Received 29 April 2024
Revised 9 November 2024
Accepted 29 November 2024

A multilayer network model for studying business ecosystems: insights from enterprise architectures in the real estate sector

Olli Vigren
Department of Civil and Architectural Engineering, KTH Royal Institute of Technology, Stockholm, Sweden, and
Kent Eriksson
Department of Real Estate and Construction Management, KTH Royal Institute of Technology, Stockholm, Sweden

Abstract

Purpose – This article proposes a Multilayer Network (MLN) model for studying business ecosystems. The model focuses on the flows of products, services and money between buyers and sellers, emphasizing that these flows form both actor-level and emergent system-level ecosystem structures.

Design/methodology/approach – The article examines two case studies of real estate owners and their suppliers, using financial transaction data to provide a detailed, data-driven view of business ecosystems.

Findings – The study advances real estate theory by deepening research on the digitalization of real estate owners, especially on their enterprise architectures and supplier networks. Despite size differences, both case firms have similar, complex supplier-network structures. The findings may inform enterprise architecture management and procurement practices in the real estate sector.

Originality/value – The MLN model defines terminology for ecosystem layers and provides methods for establishing ecosystem boundaries. This aligns with the micro-level critique in management and ecosystems research. We conclude by highlighting that event data, when available, can enhance future business ecosystem analysis by enabling the study of broader ecosystem structures with the MLN model.

Keywords Building, Business ecosystem, Case study, Digitalization, Digital technology, Enterprise architecture, Information systems, Real estate, Social network analysis

Paper type Research paper

1. Introduction

All businesses depend on other organizations as they procure, produce, and sell products and services, thereby establishing interdependent business relationships. The concept of a business ecosystem captures these relationships and the logic of value creation at the system level (Jacobides *et al*., 2018; Thomas and Ritala, 2022; Eriksson *et al*., 2019). However, business ecosystem research has often focused on broader, high-level definitions, leaving a gap in understanding the microstructures and operational dynamics within ecosystems. Despite the recognition of the importance of micro-level interactions in shaping business ecosystems (e.g. Phillips and Ritala, 2019; Roundy and Lyons, 2021; Foss *et al*., 2023), there remains a gap in

We would like to thank Paavo Ritala, Robin Gustafsson, and the participants of the SCANCOR (Stanford) seminar for their valuable comments. We would also like to thank industry colleagues in Sweden for their collaboration. This work was supported by Jan Wallanders och Tom Hedelius Foundation and Tore Browaldhs Foundation (No. Fv24-0040) and Lars Erik Lundbergs Foundation (No. 988382).

Journal of European Real Estate Research
Vol. 18 No. 1, 2025
pp. 170-191
Emerald Publishing Limited
e-ISSN: 1753-9277
p-ISSN: 1753-9269
DOI 10.1108/JERER-04-2024-0027

conceptual and empirical studies that effectively connect these micro-level network structures with macro-level structures. This gap challenges the theoretical development of business ecosystem frameworks and limits practical applications across industries.

To address this gap, we ask: How can business ecosystems be conceptualized and studied as multilayer network structures? We empirically address this question within the real estate sector, where technological innovations and expectations for sustainable development are increasingly transforming the business ecosystems. According to the World Green Building Council, buildings account for nearly 40% of global energy-related carbon emissions and 50% of all extracted materials (World Green Building Council, 2021). Consequently, the success or failure of sustainable development efforts in the real estate sector has a significant impact on the global achievement of sustainable development goals. While there has been some progress in digitalization and sustainable development within the real estate sector (e.g. Pome *et al.*, 2021; Tagliaro *et al.*, 2021; Vigren *et al.*, 2022), the literature highlights the need for further studies, particularly in the broader use, operation, and maintenance phases of buildings (Atkin and Bildsten, 2017; Bröchner *et al.*, 2019; Ullah *et al.*, 2018; Koch *et al.*, 2019; Nyoni *et al.*, 2023; Brozovsky *et al.*, 2024).

Eriksson *et al.* (2019, p. 195) define business ecosystems as "systems of workflows that contribute toward a common system-level business goal." According to this perspective, actor-to-actor flows determine the relevance of actors within a business ecosystem. Consequently, this view emphasizes the micro-level mechanisms from which macro-level business ecosystem phenomena arise (Eriksson *et al.*, 2019). Multilayer networks establish units of analysis at multiple layers within a system (e.g. Dickison *et al.*, 2016; Salehi *et al.*, 2015; Kivelä *et al.*, 2014). We conceptualize organizations as actors forming one network level, while the ecosystem represents another system level, with these levels being interconnected.

However, this view contrasts with the broader and more commonly used definitions of ecosystems. According to Moore (1993, p. 76), business ecosystems consist of groups of companies that "co-evolve capabilities around a new innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations." This definition demonstrates a significant overlap with the concept of innovation ecosystems, and the two concepts have often been used in the literature with a high degree of similarity, as shown by de Vasconcelos Gomes *et al.* (2018) in their systematic literature review. For example, Granstrand and Holgersson (2020, p. 3) define an innovation ecosystem as "the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors".

Challenges with the broader ecosystem definitions are the lack of clear boundary conditions and the limitations in conceptualizing the internal structures and processes at the microlevel, specifically concerning organizations and their relationships. Additionally, another gap in business ecosystem literature is the lack of conceptual and methodological frameworks that link micro- and macro-level perspectives. Phillips and Ritala (2019) highlight that ecosystem research lacks a "meta-level" methodological approach to guide research designs, which hinders theoretical and methodological development. The absence of practical methodological approaches is also evident in a recent call for research on ecosystem microfoundations (Roundy and Lyons, 2021), emphasizing the need for a deeper understanding of the microstructures within business ecosystems.

