et al. 2013; Battistella et al. 2013). The use of social network analysis may provide a way forward to generalize results based on common data collection and analysis methods. Additionally, SNA may help to overcome the lack of metrics in current ecosystem concepts (Oh et al. 2016), which would be critical for evaluation of ecosystem performance and a good foundation for further theorization on ecosystem concept (Tsujimoto et al. 2018; Ritala and Almpanopoulou 2017; Graça and Camarinha-Matos 2017). Further, Ritala and

Almpanopoulou (2017) argue that use of simulation modeling may help in overcoming the challenge of complexity involved, and that with these methods innovation ecosystem research can aim both for description and prediction.

A new definition of innovation ecosystem based on systems research perspective

To address the conceptual and methodological issues, this paper adopts "the complex adaptive systems agenda", proposed by Roundy et al. (2018), Ritala and Gustafsson (2018) and Phillips and Ritala (2019). Phillips and Ritala (2019) point out that the ecosystem researchers should address the conceptual, structural and temporal dimensions of ecosystems in research design. They see that to address the ecosystem boundary criteria, researchers should engage with the ecosystem to gain understanding on the particular contexts in which the ecosystem actors interact, as well as the multiple perspectives that are present in formation of business logics that characterize the ecosystems being investigated. Roundy et al. (2018) argue that only few studies on ecosystems have addressed the foundations of ecosystems, the actors and ties between the actors, that make the ecosystem. They see that this shortcoming hampers both understanding of ecosystems and theorization based on ecosystem analysis.

Therefore, this paper defines innovation ecosystem as *a system of actors that contribute towards a common system-level innovation goal*. First, this definition highlights the system nature of ecosystems, which is necessary for "the complex adaptive systems agenda". Second, this definition highlights the multilevel perspective to innovation ecosystems; that is, innovation ecosystems have both actor level properties and common system level properties, such as innovation goals. This separates ecosystems from other concepts related to organizations' interorganizational collaborations. Third, this definition sets *contribution to an innovation goal* as the boundary setting criteria for ecosystem actors, and thus puts emphasis on the ties between the actors. Fourth, this definition allows for recognition of overlapping layers of ecosystems, which are dependent on variety of innovation goals. Fifth, this definition does not limit ecosystems based on pre-set sectoral boundaries, geography, focal firm, platform, structure or actor types. Rather, these ecosystem aspects are most likely context specific and requires researchers to gain understanding on the ecosystem before determining the goals, actors and ties; in other words, as ecosystems are heterogenous, there is a need for fine-grained methods of distinguishing the ecosystem boundaries and characteristics. The definition is compatible with the idea of unstructured ecosystems that lack defined underlying structures, governance, stakeholder roles or value creation logics (Westerlund et al. 2014). This is especially noteworthy for early phase ecosystems and in quickly changing environments. In such contexts, explorative research design is recommended.

Overall, it is here argued that this definition of innovation ecosystems is operationalizable in comparison to other more multi-dimensional definitions of innovation ecosystems (for comparison, see Granstrand and Holgersson 2019). The methodological approach, and operationalization of this concept, is provided in the following sections.

Ecosystem research in real estate and construction sectors

In the real estate sector, the research on innovation has mainly focused on facility management or innovation related to building design and project phases. In the former literature stream the focus has largely been on innovativeness of facility management firms, which have been criticized of being unable to develop or sustain innovation (Mudrak et al. 2005; Cardellino and Finch 2006), much due to the strong focus on service delivery and cost optimization in the facility management businesses. Few researchers have particularly addressed real estate owner's perspective, remarking that real estate owners are often rather conservative (Engström and Hedgren 2012; Ivory 2005). Still, no notable research stream on the inter-organizational innovation related to real estate or facility management business exists.

The research on innovation in building design and project phases is more abundant. One traditional perspective is to view buildings as complex product systems (Blayse and Manley 2004; Gann and Salter 2000; Harty 2005) and focus on innovation around these systems. Others have focused more directly on actor's relations, for example on partnering (Bresnen and Marshall 2000), value chains (Slaughter 2000) or industry networks (Bossink 2004; Bygballe and Ingemansson 2014; Dubois and Gadde 2002).

Still, these perspectives, albeit focusing on inter-organizational innovation, less often provide analysis on the system level implications of the innovation activities. While the ecosystem perspective has been found applicable for project-based industries (Tsvetkova et al. 2019; Eriksson et al. 2019; South et al. 2018; Toppinen et al. 2019), it has not been much applied in innovation research in construction or real estate context (Pulkka et al. 2016). An exception is recent research on smart city concept, in which ecosystem concept is used for understanding the context of smart city development (Zygiaris 2013; Scuotto et al. 2016; Ardito et al. 2019) and adoption of smart home technologies (Ehrenhard et al. 2014).

Methodology

An explorative approach for determining the innovation ecosystem characteristics

In order to understand the real estate innovation ecosystem logic, this paper aims to empirically recognize the central innovation goals in an innovation ecosystem, as well as to recognize the relevant actors and actor ties as the central components of the ecosystem. The ecosystem in case comprises of actors contributing to the work on digital innovations in Swedish real estate industry. This as a starting point does not, however, limit the ecosystem to Swedish actors, as various actors may contribute to the innovation goals regardless their location. In this context, the real estate owners are seen central for innovation, as their actions govern other actors, through for example procurement decisions.

Traditionally, the Swedish real estate owners have been slow to adopt new innovations, but in recent years digitalization has been raised on the industry agenda as a factor that the real estate owners must consider in their businesses. In a situation where ecosystem actors are reacting to a novel phenomenon, the actors may form new innovation goals and seek for new partners to collaborate with. Because of that, relying on existing knowledge on which innovation goals and partners are relevant, may be misleading. In a situation, where existing knowledge give only limited guidance, an explorative research approach may be only possible method for identifying changes in organizational context.

Thus, this paper relies on qualitative phenomenon-based research approach (Von Krogh et al 2012). This approach in turn relies on hermeneutic process, in which a systematic interpretation of new empirical findings deepens understanding of the phenomenon as a whole. This process takes advantage of author's participation in nine digitalization seminars in the sector between 2017 and end of 2019, reading of multiple industry reports on digitalization and continuous long-term data collection. This engagement is essential for recognizing and categorizing relevant innovation goals, actors, and actor ties. Further, the author has introduced various verification strategies for each step of the research process (Morse et al. 2002), including extensive data collection from multiple sources, formal data processing procedures and evaluation of research process practices with a supervisory team.

Social network analysis

Another advantage of a qualitative approach is that it provides for in-depth understanding of the goals, actors and ties, which provide basis for discussion on the actor contribution on innovation goals. On the other hand, a qualitative approach is limited in providing generalizable knowledge. In this research, the qualitative approach is complemented with quantitative analysis of the data, particularly, with social network analysis. This allows for emergence of a broader perspective through quantification and visualization of data, which is seen important for communicating the research results within the academia and the industry.

Social network analysis (SNA) focuses on patterns of social interaction. The advantage of SNA as a method is that it provides formal structure for qualitative and quantitative empirical analysis, simulation and visualization of social networks (Bastian et al. 2009). SNA focuses on recognizing actors and relational data between the actors in a social network. The actors may be individuals, groups or organizations (Edwards 2010), depending on the interest of the researchers. The relational data can be, for example, about resource flows or diffusion of innovation between the actors. Thus, it is an appropriate method for analyzing inter-organizational structures, such as networks and ecosystems. In order to construct SNA, a researcher should define the boundaries of the system being analyzed (Edwards 2010), as well as data collection methods that lead to presentation of the actors and their ties in the system. The software used for visualization and analysis is Gephi.

Data collection

This paper relies on multiple data collection methods. The primary information source is 32 explorative, semi-structured interviews with real estate owners, suppliers and industry associations, which have been recognized relevant for the innovation ecosystem (Kytömäki and Kadefors, 2018 September). The interviews were conducted between 2017 and end of 2019. The interviewees represent large Swedish real estate owners of commercial properties, housing and community service properties, as well as suppliers' and industry associations' organizations. This selection was based on the recognition that the large actors are traditionally most active in innovation in this context. On the other hand, selection of firms from multiple property categories and actor types provide for breadth of contexts for innovation. The interviewees are managers with responsibilities for digital development in their organizations. In each interview, the interviewees were asked to name innovation goals and relevant partners for their digitalization activities. The interviews were recorded and transcribed.

The aim of data collection was to recognize the actors and actor ties in the innovation ecosystem. First the 32 interviews were read through and each actor and actor tie mentioned in the interviews was listed in an Excel workbook. Then, for each recognized actor in the network, a document search and analysis were conducted. The documents consist of firm's websites, project documents, annual reports, media archives and other relevant documents. Altogether, more than 350 documents were analyzed. These documents were either provided by the interviewees or acquired from public sources. The advantage of using multiple data sources is that sources complement each other by providing additional information and by validating existing information. The data collection was continued until each actor in the innovation ecosystem was investigated with document analysis. The document analysis aimed at recognizing innovation partners, their ties and type of activity that takes place in the partnership. The search for documents was done by combining systematic search of digitalization and innovation related information on actors' websites and media sources. The documents were read and relevant actors and actor ties were listed in the Excel workbook. This search protocol identified 126 actors and 196 actor ties.

Coding and analysis

The data analysis and coding were done in four phases: first, recognition of actor type categories, second, recognition of the innovation ecosystem goals, third, linking of individual actors with the innovation goals, and fourth, social network analysis on actors and actor ties. These phases are here explained in detail.

First phase was the recognition of the actor type categories in the list of 126 actors. The categories were defined based on the actors' descriptions of their activities and their relations to real estate owners. In cases, where an actor could have been placed in two or more categories, the main reason for their relation to the real estate owners was determining factor for categorization. For example, the firm's real estate owners have founded are also suppliers for real estate firms, but here categorized as firms founded by real estate owners. Altogether 7 categories were defined and listed in the table 1. Further subcategorizations could have been made for example based on real estate owners' property types or supplier categories. This analysis can be continued in future research. Only 4 out of 18 real estate owners especially mentioned that their tenants are an integral stakeholder in their innovation processes. As the they did not enclose the actors more specifically, or how they innovate, tenants were not included listed in the actor list or actor categorization. This, however, can be an interesting topic for further research.

Table 1. Actor categories

Categories	Definition	Number of actors
Firms founded by real estate owners	New firms, where real estate owners have been major initiators.	4
Benchmarks	Organizations real estate owners benchmark from in digital development.	17
Industry associations	Associations several industry actors are members of.	7
Owners of real estate firms	Organizations that own real estate firms, f.e. cities, municipalities and insurance companies	8
Real estate owners	Owns and manages real estate. Acts as a client for various suppliers.	29
Research and education institutes	Universities and education institutes	6
Suppliers	Firms that supply products or services to real estate owners.	55
Total	-	126

Second phase of the analysis was to identify the real estate owners' goals in the real estate innovation ecosystem. As innovation ecosystem is defined as a system of actors that contribute towards common system-level innovation goals, the innovation goals serve as the starting point for determining the ecosystem boundaries. In order to recognize these goals, 18 real estate owner interview transcriptions were imported to Nvivo12 software. Each interview was read through and phrases including expressions about innovation goals were coded into one node in an open coding process. The node was exported to excel for axial and selective coding procedure, which formed the categories of innovation goals. The axial and selective coding procedure followed Wolfswinkel et al. (2013) approach on grounded theory (Glaser and Strauss 1967), in which categories are formed through integration and refinement of categories that were identified in the data. Altogether 168 statements about innovation goals were identified and coded. The coding procedure aimed at recognizing business goals that were common for most real estate owners. Business goals were here understood as outcomes of value creation processes, leaving organizational process perspectives aside.

Table 2 summarizes the categories of digitalization goals: operational efficiency, tenant satisfaction and new revenue streams. While the categories are not entirely mutually exclusive, the categorization is based on interpretation on the justifications given by the interviewees. Neither are the categories exhaustive, as each coding process step leave details out and highlight others. For example, the category “Tenant satisfaction” includes goal that aim at increasing satisfaction of real estate owners’ tenants, while potentially improving the satisfaction of all building users. The categories should thus be interpreted broadly.

Table 2. Real estate owners’ digitalization goals

Operational efficiency	Tenant satisfaction	New revenue streams
Maintenance management processes and systems	Attractive locations	New services
Building data management	Customer communication and service	Digital platforms for services
Operational cost optimization, f.e. energy	Customer experience in buildings	e-commerce
Efficient use of space	Digital services	Events
Administration efficiency	Home deliveries	New customer segments
Customer service optimization	Safety and security	New contract forms
Sales and renting processes	Tenant selection	
Other organizational processes	Sharing of resources among tenants	

In the third part of the analysis the three innovation goal categories were linked to actor categories by specifying the ties between actors in relation to innovation goals. The aim was to recognize to which goals each actor contributes to and mark these goals as an actor attribute. Each actors’ statements of their activities, such as mission statements or descriptions of value offerings, and the descriptions of the ties between the actors and real estate owners, were used to distinguish the contributions. Where this contribution was not clear, the actor attribute was set as “other”.

The category “other” consists of activities, such as education (2 ties), benchmark (39) and ownership of real estate firms (2). The analysis of the data show that these ties have an impact on the real estate owners’ digitalization goals, but the contribution to a certain innovation goal category is unspecified in the data. For example, real estate owners benchmark each other and companies that are known to be forerunners in digital development. While many of these ties are rather informal, the interviews show that benchmarking as an activity has an impact on forming digitalization strategies and goals in real estate firms. Similarly, the owners of real estate firms have a demonstrable impact on the real estate owners’ innovation goals at large, but specifying that for a particular digitalization goal is not feasible. These ties have an important role to play, especially in the early phases of innovation process (Kytömäki and Kadefors, 2018 September).