To address this gap, we propose a Multilayer Network (MLN) model for studying business ecosystems as multilayer network structures. We draw on Social Network Analysis (SNA), a theory and methodology identified as a potential improvement to business ecosystem research (e.g. Shipilov and Gawer, 2020; Tsujimoto *et al.*, 2018; Alvedalen and Boschma, 2017; Spigel and Harrison, 2018; Neumeyer and Santos, 2018). SNA focuses on human interactions that produce social structures, characterized in terms of network structures (Wasserman and Faust, 1994; Scott, 2013; Borgatti *et al.*, 2013). Given that business ecosystems have characteristics of network structures, SNA provides a natural theoretical and methodological complement to business ecosystem theory. However, its application in business ecosystem research remains underexplored. Notable examples of network analysis in ecosystems include the works of Battistella *et al.* (2013), Sloane and O'reilly (2013), Clarysse *et al.* (2014), and Basole *et al.* (2015). These studies, however, typically focus on a single level, such as the network of actors within the ecosystem. Our contribution to this literature involves expanding the definition and framework introduced by Eriksson *et al.* (2019) by explicating how the business ecosystem structures are formed as multilayer network structures. Furthermore, by utilizing actual invoice data between buyers and sellers, we provide a more detailed, data-driven description of the ecosystem structures, compared to analyses where actors and ties are either assumed or derived from other sources.

We apply the MLN model to study enterprise architectures (EAs) in the real estate sector. EAs are information system architectures covering how multiple information systems are integrated at the organizational level (Winter and Fischer, 2006; Barbosa *et al.*, 2019; Hacks *et al.*, 2017). They are an important prerequisite for digitalization, as organizations rely on multiple data sources, systems to store and analyze the data, and multiple use-cases of data. EAs enable the collection, sharing, and utilization of information internally within organizations and externally with stakeholders, such as suppliers. Therefore, the management, development, and maintenance of EAs have significant implications for the performance of organizations. Our approach to studying EAs as buyer-seller relations forming ecosystem structures aligns with existing research on stakeholder perspectives on EAs (Hacks *et al.*, 2017). Research on EAs in real estate is scarce, although recent important contributions propose models and methods for platform-based designs (Sulzer *et al.*, 2023; Shaw, 2020) and developing real estate energy systems (Wetter and Sulzer, 2023; Koirala *et al.*, 2024).

This article makes two contributions. First, the MLN model extends business ecosystem theory by explaining relationships between micro- and macro-level phenomena in business ecosystems. We empirically show how micro-level business relationships form macro-level business ecosystem structures. Specifically, the model expands upon the definition and framework introduced by Eriksson *et al.* (2019) and aligns with the multilayer networks literature (Dickison *et al.*, 2016; Salehi *et al.*, 2015; Kivelä *et al.*, 2014). Second, the application of the MLN model to the real estate sector expands research on innovation and digitalization of real estate owners.

Furthermore, the article aligns with stakeholder perspectives on EAs (Hacks *et al.*, 2017) and proposes new research avenues regarding EAs in real estate research. The empirical findings highlight the need for further research, and the MLN model offers pathways to address these needs. The literature on EAs in real estate is in its early stages. Additionally, we discuss the potential benefits of using event data for business ecosystem analysis in future studies. Event data, when available, enables the study of much broader ecosystem structures in accordance with the MLN framework. Finally, we see that the MLN model holds potential for industry development. It allows for a nuanced understanding of how individual organizations interact within complex business ecosystems. This enables stakeholders to optimize their collaboration strategies, particularly in buyer-seller relations.

The next section introduces the MLN model, followed by the research methodology and results. The discussion and conclusion then highlight the contributions of this study and outline opportunities for future research.

2. Theoretical framework

This section reviews previous research on business ecosystems, particularly focusing on the microstructures of business ecosystems, and introduces the MLN model for studying business ecosystems as multilayer network structures.

2.1 Theoretical frameworks for studying the microstructures of business ecosystems

Theoretical models for conceptualizing and researching the microstructures of ecosystems help us understand how individual actors and their interactions create larger systems. These models have emerged in response to critiques of the broad, macro-level explanations in business ecosystem research, reflecting the concerns raised by the microfoundations movement in management and organization studies (Aguinis and Molina-Azorín, 2015; Teece, 2007; Felin *et al*., 2015; Barney and Felin, 2013; Roundy and Fayard, 2019; Roundy and Bayer, 2019). This microlevel critique also aligns with the broader critiques of ecosystem conceptualizations, particularly regarding the lack of conceptual clarity, an issue many scholars have highlighted (e.g. Oh *et al*., 2016; Stam, 2015; Scaringella and Radziwon, 2018), as well as the lack of methodological frameworks for empirical research (e.g. Phillips and Ritala, 2019; Malecki, 2018). Collectively, these critiques put forward the need for a more nuanced and critical evaluation of mainstream ecosystem conceptualizations.

Table 1. Microstructural perspectives in business ecosystem theory

Microstructural perspectives in ecosystem research	Main contribution	Authors	Limitations in the current ecosystem literature from microstructure perspectives
Network analysis models	Offers concepts and metrics to study the structures of ecosystems, treating organizations as actors (nodes) in the network and conceptualizing their relationships as ties	e.g. • Shipilov and Gawer (2020) • Battistella *et al*. (2013) • Clarysse *et al*. (2014) • Basole *et al*. (2015) • Sloane and O'reilly (2013)	• Focus on static network snapshots, neglecting dynamics • Lack of multilayer network frameworks and operationalizations
Ecosystem structure models	Highlights interdependencies, alignment, and roles, among actors in ecosystems	e.g. • Adner (2006, 2017) • Jacobides *et al*. (2018) • Thomas and Ritala (2022)	• One-dimensional focus on organizations and their interdependencies • Lack of clarity in terminology related to ecosystem layers
Ecosystem strategy models	Highlights how organizations strategize in ecosystems	e.g • Teece (2007) • Hannah and Eisenhardt (2018) • Dattée *et al.* (2018)	• In focusing on firms, strategizing, and orchestration, there is often a limited conceptualization of other ecosystem-level phenomena
Digital platform models	Highlights how digital technologies facilitate value creation by connecting various actors within business ecosystems	e.g. • Gawer and Cusumano (2014) • Tiwana (2014) • Rochet and Tirole (2003)	• Often lacks conceptualizations of ecosystem-level phenomena beyond actors' interdependence with each other through the platform

Source(s): Authors' own work

In the following, we categorize these microlevel perspectives into four categories: (1) network analysis models, (2) ecosystem structure models, (3) ecosystem strategy models, and (4) digital platform models (Table 1). This conceptualization bypasses the individual level, as well as behavioral and institutional theories. While these theories provide important perspectives on ecosystem microstructures, the focus of this article is primarily on theories where organizations are the main actors that collectively form the ecosystem. We present the primary contributions of each type and illustrate how our MLN model compares to them.