The fourth, and final, part of the analysis was to import actor and tie lists to Gephi software for SNA. This was done separately for each innovation goal actor lists and for the network as a whole. The imported columns were organization label and type and tie source and target. Ties were imported as undirected and unweighted.

For the purposes of this paper, the presentation of the statistical analysis is on the level of actor categories and on the ecosystem as a whole, and the figures are called actor type properties and ecosystem properties. The ecosystem is presented as four layers. The presentations include following figures:

- Number of Actors (In Gephi, actors are called nodes): the total sum of actors in the actor category or ecosystem layer
- Number of Ties (In Gephi, ties are called edges): the total sum of ties between actors in the actor category or ecosystem layer
- Average Degree: a degree of an actor (node) in a graph refers to the number of actors it is connected to, and Average degree for a graph is a measure of how many ties (edges) there are compared to its number of vertices (Khokhar 2015).
- Network Diameter: the shortest path between the two most distant actors (nodes) in the network (Khokhar 2015).
- Graph Density: measure of how close the graph is to a complete graph; defined as the ration of the total number of actors (node) to the total number of ties (edges) (Khokhar 2015).
- Average Path Length: the average path distance between all pairs of nodes.
- Average Eigenvector Centrality: In graph theory, the centrality of an actor (node) is a measure of its importance; Eigenvector Centrality takes into consideration the connections of neighboring nodes (Khokhar 2015). Average for an actor group or ecosystem layer is a measure of the actors' importance in average in a given ecosystem.

As a result, 4 network pictures and tables were exported from Gephi. Networks are presented using ForceAtlas2 graph layout algorithm.

Results

This section presents the results and interpretation of the social network analysis. The interpretation is based on qualitative interview data, visualizations if the ecosystem layers and statistical analysis. figures 1-5 and tables 3-7 present the four different layers of the innovation ecosystem: first is the "complete ecosystem", which consist of all the 126 actors and 196 actor ties that were recognized as relevant in the data collection procedure; second is the “operational efficiency ecosystem”, which consists of 94 actors and 133 ties that are relevant for the operational efficiency -goal; third is the “tenant satisfaction ecosystem”, which consists of 64 actors and 63 ties that are relevant for the tenant satisfaction -goal; and finally, fourth is the “new revenue streams ecosystem”, which consists of 13 actors and 11 ties that are relevant for the new revenue streams -innovation goal. In the following, each ecosystem layer is discussed separately and then in comparison.

Ecosystem layer 1: The “complete ecosystem” on digitalization

The “complete ecosystem” on digitalization consists of 126 actors. The visual presentation shows that the constellation of actors is fairly loosely coupled, as none of the actors, or actor groups, have a central position in the ecosystem. The actor that has the highest Number of Ties is a real estate owner, which is connected to 21 other actors (17% of 126 actors). This particular concentration is due to a research project, which has drawn together real estate owners, suppliers and research institutes. Overall, the actors in the ecosystem are connected on average to 3.1 other actors (see also the Graph Density in table 7), indicating that collaboration between the actors is fairly limited. Still, the interviews show that the actors are actively seeking for new collaborations, which raises the question of why is it so challenging to form new collaborations.

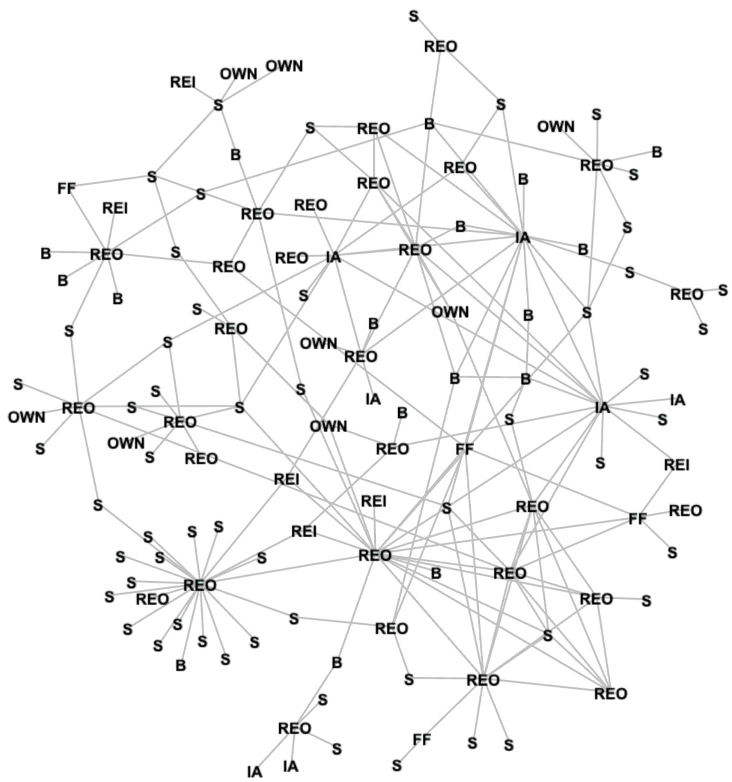
In this ecosystem constellation, the real estate owners can, to a large degree, control the inclusion, exclusion and actions of other actors, and thus they have a relatively seminar role in the ecosystem. This is evident both from the interviews as well as based on their relatively high Average Eigenvector Centrality. The real estate owners guide the development of the ecosystem, for example by imposing requirements through procurement decisions and partner selection, memberships in industry associations and by founding new companies. They, however, are limited in capabilities for doing so.

Thus, suppliers have an important role in providing technologies, services and expertise to the real estate owners. By the Number of Actors, they represent the largest group of actors in the ecosystem (44%). Interestingly, the building project phase suppliers, such as construction project contractors, were not seen relevant for digitalization by the interviewed managers in real estate owner organizations. More so, the real estate owners are looking for suppliers that can help them in managing the existing building stocks. The suppliers, at large, have a relatively low Average Degree and Average Eigenvector Centrality, which indicates that they have a relatively low power and influence in the ecosystem. Visual presentation shows that they are mainly connected to the real estate owners, indicating that there is very little collaboration between the suppliers. Also, comparison of Eigenvector Centralities per supplier-actors show that only four of them have above ecosystem-average Eigenvector Centrality, which indicates that only few of them have a position to foster knowledge transfer within the ecosystem.

The interviews with the real estate owners and industry associations show that the industry associations have a central role in orchestrating development projects and knowledge transfer in the ecosystem. This conclusion is also supported by the statistics, as industry associations have the highest Average Degree and Average Eigenvector Centrality in the ecosystem, that is, 103% above the ecosystem average. An interview with a representative of an industry association gives more insight to their role: the interviewee sees that they can act as a trusted advisor in the industry and as a matchmaker between the real estate owners and suppliers. Therefore, the industry associations may complement the lack of necessary capabilities on digitalization at suppliers' and real estate owners' organizations. This makes them, among the few of the largest real estate owners, most central actors for the digital development in the ecosystem.

The firms founded by real estate owners is a small set of actors (4) with a high Average Degree and Average Eigenvector Centrality. Together with real estate owners and industry associations, they have central roles in certain parts of the ecosystem. Also, research and education institutes are a small set of actors (6), but they are relatively loosely connected to other actors in the ecosystem, and thus their direct role in digital development in the sector is limited. However, it may be that they have a central role as a part of knowledge ecosystem (Clarysse et al. 2014), or they may have more an indirect role towards the innovation goals of real estate owners or a direct role towards other potential innovation goals. It is also so, that the firm's real estate owners benchmark from and the owners of real estate firms are seen relevant actor groups for the innovation goals, but they too have a limited role based on their Average Eigenvector Centrality and Average Degree. The owners assign policies and have expectations related to governance, which impact the real estate owner's digitalization and sustainability goals. Also, the real estate owner's benchmark from other companies, mainly global digital leaders in the telecom, information technology, commerce and hospitality sectors.

Figure 1. The “complete ecosystem”



FF = Firms founded by Real Estate owners, B = Benchmarks, IA = Industry Associations, OWN = Owners of Real Estate Firms, REO = Real Estate Owners, REI = Research and Education Institutes, S = Supplier

Table 3. Ecosystem properties of the “complete ecosystem” – comparison per actor type

Actor type	No. Actors	Avg. Degree	Avg. Eigenvector centrality
Industry associations	7	6,71	0,280
Real estate owners	29	6,21	0,252
Firms founded by real estate owners	4	4,00	0,207
Research and education institutes	6	1,83	0,130
Benchmarks	17	1,82	0,087
Suppliers	55	1,69	0,082
Owners of real estate firms	8	1,50	0,062
All	126	3,10	0,138

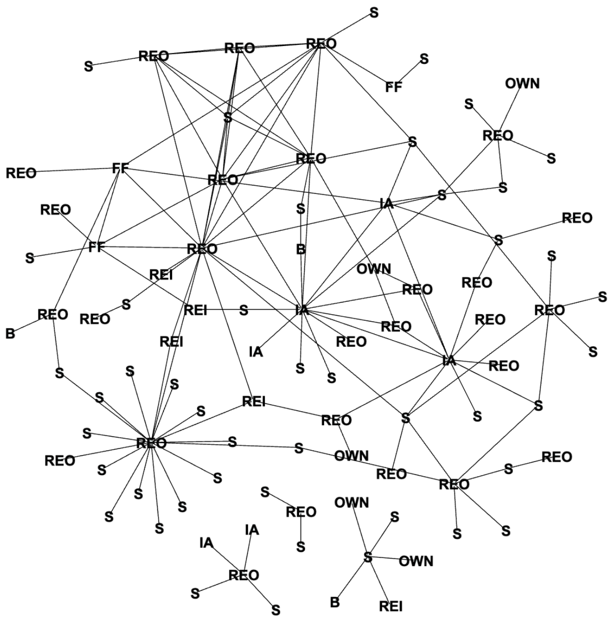
Ecosystem layer 2: The “operational efficiency ecosystem”

The “operational efficiency ecosystem” consists of 94 actors, and here only the actors that contribute towards the efficiency-goal are presented. There are a few considerations that can be done. First, the “operational efficiency ecosystem” contains 32 actors less than the “complete ecosystem”. This is largely because 10 of the suppliers and 14 of the benchmarks counted in the “complete ecosystem” does not contribute towards the operational efficiency innovation goal. These ties mainly serve the purpose of learning about the digitalization opportunities. Second, in this ecosystem layer, there are constellations of actors, which form small islands of development. This raises an interesting question how these islands may be connected to general digitalization development through the “complete ecosystem” -layer.

Third, also in this ecosystem layer, firms founded by real estate owners, industry associations and real estate owners form the core (top3 categories) of the ecosystem in terms of having high Average Degree and high Average Eigenvector Centrality compared to other actor categories. This is because these actors have been able to agree on certain efficiency related actions and tie research institutions and suppliers around these goals. Therefore, the decision making by these actor categories guide the digital development in the industry. Still, a comparison of Eigenvector Centrality on individual real estate owner actors shows that some of the largest real estate owners have central positions in the ecosystem, and thus their importance in decision making for the whole ecosystem is greater. This view is supported by many of the interviewees, who see that the large real estate owners should act and guide the development on behalf of the whole industry.

Finally, the ecosystem layer is loose in terms of goals, as the operational efficiency goal comprises of several sub-goals. This complicates the functioning of the ecosystem as a whole. For example, several interviewed actors state that they would be willing to act on their operational efficiency goals, but due to limited resources and risk aversion, they need other actors for collaboration. The challenge is to find the right actors and to agree on common goals. Also, the operational efficiency goals have traditions in the sector, mainly in sustainability, energy efficiency and implementation of administration software and thus many of the ties are well established.

Figure 2. The “operational efficiency ecosystem”



FF = Firms founded by Real Estate owners, B = Benchmarks, IA = Industry Associations, OWN = Owners of Real Estate Firms, REO = Real Estate Owners, REI = Research and Education Institutes, S = Supplier

Table 4. Ecosystem properties of the “operational efficiency ecosystem” – comparison per actor type

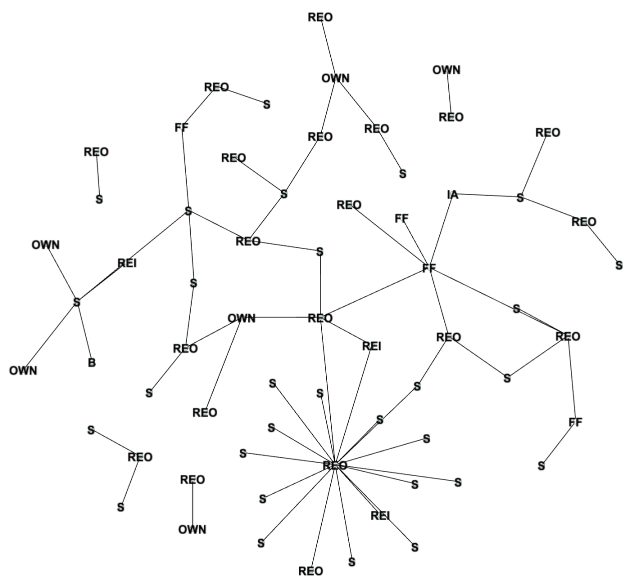
Actor type	No. Actors	Avg. Degree	Avg. Eigenvector centrality
Firms founded by real estate owners	3	4,67	0,263
Industry associations	6	5,83	0,229
Real estate owners	27	4,52	0,226
Research and education institutes	5	1,80	0,145
Suppliers	45	1,67	0,081
Benchmarks	3	1,33	0,045
Owners of real estate firms	5	1,40	0,040
All	94	2,83	0,138

Ecosystem layer 3: The “tenant satisfaction ecosystem”

The “tenant satisfaction ecosystem” consists of 64 actors. Overall, this ecosystem layer is least concentrated in terms of network centrality measures. The Average Eigenvector Centrality is lowest, which means that the actors, on average, are in positions in the ecosystem, where they have relatively low influence on the ecosystem as a whole. Also, the Average Path Length and Network Diameter are longest (see table 7) compared to other ecosystem layers, meaning that information transfer between actors may be challenging. Consequently, it would be interesting to study the flow of information, for example successes and failures of "tenant satisfaction" -projects, through other ecosystem layers.