Network analysis models provide a conceptual and methodological framework for studying ecosystems as network structures (Shipilov and Gawer, 2020; Tsujimoto *et al*., 2018; Alvedalen and Boschma, 2017; Spigel and Harrison, 2018; Neumeyer and Santos, 2018). Social Network Analysis focuses on human interactions that create social structures, which can be defined by their network characteristics (Wasserman and Faust, 1994; Scott, 2013; Borgatti *et al*., 2013). Most business ecosystem research based on networks uses concepts and metrics from network analysis to study the structures of ecosystems, treating organizations as actors (nodes) in the network and conceptualizing their relationships as ties (e.g. Battistella *et al*., 2013; Sloane and O'reilly, 2013; Clarysse *et al*., 2014; Basole *et al*., 2015). Such models are important for understanding how information and resources flow within the network. Centrality measures and other network metrics are important components of such network analysis, as they can be used to categorize actor roles and positions in ecosystems (Freeman *et al*., 1979). While network analysis would also allow for dynamic studies of networks, existing research primarily examines networks at specific moments in time. Furthermore, network analysis supports multilayer network conceptualizations and analyses; however, current research lacks such frameworks in relation to business ecosystem concepts and operationalizations in empirical studies.

Ecosystem structure models in ecosystem theory describe how ecosystems function and evolve over time (e.g. Moore, 1993; Adner, 2006; Adner, 2017; Jacobides *et al*., 2018). They provide insights into the interactions among various organizations and how these interactions contribute to value creation. Adner's (2017) concept of "alignment structures" is an example, illustrating how actors adjust their operations to meet the requirements and expectations of the ecosystem. Similarly, Jacobides *et al*. (2018) argue that business ecosystems emerge around supermodular or unique complementarities between actors, and that these complementarities may occur in production or consumption. Other scholars, such as Thomas and Ritala (2022), have expanded the literature to include dynamic perspectives on ecosystem emergence. The main contribution of ecosystem structure models is to highlight the interdependencies and alignment among diverse actors in ecosystems. However, a limitation of these models is their often one-dimensional focus on organizations and their interdependencies, without clarifying the terminology related to ecosystem layers. Ecosystems are conceptualized as interorganizational structures (cf. Gulati *et al*., 2012) or viewed as a "meso-level perspective" for organizations (Mazzucato and Robinson, 2018). Additionally, it is suggested that ecosystems are composed of multiple layers (Carayannis and Campbell, 2009). However, the hierarchical classifications within ecosystem theory are inconsistent, and there is no widely recognized typology for these layers.

Ecosystem strategy models in ecosystem theory relate to strategic decision-making, emphasizing how organizations navigate complex ecosystem environments. Here, the dynamic capabilities framework (Teece, 2007; Foss *et al*., 2023) serves as a key contribution, aligning with a long tradition of strategic management research on firm resources and performance in the context of dynamic industries or a firm's environment (e.g. Barney, 1991; Amit and Schoemaker, 1993; Teece *et al*., 1997). Ecosystem strategy models also address firms' strategic options within ecosystems (e.g. Hannah and Eisenhardt, 2018; Dattée *et al*., 2018), as well as ecosystem orchestration (e.g. Nambisan and Sawhney, 2011; Gawer and Phillips, 2013), which serves as an example of the important ecosystem-level roles of certain actors. The main contribution of ecosystem strategy models in ecosystem theory is to enhance understanding of how organizations leverage dynamic capabilities and strategic decision-making to navigate complex environments and orchestrate ecosystems effectively, thereby influencing their performance. However, ecosystem strategy models often lack conceptualizations of ecosystem-level phenomena, such as the dynamics of system-level networks; for example, they may not adequately address how interorganizational networks among firms influence collective innovation outcomes and resource allocation within an ecosystem.

Digital platform models center on how digital technologies, such as platforms (e.g. Gawer and Cusumano, 2014; Cennamo, 2021) or architectures (e.g. Tilson *et al.*, 2010; Henderson and Clark, 1990), connect actors and facilitate value creation in business ecosystems. Here, technologies such as data, applications and interfaces, as well as developer communities, represent important microstructures of platform ecosystems (e.g. Tiwana, 2014). On the other hand, an equally important perspective is how platform ecosystems emerge in response to technological trends and market needs, and how multiple platform ecosystems compete with each other in markets, which is why platforms themselves can be viewed as microstructures of business ecosystems (Thomas *et al.*, 2014). A related concept is digital business ecosystems, which emphasizes value co-creation within business ecosystems through shared digital platforms (Senyo *et al.*, 2019, p. 53). Within the literature on digital platforms, topics such as technology ecosystem governance (e.g. Wareham *et al.*, 2014), two-sided markets and network effects (e.g. Rochet and Tirole, 2003), and strategic management at both the actor and ecosystem levels (McIntyre and Srinivasan, 2017) are important themes that cross organizational and system-level characteristics of business ecosystems. This research has developed in several research domains, which has complicated the emergence and spread of common concepts. Thus, for example, Constantinides *et al.* (2018) call for interdisciplinary research on platforms. Overall, this literature contributes to understanding how digital technologies facilitate value creation by connecting various actors within business ecosystems. However, with its main conceptualizations of digital technologies and actor constellations, this literature also often lacks conceptualizations of ecosystem-level phenomena beyond actors' interdependence with each other through the platform.