Another remark about the "tenant satisfaction" ecosystem layer is that it is dominated by real estate owners (31%) and suppliers (45%), which indicates that work on tenant satisfaction goals is largely done in supplier-buyer -relationships. Also, the interviews show that the firms founded by real estate owners (4) are relevant actors for tenant satisfaction, but they seem to have a limited role towards other innovation ecosystem actors. The other actor groups, namely research and education institutes (3), industry associations (1), owners of real estate firms (6) and benchmarks (1) are related to tenant satisfaction goal through collaborations, but their influence is rather indirect.

Figure 3. The "tenant satisfaction ecosystem"



FF = Firms founded by Real Estate owners, B = Benchmarks, IA = Industry Associations, OWN = Owners of Real Estate Firms, REO = Real Estate Owners, REI = Research and Education Institutes, S = Supplier

Table 5. Ecosystem properties of the “tenant satisfaction ecosystem” – comparison per actor type

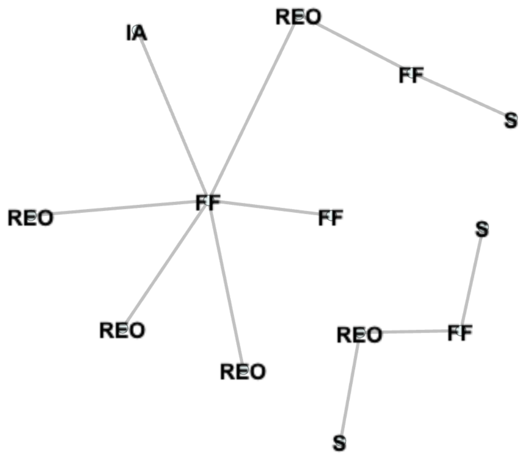
Actor type	No. Actors	Avg. Degree	Avg. Eigenvector centrality
Research and education institutes	3	1,33	0,202
Suppliers	29	1,52	0,130
Real estate owners	20	2,70	0,123
Firms founded by real estate owners	4	2,75	0,107
Industry associations	1	2,00	0,091
Owners of real estate firms	6	1,67	0,044
Benchmarks	1	1,00	0,033
All	64	1,97	0,120

Ecosystem layer 4: The “new revenue streams ecosystem”

The “new revenue streams ecosystem” consists of 13 actors, which is 10% of the actors in the “complete ecosystem”. The actor groups focusing on “new revenue streams” -goal are real estate owners (5), firms founded by real estate owners (4), industry associations (1) and suppliers (3). This ecosystem layer has the highest network centrality if measured by Network Diameter, Graph Density, Average Path Length or Average Eigenvector Centrality. This means the actors focusing in new revenue streams are a small and well-connected group of organizations. These actors are among the most central ones also on the other ecosystem layers, which indicates that the individual digitalization goals have much complementarities.

The interviews show that real estate firms have founded new companies mainly for two reasons. First, they have recognized opportunities to improve core business and searched for solutions in the market. In cases where these solutions have not been satisfactory, they have founded firms to fill the gap. Second reason is that they see opportunities in offering these new services to other real estate companies. On this ecosystem layer, only the firm’s real estate owners have established as subsidiaries are presented, but new in-house ventures are also initiated in the real estate owner organizations, and these may later be converted into subsidiaries. Such business development and boundary spanning activities are new to the real estate sector and may challenge the way we understand real estate management.

Figure 4. The “new revenue streams ecosystem”



FF = Firms founded by Real Estate owners, IA = Industry Associations, REO = Real Estate Owners, S = Supplier

Table 6. Ecosystem properties of the “new revenue streams ecosystem” – comparison per actor type

Actor type	No. Actors	Avg. Degree	Avg. Eigenvector centrality
Real estate owners	5	1,40	1,816
Firms founded by real estate owners	4	2,75	0,443
Industry associations	1	1,00	0,398
Suppliers	3	1,00	0,249
Benchmarks	-	-	-
Owners of real estate firms	-	-	-
Research and education institutes	-	-	-
All	13	1,69	0,326

Comparison and conclusion of four ecosystem layers

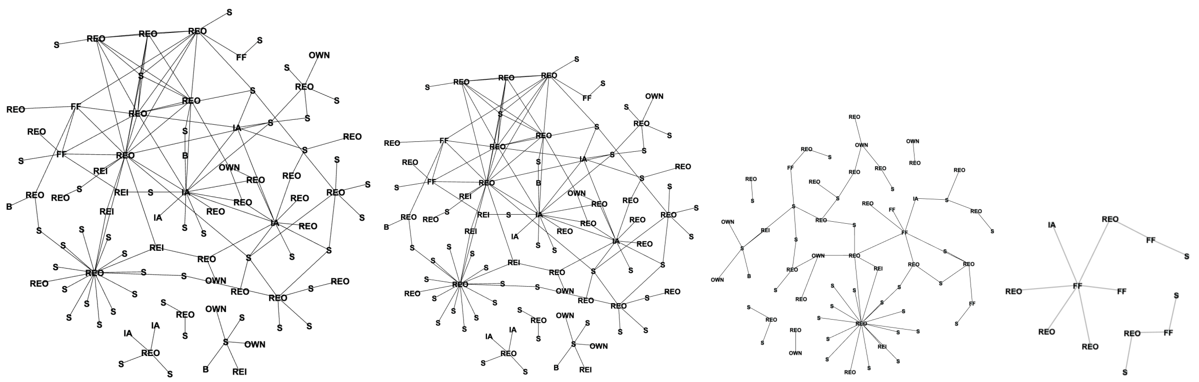
The figure 5 and table 7 present the four layers of the innovation ecosystem for comparison. Overall, the “complete ecosystem” presents all the relevant actors for digital development in the innovation ecosystem and other figures present those actors that contribute towards each innovation goal. The presentation shows that “operational efficiency” has fewer actors than “complete ecosystem” (-25%), “tenant satisfaction ecosystem” fewer than “operational efficiency ecosystem” (-32%) and “new revenue streams ecosystem fewer than operational efficiency ecosystem” (-80%).

This is an interesting observation, as most interviewed real estate owners state that they have the desire to pursue all of the three goals. But as the ecosystems are based on actual contributions of collaborating actors, that is contractual arrangements, participation on innovation projects or other similar form of collaboration, from this it can be concluded that most goals real estate owners have formulated does not actualize into collaborations. One of the interviewed innovation managers at large real estate owners said that moving from operational efficiency -goal to tenant satisfaction or new revenue streams -goals is challenging, as that requires understanding of how digital technologies can improve tenant' experience of build environment and related services, as well as formulation of new business models. Due to these uncertainties, the real estate owners are reluctant to invest.