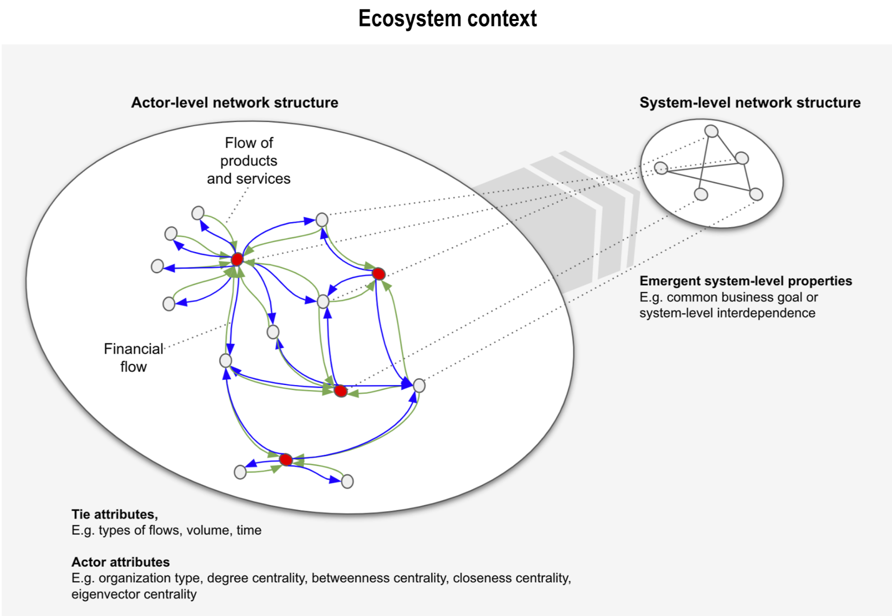
In summary, scholars from various fields, including strategic management, economics, organizational studies, and information systems, have contributed to our understanding of business ecosystem microstructures. However, the primary limitation noted in this article is the inconsistency in theoretical classifications of micro- and macrostructures, and the absence of a widely recognized typology for these layers (e.g. Gulati *et al.*, 2012; Mazzucato and Robinson, 2018; Carayannis and Campbell, 2009). This lack of consensus complicates the overall theory of business ecosystems. Table 1 summarizes the main contributions and limitations of these theories from the perspective of business ecosystem microstructures.

2.2 A multilayer network model for studying business ecosystems

This section develops the MLN model for studying business ecosystems. We introduce relevant concepts related to business ecosystems and how these concepts relate to each other in the model (Figure 1).

Business ecosystem definition: Eriksson *et al.* (2019, p. 195) define business ecosystems as "systems of workflows that contribute toward a common system-level business goal." We adopt this definition, acknowledging that business ecosystems consist of *actor-level network structures*, which include flow mechanisms connecting various actors, and *system-level network structures*, which represent emergent properties such as shared business goals or system-level interdependence. Furthermore, these network structures are embedded in *Ecosystem contexts*, which encompass broader institutional elements impacting business ecosystems (Scott, 2013; DiMaggio and Powell, 1983; cf. Granovetter, 1985; Engwall, 2003).

Social Network Analysis: We turn to the literature on SNA to describe flows, actors, and product/service systems. This approach is motivated by the fact that flows form patterns of social activity that constitute networks, and SNA offers a rich set of theories, methods, and metrics for studying network structures. SNA is both a theoretical and methodological research perspective with long-standing traditions in social science research and has now been



Source(s): Authors' own work

Figure 1. The MLN model: business ecosystems as multilayer network structures

applied in many other fields. SNA focuses on human interactions that produce social structures, which are characterized as network structures (Scott, 1988). This emphasis on structure differentiates SNA from other network theories (e.g. Gulati, 1998). We argue that SNA provides a natural theoretical and methodological basis for understanding business ecosystems, as both social networks and business ecosystems are fundamentally network-based structures due to the interdependencies between the actors (Shipilov and Gawer, 2020; Battistella *et al*., 2013; Clarysse *et al*., 2014; Basole *et al*., 2015; Sloane and O'reilly, 2013).

Flows and ties: Flows in SNA can take many forms, such as the flow of resources or the transfer of money (Scott, 2013; Burt, 1992). In the MLN model, two types of flows are present: flows of products and services, and monetary flows to pay for these products and services. Both flows occur in bilateral relations between two types of actors: buyers and sellers. It is assumed that the flows consist of singular but consecutive events, such as purchase decisions, and the flows contain assets, such as digital technologies that the buyers procure from the sellers. Therefore, it is the flows in the larger product/service system (e.g. Tsujimoto *et al*., 2018; Battistella *et al*., 2013) around which actor constellations emerge, as actors assume different functional roles in the ecosystem. The flows may contain tie attributes, such as strength, direction, timing, or assets. Ties can be either direct or indirect. In other words, actors have direct ties due to flows between them, or indirect ties, where an actor is connected to another through a third party or system-level interdependence, such as a shared business goal. Therefore, for example, suppliers are in competition with each other if they serve the same buyers with similar offerings in the ecosystem. We acknowledge that actors may also have intangible ties (Battistella *et al*., 2013), such as shared norms, values, trust, or co-location, but we view these as attributes of the broader ecosystem context.

This perspective of ecosystems-as-flow structures aligns with definitions that arise from the industrial ecosystem research tradition (e.g. Eriksson *et al*., 2019; Tsvetkova and Gustafsson, 2012; Adamides and Mouzakitis, 2009). For example, Tsvetkova and Gustafsson (2012) argue that "industrial ecosystems can be perceived as complex systems" – similar to natural ecosystems

(Levin, 1998) – and that these systems fundamentally consist of flows, such as material, energy, products, services, and money (Tsvetkova and Gustafsson, 2012). According to these definitions, it is the actor-to-actor flows that determines which actors are relevant in a business ecosystem, thereby establishing the ecosystem boundaries. However, it must be noted that this view contrasts with the broader and more commonly used definitions of ecosystems, which empathize co-location, "sets of actors" or "loose connections" without clear system boundaries.

Actors: Actors in the MLN model are conceptualized as firms or other types of organizations. In SNA, the actors represent the nodes in the network, and actors may have various actor attributes, such as organization type or other metrics. Actors' position in a network is an important attribute (Borgatti *et al*., 2013), as actors' position yields them an access to the assets that flow in the network and determines which constraints and opportunities they encounter. Actors' position in a network can be measured with centrality measures, such as degree centrality, betweenness centrality, closeness centrality or eigenvector centrality (e.g. Freeman *et al*., 1979).

Network: In the MLN model, flows and actors are conceptualized as ties and nodes, which together form networks (Borgatti *et al*., 2013). These networks encompass both *actor-level network structures* and emergent *system-level network structures*. Here, emergence can be understood as the ecosystem-level phenomena that arise from *the actor-level network structures* (Phillips and Ritala, 2019; Peltoniemi, 2006). Each organization makes decisions with limited information and in response to others (Peltoniemi, 2006), although some actors are in more central positions and may therefore have more influence. On the other hand, the emergent ecosystem-level phenomena are attributes of the whole ecosystem and cannot be derived from any single organization. Here, SNA serves as a methodological instrument to describe these network structures within business ecosystems. The inherent advantage of SNA lies in its established methodological toolbox for describing network structures and properties, such as distance, density, network diameter, modularity, connected components, and network clusters, which can be used to analyze business ecosystems (Freeman *et al*., 1979; Wasserman and Faust, 1994; Scott, 2013; Borgatti *et al*., 2013). Furthermore, SNA allows for *multilayer network* analysis (e.g. Dickison *et al*., 2016; Salehi *et al*., 2015; Kivelä *et al*., 2014), which, in the MLN model, is utilized to define *actor-level* and *system-level network structures*.

To conclude, in the MLN model, the flows of products and services, along with the monetary transactions used to pay for them, tie actors together in an *actor-level network structure* that describes the microstructures of business ecosystems. Ties and actors have attributes that can be used to analyze these microstructures. *System-level network structures*, such as common business goals or system-level interdependence, emerge from the microstructures. Both *actor-level* and *system-level network structures* have network properties, and together they form a business ecosystem. The aim of the MLN model as a structure of ideas is to provide a conceptual framework for empirical research on business ecosystems.

3. Methodology

To empirically validate the MLN model, we operationalized it in a study of a business ecosystem within the context of the Swedish real estate industry. We demonstrate how the MLN model can be used to identify *actor-level* and *system-level network structures*.

3.1 Real estate as a research context

Research in this context was motivated by the following factors: (1) the built environment sector is complex in its supply chains (e.g. Dubois and Gadde, 2002), and the business ecosystem theory provides an excellent framework for understanding this complexity; (2) new demands for digitalization and sustainability (Vigren *et al*., 2022) create a need to reassess existing business relationships; (3) the authors had access to a unique dataset of financial transactions between buyer and sellers, which aligns well with the purpose of demonstrating the MLN model. Furthermore, there is a research gap in understanding business ecosystems related to digitalization and innovation in the real estate sector, as well as in the broader use, operation, and maintenance phases of buildings (Atkin and Bildsten, 2017; Bröchner *et al.*, 2019; Ullah *et al.*, 2018; Koch *et al.*, 2019; Nyoni *et al.*, 2023; Brozovsky *et al.*, 2024).

Specifically, business ecosystem analysis can identify lock-ins within the business ecosystem structures (Eriksson *et al.*, 2019) and can help break the current path dependencies (Sydow *et al.*, 2009) related to these structures. This is important because organizations need to reassess their supplier networks to identify opportunities for meeting new business goals related to digitalization and sustainability. The real estate sector has traditionally been seen as an environment where success has been attributed to factors other than innovation. Real estate owners, whose core business involves developing, maintaining, leasing, buying, and selling properties (Vigren *et al.*, 2022), have generally been perceived as traditional actors (Engström and Hedgren, 2012), and innovation efforts are often limited by path-dependencies in established practices and assets (Troje, 2023; Bäcklund *et al.*, 2024).

However, there are increasing expectations regarding digitalization and sustainability in the sector (Pome *et al.*, 2021; Tagliaro *et al.*, 2021; Vigren, 2022). Real estate owners and their suppliers have begun investing resources in innovation and establishing new roles and processes to foster innovation (Vigren *et al.*, 2022). In Sweden, digitalization and sustainability have been recognized as key development areas in the real estate sector, and country is generally known for its ambitious sustainability goals. Therefore, we see practical relevance in the fact that digitalization and sustainability are important drivers for industry development, and the MLN model provides a nuanced understanding of how organizations interact within complex business ecosystems.

Our focus is on understanding supplier–buyer relationships related to digitalization, and we therefore focus on suppliers of digital technologies in the real estate sector. Due to the growing interest in digitalization, firms have an increasing need to examine their information systems. These systems are central as companies aim to reduce their emissions and develop new data-driven services and processes. In this context, we find the concept of enterprise architecture relevant, as it provides a theoretical model for understanding information systems at the organizational level. EAs models are typically viewed as information system architectures at the enterprise level, aiming to integrate business and IT perspectives (Kotusev *et al.*, 2015). A summary of the literature and concepts can be found in Barbosa *et al.* (2019). However, no generally accepted definition for the term exists. EAs can combine different perspectives as EA subsystems, such as business, data, information, applications, and technology. Extensions to these core perspectives focus on aspects such as strategy and governance (Barbosa *et al.*, 2019), stakeholder perspectives (Hacks *et al.*, 2017), and layered architecture models and dependencies (Winter and Fischer, 2006). EA models often focus on the current state of EA, aiming to describe opportunities for improvement and its management (Barbosa *et al.*, 2019). They can also focus on desired states, for example, by defining reference architectures (Timm *et al.*, 2017; Sanchez-Puchol and Pastor-Collado, 2017).

In this article, we model EAs by aggregating financial data from invoices from technology suppliers to real estate owner case firms. We analyze the total cost of EAs and categories of suppliers. This aligns with the research on EA stakeholder perspectives (Hacks *et al.*, 2017) and expands EA research in the real estate sector. Especially, the current real estate research does not cover the analysis of EA models, although recent important contributions propose models and methods for platform-based designs (Sulzer *et al.*, 2023; Shaw, 2020) and developing real estate energy systems (Wetter and Sulzer, 2023; Koirala *et al.*, 2024). Therefore, this article enhances understanding of innovation in the real estate sector by analyzing EA models.