The ecosystem properties show that the Average Degree decreases and Graph Density grows when moving from "complete ecosystem" to "new revenue streams ecosystem". One reason for this can be that more firms are able to take part, for reasons such as resource commitment, access to collaborations or capabilities, in operational efficiency and tenant satisfaction -goals, than in new revenue streams -goal.

It can be concluded that the four ecosystem layers are distinct in the sense that they have different ecosystem goals and different constellation of actors, and consequently different ecosystem properties. Yet, as the analysis show, the layers have much similarities and interconnections through all ecosystem layers.

Figure 5. The four ecosystem layers



Complete ecosystem | Operational efficiency ecosystem | Tenant satisfaction ecosystem | New revenue streams ecosystem

Legend: FF = Firms founded by Real Estate owners, B = Benchmarks, IA = Industry Associations, OWN = Owners of Real Estate Firms, REO = Real Estate Owners, REI = Research and Education Institutes, S = Supplier

Table 7. Comparison of ecosystem properties

Ecosystem properties	Complete ecosystem	Operational efficiency ecosystem	Tenant satisfaction ecosystem	New revenue streams ecosystem
No. Actors	126	94	64	13
No. Ties	196	133	63	11
Avg. Degree	3,095	2,830	1,969	1,692
Network Dia.	8	7	12	4
Graph Density	0,025	0,030	0,031	0,141
Avg. Path Length	3,978	3,472	4,914	2,143
Avg. Eigenvector centrality	0,138	0,138	0,120	0,326

Discussion

Contribution and future research

The debates about rigor in ecosystems research have taken pace in recent years. On the one hand researchers have called for conceptual rigor for ecosystem research (Tsujimoto et al. 2018; Ritala and Almpanopoulou 2017; Oh et al. 2016), but this has been challenging due to fast growth of the ecosystem research and multitude of definitions used. On the other hand, several authors have challenged the methodological rigor in ecosystem research (Oh et al. 2016; Phillips and Ritala 2019). This paper, following the call for "complex adaptive systems agenda" on ecosystem research (Roundy et al. 2018; Ritala and Gustafsson 2018; Phillips and Ritala 2019), aimed at addressing these gaps by presenting an operationalizable definition for innovation ecosystem - *a system of actors that contribute towards a common system-level innovation* goal, and by providing a methodological and empirical approach to study innovation ecosystems.

One of the challenges in the methodological approach proposed by Phillips and Ritala (2019) is the excessive data gathering requirements. The methodological approach in this paper benefits of authors previous research on digitalization in the real estate sector (Kytömäki and Kadefors, 2018 September), which helped in data collection and interpretation in the analytical phases. This kind of in-depth study may not always be possible and the researchers should always allocate time for activities that yield best results. For this purpose, the methodological approach proposed in this paper may provide structure.

Also, Phillips and Ritala (2019) specifically address the methodological questions related to conceptual, structural and temporal dimensions of ecosystems. To build on their work, this paper has highlighted the methodological questions related to multilevel analysis of innovation ecosystems, that is analysis of both actor level and system level properties, as well as the methodological questions related to analysis of multiple ecosystem layers.

The multilevel analysis of ecosystems is dependent on congruence of actor and system level attributes. Here, based on the definition, the ecosystems are defined by actor-level contribution to a system-level goal, and the methodology proposes a method to construct this congruence. However, the question of congruence could be expanded to other attributes than goals. What are the actor and system level properties of digital infrastructures (Tilson et al. 2010) and how are they in congruence? What are the capabilities in both levels and how are they in congruence? Also, recent research has addressed the concept of ecosystem business model (Westerlund et al. 2014; Hellström et al. 2015; Tsvetkova and Gustafsson 2012), which focus on the value creation and capture mechanisms on both firm level and ecosystem level. Such research can help to unlock previously unattainable innovation potential. This may be particularly important for ecosystems, where the ecosystem structure does not otherwise support systemic innovations.

Also, the multiple layers of ecosystems provide opportunities for theoretical and empirical research (Pombo-Juárez et al. 2017). The perspective in this paper is analytical and limited to identification of different layers. Future research could explore the systemic perspectives, such as emergence or self-organizing, in different ecosystem layers, as well as the question of how different ecosystem layers complement each other. For that purpose, this paper may help by providing an analytical framework.

Further, this paper makes an argument for using social network analysis as a tool for ecosystems research. This approach has several benefits. First, by adoption of existing SNA methods, ecosystem researchers may benefit of already existing methodological standardization, which can help to conduct rigorous research. Second, SNA provides statistics that can make ecosystem research more comparable and transferable. Third, SNA provides visualizations that help in communication of the research, both towards academic and non-academic audiences. Fourth, quantification through SNA may provide basis for functional analysis, such as ecosystem performance analysis (Graça et al. 2017), normative research or ecosystem life-cycle analysis (Rong et al. 2013; Basole et al. 2015). Finally, on one hand theoretical research on ecosystems has largely revolved around definitions and empirical research is lagging behind. On another hand, empirical research has largely relied on qualitative case studies. SNA can provide an avenue towards testing of existing theorizations, as well as building new empirically based theories.

This paper also engages in debate on innovation in the built environment sector. It addresses the gap in research on innovativeness of real estate organizations, and extends the literature stream on innovativeness of facility management organizations (Cardellino and Finch 2006). This paper also extends the use of social network analysis (Zheng et al. 2016) and ecosystem concept (Pulkka et al. 2016) in built environment sector innovation research. One open question for future research is how the innovation, knowledge and entrepreneurial ecosystems are interconnected in the industry, and how to overcome the challenges for creating new collaborations for innovation in the sector. Another dimension would be to expand analysis across the building project phases.

Limitations of the research

The analysis provided in this paper contain limitations to the methodological discussions, as well as for the analysis and results provided in this paper. These limitations may be of use for considerations on future research designs on ecosystems research.

First, the methodological approach has been pragmatic. The use of multiple methods for data collection and analysis is time consuming and manual work with data is prone to error. To counterbalance this, the protocol for data analysis has been designed to ensure consistency and time limitations. For this reason, the analysis does not comprehensively present the scope of interpretations allowed by the data. For example, qualitative data presentation could be expanded by presentation of counter examples, critical cases and triangulation of viewpoints with expert opinions.

Also, the data collection does not claim to be exhaustive for at least four reasons. First, the organizations provide only limited information on their partnerships in interviews or in documents. Second, a selection of a certain group of organizations as the starting point for data collection directs the search and the search protocol. Third, as the data was collected during multiple years, new partnerships have emerged and some have ceased to exist, and fourth, although the search protocol was structured, it relies on interpretations of the researcher and the interviewees. The selection of each actors and tie was based on the researcher, the interviewees and the document authors' interpretation of relevance, which here is defined as contribution to innovation goals. Where the contribution was unclear, the actor and actor tie were not included in the data.