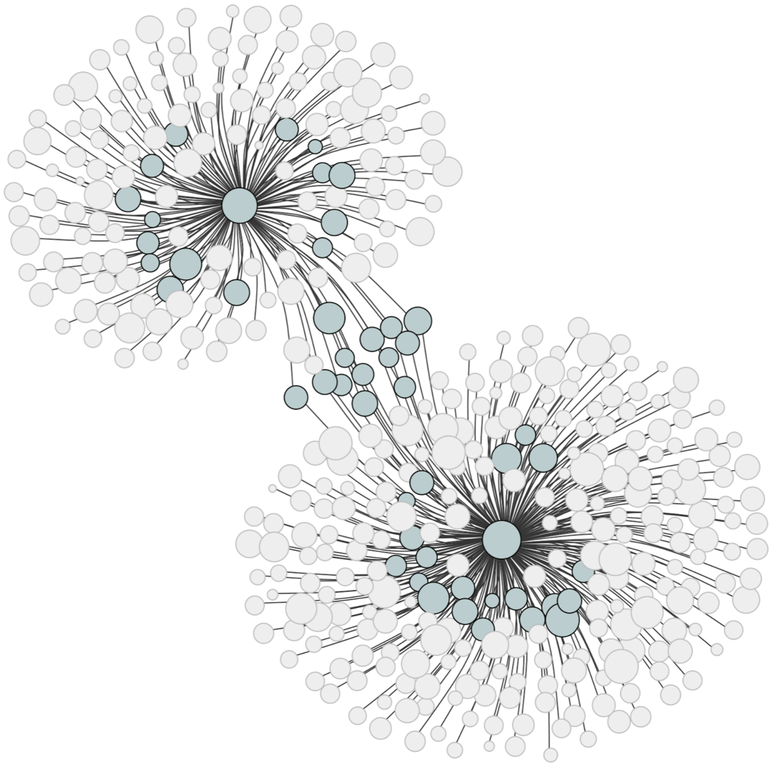
3.2 Approach to the case study

The study was conducted in collaboration with a Swedish real estate industry association—an organization that supports industry development and represents the interests of over 300 non-profit municipal and private housing companies throughout Sweden. A key advantage of this collaboration was access to relevant real estate owner cases and their financial data, along with opportunities to validate the study's findings by presenting them to both the case firms and the industry association, which may have increased the internal validity of the research (Shenton, 2004).

These cases were selected because they represent typical examples (Yin, 2009) within the category of municipality-owned real estate firms. As is common for such companies, they share similar ownership structures, governance, goals, and operations. However, they differ in size: Firm A owns and manages approximately 1,500 apartments and has around €10m in revenue, while Firm B owns and manages approximately 12,000 apartments and has about €100m in revenue. Additionally, this case selection highlights and facilitates the comparison of local buyer-seller relationships across different regions of Sweden. Therefore, the cases also demonstrate variety within the category of municipality-owned real estate firms, reflecting diversity (Eisenhardt and Graebner, 2007) in this sector. Given their representativeness, these cases were appropriate for identifying patterns that may be generalizable to similar firms in the real estate sector.

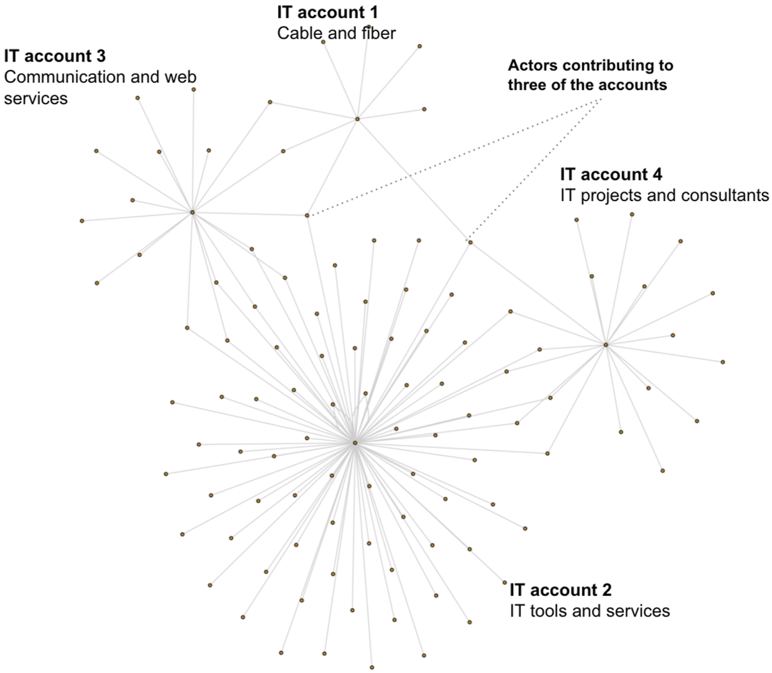
3.3 Data collection and analysis

The aim of the analysis was to identify relationships at the *actor-level network structures* and to analyze how these relationships contribute to the *system-level network structures*. The dataset consists of all invoices received by the case firms during one fiscal year. Therefore, it is event-based data, where an event — an invoice — represents a monetary flow between a buyer



Source(s): Authors' own work

Figure 2. Actor-level network structure – two case firms and 412 suppliers



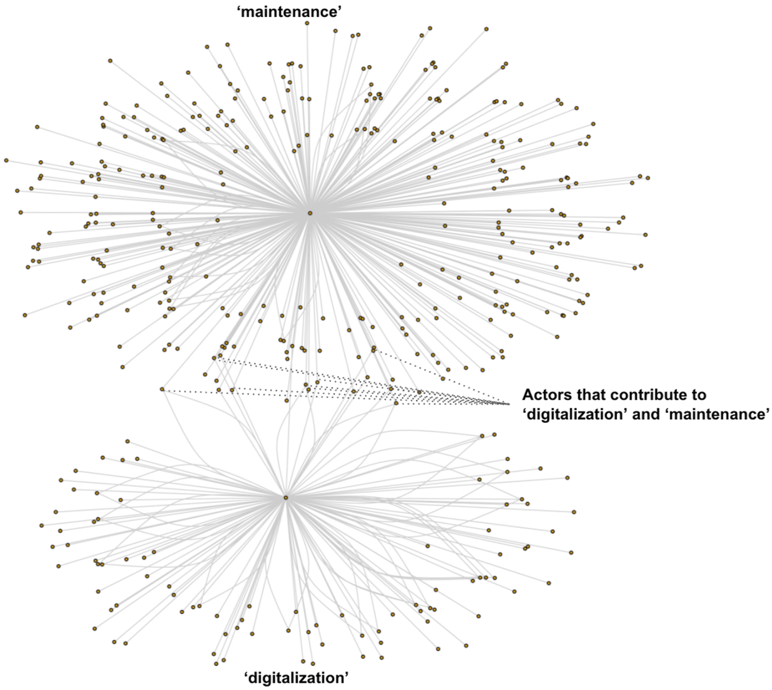
Source(s): Authors' own work

Figure 3. System-level network structure of the "digitalization" network

and a seller, along with the corresponding flow of products and services. This serves as the basic building block of the analysis, in accordance with the MLN model. The data were aggregated for the full fiscal year for each supplier and cost center, allowing for consolidated presentations in Figures 2 - 4.