Conclusion

This paper has argued that the innovation ecosystem concept can be useful for research on interorganizational structures and processes by conceptualizing business logics specific to certain activities. In addition to this, ecosystem concept can be used as a framework for analysis. Yet, ecosystems research has lacked rigor in formulating these conceptualizations and analytical frameworks. To this gap, this paper has attempted to structure an answer.

First, this paper has provided a definition for innovation ecosystem - *a system of actors that contribute towards a common system-level innovation goal.* By focusing on the systemic nature of ecosystems, this definition addresses the call for "complex adaptive systems agenda" on ecosystem research (Roundy et al. 2018; Ritala and Gustafsson 2018; Phillips and

Ritala 2019). Further, this definition paves the way for analytical frameworks that consider the actor-level and system-level attributes, such as various innovation goals. It also allows for recognition of multiple ecosystem layers. In comparison to already existing definitions of ecosystems, the definition proposed in this paper aims at being more operationalizable.

Second, this paper provides a method for operationalization of the innovation ecosystem definition. This operationalization relies on qualitative interviews, observations and document analysis for data collection and as basis for interpretation on the ecosystem characteristics. Also, it exploits social network analysis as a tool for quantitatively specifying ecosystem properties. This method can help in conducting, communicating and comparing ecosystem research in the future. By making ecosystems measurable, it may pave the way for functional ecosystem performance analysis and normative research.

Third, following the definition and method, this paper provides analysis of real estate innovation ecosystem. The analysis identifies digitalization goals, relevant actors and actor ties in relation to these innovation goals. Further, the four innovation ecosystem layers related to these goals are compared. Thus, this paper provides a novel research approach to research in the built environment sector. Finally, this paper encourages for systems thinking about organizational phenomena.

References

Adner, R. (2017). Ecosystem as structure: an actionable construct for strategy. Journal of management, 43(1), 39-58.

Adner, R., and Kapoor, R. (2010). Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations. Strategic management journal, 31(3), 306-333.

Ardito, L., Ferraris, A., Petruzzelli, A. M., Bresciani, S., & Del Giudice, M. (2019). The role of universities in the knowledge management of smart city projects. Technological Forecasting and Social Change, 142, 312-321.

Baggio, R., & Del Chiappa, G. (2014). Real and virtual relationships in tourism digital ecosystems. Information Technology & Tourism, 14(1), 3-19.

Basole, R. C. (2009). Visualization of interfirm relations in a converging mobile ecosystem. Journal of information Technology, 24(2), 144-159.

Basole, R. C. (2014). Visual business ecosystem intelligence: Lessons from the field. IEEE computer graphics and applications, 34(5), 26-34.

Basole, R. C., Clear, T., Hu, M., Mehrotra, H., & Stasko, J. (2013). Understanding interfirm relationships in business ecosystems with interactive visualization. IEEE Transactions on visualization and computer graphics, 19(12), 2526-2535.

Basole, R. C., Russell, M. G., Huhtamäki, J., Rubens, N., Still, K., & Park, H. (2015). Understanding business ecosystem dynamics: A data-driven approach. ACM Transactions on Management Information Systems (TMIS), 6(2), 6.

Bastian M., Heymann S., Jacomy M. (2009). Gephi: an open source software for exploring and manipulating networks. International AAAI Conference on Weblogs and Social Media.

Battistella, C., Colucci, K., De Toni, A. F., & Nonino, F. (2013). Methodology of business ecosystems network analysis: A case study in Telecom Italia Future Centre. Technological Forecasting and Social Change, 80(6), 1194-1210.

Blayse, A. M., & Manley, K. (2004). Key influences on construction innovation. Construction Innovation, 4(3). pp. 143-154.

Bossink, B. A. (2004). Managing drivers of innovation in construction networks. Journal of construction engineering and management, 130(3), 337-345.

Bresnen, M., & Marshall, N. (2000). Partnering in construction: a critical review of issues, problems and dilemmas. Construction management & economics, 18(2), 229-237.

Bygballe, L. E., & Ingemansson, M. (2014). The logic of innovation in construction. Industrial marketing management, 43(3), 512-524.

Cardellino, P., & Finch, E. (2006). Evidence of systematic approaches to innovation in facilities management. Journal of Facilities Management, 4(3), 150-166.

Chesbrough, H., Kim, S., & Agogino, A. (2014). Chez Panisse: Building an open innovation ecosystem. California management review, 56(4), 144-171.

Clarysse, B., Wright, M., Bruneel, J., & Mahajan, A. (2014). Creating value in ecosystems: Crossing the chasm between knowledge and business ecosystems. Research policy, 43(7), 1164-1176.

de Vasconcelos Gomes, L. A., Facin, A. L. F., Salerno, M. S., & Ikenami, R. K. (2018). Unpacking the innovation ecosystem construct: Evolution, gaps and trends. Technological Forecasting and Social Change, 136, 30-48.

Dubois, A., & Gadde, L. E. (2002). The construction industry as a loosely coupled system: implications for productivity and innovation. Construction Management & Economics, 20(7), 621-631.

Edwards, G. (2010). Mixed-method approaches to social network analysis. ESRC National Centre for Research Methods Review paper. NCRM/015.

Ehrenhard, M., Kijl, B., & Nieuwenhuis, L. (2014). Market adoption barriers of multi-stakeholder technology: Smart homes for the aging population. Technological forecasting and social change, 89, 306-315.

Engström, S., & Hedgren, E. (2012). Sustaining inertia? Construction clients' decision-making and information-processing approach to industrialized building innovations. Construction innovation, 12(4), 393-413.

Eriksson, K., Wikström, K., Hellström, M., & Levitt, R. E. (2019). Projects in the Business Ecosystem: The Case of Short Sea Shipping and Logistics. Project Management Journal, 50(2), 195-209.

Gann, D. M., & Salter, A. J. (2000). Innovation in project-based, service-enhanced firms: the construction of complex products and systems. Research policy, 29(7-8), 955-972.

Giesecke, S. (2017). Wiring up multiple layers of innovation ecosystems: Contemplations from Personal Health Systems Foresight. Technological forecasting and social change, 115, 278-288.

Glaser, B. and Strauss, A. (1967) The Discovery of Grounded Theory: Strategies for Qualitative Research. Aldine, Chicago

Graça, P., & Camarinha-Matos, L. M. (2017). Performance indicators for collaborative business ecosystems—Literature review and trends. Technological Forecasting and Social Change, 116, 237-255.

Granstrand, O., & Holgersson, M. (2019). Innovation ecosystems: A conceptual review and a new definition. Technovation, 102098.

Gulati, R., Puranam, P., & Tushman, M. (2012). Meta-organization design: Rethinking design in interorganizational and community contexts. Strategic management journal, 33(6), 571-586.

Harty, C. (2005). Innovation in construction: a sociology of technology approach. Building Research & Information, 33(6), 512-522.

Hellström, M., Tsvetkova, A., Gustafsson, M., & Wikström, K. (2015). Collaboration mechanisms for business models in distributed energy ecosystems. Journal of Cleaner Production, 102, 226-236.