In accounting, a cost center (or cost account) is a specific department or unit within an organization that incurs costs in its operations. The primary purpose of a cost center is to track and manage costs associated with various business functions. We focused on two types of cost centers and excluded others from the analysis. First, we analyzed cost centers related to "digitalization", i.e. those associated with information technologies and services. Specifically, these include "IT account 1 – Cable and fiber," "IT account 2 – IT Tools and services," "IT account 3 – Communication and web services," and "IT account 4 – IT Projects and consultants." As a whole, this constitutes what we mean by enterprise architecture in this context. Second, we analyzed all cost centers related to "digitalization" and "maintenance" because we wanted to understand how "digitalization", typically seen as a support function, contributes to "maintenance", which is generally viewed as a core business function in the real estate industry.

This methodology relies on the basic accounting principles of aggregating data from invoices to cost centers, which is used for the purposes of internal and external financial reporting and cost management (Kulmala *et al.*, 2002). Therefore, the data and methodology relies on how the data is structured according to the Swedish financial reporting standards. We are not aware of the use of similar methodology — or event-based data, for that matter — in the research of business ecosystems. The data was structured in Excel and analyzed in *R* using the *R* igraph package (Csardi and Nepusz, 2006), as it provides a comprehensive set of tools for SNA data management, analysis, metrics, and network visualizations.



Source(s): Authors' own work

Figure 4. System-level contribution of "digitalization" to "maintenance"

4. Findings

The findings section first presents the *actor-level network structure*, followed by the *system-level network structures* related to "digitalization" and "maintenance".

4.1 Actor-level network structure

Figure 2 presents the *actor-level network structure* in the MLN model, which is also a typical representation in previous network-based business ecosystem studies (e.g. Battistella *et al.*, 2013; Clarysse *et al.*, 2014; Basole *et al.*, 2015; Sloane and O'reilly, 2013). The network consists of two real estate owners (buyers; central nodes) and their 412 suppliers (sellers). Altogether, there are 473 ties between the buyers and sellers, as a seller can have a tie with both case firms and with multiple cost accounts within a case firm. Therefore, the network consists of two egocentric networks. The ties between the case firms and suppliers are presented, but potential supplier-supplier ties are not represented in the data or analysis. The suppliers in the middle of the figure, highlighted in light green, supply both case firms, while the suppliers in light green close to the case firms provide services to more than one cost account within a case firm. Other suppliers provide services to a single cost account in one of the case firms. Altogether, there are 50 nodes (12%, including case firms) that have more than one tie (degree >1). The main finding is that both firms have similar network structures, there are few common suppliers between the case firms, and both firms rely on many local suppliers that contribute to their business.

4.2 System-level network structure of the "digitalization" network

Figure 3 presents the system-level network structure in the MLN model, focusing on the "digitalization" network, i.e. the IT cost centers 1–4. This is a novel presentation in business ecosystem research. Here, the central nodes in the stars represent the cost accounts and the other nodes represent the suppliers contributing to the business functions associated with these cost accounts. Therefore, the "digitalization" network consists of the suppliers that provide digital technologies and services to the case firms. Furthermore, the data is aggregated based on combining the cost account data of both case firms, and therefore the figure presents the relationships between suppliers and the system-level business functions. In other words, this data aggregation represents emergence from actor-level to system-level network structure.

Altogether, the "digitalization" network consists of 107 nodes and 123 ties. Dotted lines indicate some of the suppliers that are central in the system, as they provide services to multiple cost accounts. An interesting finding is that "IT Account 2 – IT Tools and services" has many suppliers at the system level, while other IT accounts have fewer suppliers. This may have implications for associated digitalization strategies and procurement, as managing multiple business relationships requires resources. In contrast, "IT Account 1 – Cable and fiber" has only a few suppliers. Another noteworthy finding relates to suppliers in central network positions, as they are likely to gain more information and access to resources compared to other actors within the network. Interestingly, some suppliers in the "digitalization" network cannot be classified as traditional IT suppliers. Instead, food stores and other local non-IT vendors contribute to the IT functions of the real estate firms. This suggests that strong assumptions about specific ties and interdependencies in business ecosystems may be premature and could be challenged by data.

4.3 System-level contribution of "digitalization" to "maintenance"

Figure 4 presents the *system-level network structure* in the MLN model, focusing on how the "digitalization" network contributes to the "maintenance" network. This also represents a novel presentation in business ecosystem research, and here too, these "digitalization" and "maintenance" network structures emerge from the *actor level* to the *system level*. The relationship between "digitalization" and "maintenance" is particularly interesting, as digitalization is often viewed as a support function for maintenance, which is seen as a core business function in the real estate and facility management sector. In the figure, the upper star-shaped structure represents the "maintenance" network, while the lower star-shaped structure represents the "digitalization" network. The central nodes in these star-shaped structures are the cost centers related to the "digitalization" and "maintenance" of both case firms. As in previous figures, the other nodes represent suppliers. Furthermore, actors with ties to both "digitalization" and "maintenance" are considered central actors based on their network positions. Altogether, the network consists of 402 nodes and 441 ties. Since the actors contributing to "digitalization" are primarily technology suppliers, the interpretation is that "digitalization" contributes to "maintenance", rather than vice versa. The main findings are that there are few actors directly involved in both "digitalization" and "maintenance," and that "maintenance" has more suppliers overall, many of which are local.

5. Discussion

The discussion section interprets the findings and outlines contributions and implications for real estate theory and business ecosystem theory. Additionally, we propose further research on real estate enterprise architectures and discuss the benefits of using event data for business ecosystem analysis in future studies.

5.1 Contributions and implications for real estate theory

The main contribution to the real estate theory relates to the operationalization of the MLN model in the real estate sector, and this expands research on digitalization of real estate owners (Engström and Hedgren, 2012; Vigren *et al.*, 2022; Bäcklund *et al.*, 2024). Previous research lacks perspectives related to real estate business ecosystems and buyer-seller relationships related to digitalization.

First, we analyzed supplier networks and found that both case firms, despite their different sizes, have similar supplier-network structures, which indicates that real estate owners have similar operations and needs for suppliers. Furthermore, real estate owners use many local service providers, which isn't surprising, given the highly location-based nature of the business.