Ivory, C. (2005). The cult of customer responsiveness: is design innovation the price of a client-focused construction industry?. Construction Management and Economics, 23(8), 861-870.

Jacobides, M. G., Cennamo, C., & Gawer, A. (2018). Towards a theory of ecosystems. Strategic Management Journal, 39(8), 2255-2276.

Kapoor, R., & Agarwal, S. (2017). Sustaining superior performance in business ecosystems: Evidence from application software developers in the iOS and Android smartphone ecosystems. Organization Science, 28(3), 531-551.

Khokhar, D. (2015). Gephi cookbook. Livery Place, UK: Packt Publishing Ltd.

Kytömäki, O., & Kadefors, A. (2018 September). Digitalization and innovation in the real estate sector. In ARCOM 34th Annual Conference. ARCOM.

Li, Y. R. (2013). The technological roadmap of Cisco's business ecosystem. In Software Ecosystems. Edward Elgar Publishing.

Lu, C., Rong, K., You, J., & Shi, Y. (2014). Business ecosystem and stakeholders' role transformation: Evidence from Chinese emerging electric vehicle industry. Expert Systems with applications, 41(10), 4579-4595.

Moore, J. F. (1993). Predators and prey: a new ecology of competition. Harvard business review, 71(3), 75-86.

Morse, J. M., Barrett, M., Mayan, M., Olson, K., & Spiers, J. (2002). Verification strategies for establishing reliability and validity in qualitative research. International journal of qualitative methods, 1(2), 13-22.

Mudrak, T., van Wagenberg, A., & Wubben, E. (2005). Innovation process and innovativeness of facility management organizations. Facilities, 23(3/4), 103-118.

Oh, D. S., Phillips, F., Park, S., & Lee, E. (2016). Innovation ecosystems: A critical examination. Technovation, 54, 1-6.

Phillips, M. A., & Ritala, P. (2019). A complex adaptive systems agenda for ecosystem research methodology. Technological Forecasting and Social Change, 148, 119739.

Phillips, M. A., & Srai, J. S. (2018). Exploring emerging ecosystem boundaries: defining 'the game'. International Journal of Innovation Management, 22(08), 1840012.

Pombo-Juárez, L., Könnölä, T., Miles, I., Saritas, O., Schartinger, D., Amanatidou, E., & Giesecke, S. (2017). Wiring up multiple layers of innovation ecosystems: Contemplations from Personal Health Systems Foresight. Technological forecasting and social change, 115, 278-288.

Pulkka, L., Ristimäki, M., Rajakallio, K., & Junnila, S. (2016). Applicability and benefits of the ecosystem concept in the construction industry. Construction management and economics, 34(2), 129-144.

Ritala, P., & Almpanopoulou, A. (2017). In defense of 'eco'in innovation ecosystem. Technovation, 60, 39-42.

Ritala, P., & Gustafsson, R. (2018). Q&A. Innovation and Entrepreneurial Ecosystem Research: Where Are We Now and How Do We Move Forward?. Technology Innovation Management Review, 8(7).

Ritala, P., Agouridas, V., Assimakopoulos, D., & Gies, O. (2013). Value creation and capture mechanisms in innovation ecosystems: a comparative case study. International Journal of Technology Management, 63(3-4), 244-267.

Rohrbeck, R., Hölzle, K., & Gemünden, H. G. (2009). Opening up for competitive advantage–How Deutsche Telekom creates an open innovation ecosystem. R&d Management, 39(4), 420-430.

Rong, K., Hu, G., Lin, Y., Shi, Y., & Guo, L. (2015). Understanding business ecosystem using a 6C framework in Internet-of-Things-based sectors. International Journal of Production Economics, 159, 41-55.

Rong, K., Lin, Y., Shi, Y., & Yu, J. (2013). Linking business ecosystem lifecycle with platform strategy: a triple view of technology, application and organisation. International journal of technology management, 62(1), 75-94.

Roundy, P. T., Bradshaw, M., & Brockman, B. K. (2018). The emergence of entrepreneurial ecosystems: A complex adaptive systems approach. Journal of Business Research, 86, 1-10.

Scaringella, L., Radziwon, A., (2018). Innovation, entrepreneurial, knowledge, and business ecosystems: old wine in new bottles? Technol. Forecast. Soc. Chang. 136, 59–87.

Scuotto, V., Ferraris, A., & Bresciani, S. (2016). Internet of Things: Applications and challenges in smart cities: a case study of IBM smart city projects. Business Process Management Journal, 22(2), 357-367.

Slaughter, E. S. (2000). Implementation of construction innovations. Building research & information, 28(1), 2-17.

South, A., Eriksson, K., & Levitt, R. (2018). How infrastructure public–private partnership projects change over project development phases. Project Management Journal, 49(4), 62-80.

Tilson, D., Lyytinen, K., & Sørensen, C. (2010). Digital infrastructures: The missing IS research agenda. Research commentary. Information Systems Research, 21(4), 748-759.

Toppinen, A., Miilumäki, N., Vihemäki, H., Toivonen, R., & Lähtinen, K. (2019). Collaboration and shared logic for creating value-added in three Finnish wooden multi-storey building projects. Wood Material Science & Engineering, 14(5), 269-279.

Tsujimoto, M., Kajikawa, Y., Tomita, J., & Matsumoto, Y. (2018). A review of the ecosystem concept—Towards coherent ecosystem design. Technological Forecasting and Social Change, 136, 49-58.

Tsvetkova, A., & Gustafsson, M. (2012). Business models for industrial ecosystems: a modular approach. Journal of Cleaner Production, 29, 246-254.

Tsvetkova, A., Eriksson, K., Levitt, R. E., & Wikstrom, K. (2019). Workflow Interdependence Analysis of Projects in Business Ecosystems. The Engineering Project Organization Journal, 8.

Valkokari, K. (2015). Business, innovation, and knowledge ecosystems: How they differ and how to survive and thrive within them. Technology Innovation Management Review, 5(8).

Von Krogh, G., Rossi-Lamastra, C., & Haefliger, S. (2012). Phenomenon-based research in management and organisation science: When is it rigorous and does it matter?. Long Range Planning, 45(4), 277-298.

Westerlund, M., Leminen, S., & Rajahonka, M. (2014). Designing business models for the internet of things. Technology Innovation Management Review, 5-14.

Wolfswinkel, J. F., Furtmueller, E., & Wilderom, C. P. (2013). Using grounded theory as a method for rigorously reviewing literature. European journal of information systems, 22(1), 45-55.

Zhang, J., & Liang, X. J. (2011). Business ecosystem strategies of mobile network operators in the 3G era: The case of China Mobile. Telecommunications policy, 35(2), 156-171.

Zheng, X., Le, Y., Chan, A. P., Hu, Y., & Li, Y. (2016). Review of the application of social network analysis (SNA) in construction project management research. International journal of project management, 34(7), 1214-1225.

Zygiaris, S. (2013). Smart city reference model: Assisting planners to conceptualize the building of smart city innovation ecosystems. Journal of the Knowledge Economy, 4(2), 217-231.