Second, we analyzed their digitalization networks based on their IT cost accounts and conceptualized that these supplier networks constitute the stakeholders of the real estate owners' enterprise architectures in this context. The finding that different IT cost accounts have varying numbers of suppliers, resulting in distinct network structures, may have implications for related digitalization strategies and procurement, as managing multiple business relationships requires resources. Additionally, research on EAs in real estate is scarce. However, recent contributions propose models and methods for platform-based designs (Sulzer *et al.*, 2023; Shaw, 2020) and real estate energy system modeling (Wetter and Sulzer, 2023; Koirala *et al.*, 2024). We concur with these authors on the necessity for more research on EAs. In this article, by analyzing EA stakeholders at both the case firm and system levels, we have empirically demonstrated the complexity associated with these EAs. Notably, both case firms had several dozen IT suppliers, highlighting the complexities involved in managing digitalization within the industry. Appropriate pathways for future research include mapping EAs in the real estate sector, as well as analyzing digitalization strategies and governance (Barbosa *et al.*, 2019), stakeholder perspectives (Hacks *et al.*, 2017), and layered architecture models and dependencies (Winter and Fischer, 2006).

Third, the case studies also showed that real estate owners were not aware of the overall status or costs of their enterprise architectures. This finding is consistent with results from other sectors (Kulmala *et al.*, 2002). Thus, we concur with Kulmala *et al.* (2002) that analyzing cost structures related to EAs can help firms understand the bigger picture. On the other hand, real estate owners often have limited resources or expertise to develop EAs, and their roles and responsibilities related to it are dispersed across various departments within organizations (Vigren *et al.*, 2022). Therefore, the development of EAs should be initiated by setting clear goals for development, such as establishing reference architectures (Timm *et al.*, 2017; Sanchez-Puchol and Pastor-Collado, 2017), and by aligning the organization with these goals (Bäcklund *et al.*, 2024).

Fourth, the complexities for real estate owners to manage digitalization and supplier networks also present challenges for potential technology suppliers, such as PropTech startups. It may be difficult for them to justify why their technology brings added value in addition to already existing technologies, especially when existing technologies have lock-in mechanisms and path-dependencies that limit the transition to new technologies. A central question for technology providers is how their technologies integrate with the existing EA. Moreover, our conversations with PropTech firms show that it is difficult for them to even get sales meetings with real estate owners because they are busy, and the areas of responsibility for technology acquisitions in real estate owner organizations are unclear.

Finally, another noteworthy finding relates to suppliers in central network positions, as they are likely to gain more information and access to resources than other actors within the network. SNA theory suggests that actors connecting networks operate in bridging positions (high betweenness centrality) and play central roles in the network (Burt, 1992; Borgatti *et al.*, 2013). Consequently, these actors are important to the functioning of the entire business ecosystem (Adner, 2006, 2017; Jacobides *et al.*, 2018). However, business ecosystems may also develop strong dependencies on actors occupying these bridging positions. This dependency issue emerged in discussions with the case firms and the industry development organization, as their representatives expressed concerns about real estate owners' reliance on certain large national and international IT system suppliers. It is true that some IT suppliers maintain asymmetrical relationships with decentralized buyers in the real estate sector, leading to lock-ins and path dependency from the perspective of real estate owners. These lock-ins impact both digitalization and maintenance, thereby potentially hindering advancements in digitalization and sustainability across the broader business ecosystem. Nevertheless, business ecosystem analysis may help by uncovering these lock-ins (Eriksson *et al.*, 2019; Sydow *et al.*, 2009; Troje, 2023), making them both measurable and manageable.

5.2 Contributions and implications for business ecosystem theory

We contribute to business ecosystem theory by expanding upon the definition and framework introduced by Eriksson *et al.* (2019), explicating how business ecosystem structures are formed as multilayer network structures. This framework and analysis are similar to those of Battistella *et al.* (2013), Clarysse *et al.* (2014), Basole *et al.* (2015), and Sloane and O'reilly (2013), but differ by conceptually explaining how macro-level strucutres emerge from actor-level network structures and by basing this analysis on event data. Using actual invoice data between buyers and sellers provides a more detailed, data-driven description of the microstructures of the ecosystem, compared to analyses in which actors and ties are either assumed or derived from other sources.

Furthermore, the MLN model, built on the idea that the most central building block of business ecosystems is the flows between actors – where products, services, and money are exchanged – aligns with the industrial ecosystem view of business ecosystems (Tsujimoto *et al.*, 2018; Eriksson *et al.*, 2019; Tsvetkova and Gustafsson, 2012; Adamides and Mouzakitis, 2009). We argue that flow-based analysis determines which actors are relevant in a business ecosystem, thereby establishing ecosystem boundaries (Phillips and Ritala, 2019), and provides a meaningful unit of analysis compared to definitions that empathize "sets of actors" or "loose connections" without clear system boundaries. This approach also aligns with the broader micro-level critique in management and ecosystems research (Aguinis and Molina-Azorín, 2015; Teece, 2007; Felin *et al.*, 2015; Barney and Felin, 2013; Roundy and Fayard, 2019; Roundy and Bayer, 2019). Additionally, this

Table 2. Potential contributions of the MLN model to ecosystem research

Microstructural perspectives in ecosystem research	Limitations in the current ecosystem literature from microstructure perspectives	How may the MLN model contribute to future business ecosystem research?
Network analysis models	• Focus on static network snapshots, neglecting dynamics • Lack of multilayer network frameworks and operationalizations	• Provides definitions for multilayer network analysis • Similar to previous network research, it offers avenues for dynamic network analysis
Ecosystem structure models	• One-dimensional focus on organizations and their interdependencies • Lack of clarity in terminology related to ecosystem layers	• Establishes boundary conditions for ecosystem structures • Defines terminology for ecosystem layers
Ecosystem strategy models	• In focusing on firms, strategizing, and orchestration, there is often a limited conceptualization of other ecosystem-level phenomena	• Introduces concepts for distinguishing between actor-level and system-level phenomena, although strategies or platforms are not analyzed in this article
Digital platform models	• Often lacks conceptualizations of ecosystem-level phenomena beyond actors' interdependence with each other through the platform.	

Source(s): Authors' own work

ecosystems-as-flows theory aligns with the concept of natural ecosystems, in which flows – such as nutrients, energy, materials, or information – are the central building blocks (Levin, 1998).

Moreover, this ecosystems-as-flows theory is compatible with other definitions that consider ecosystems as structures, such as those by Jacobides *et al*. (2018) and Adner (2017). The ecosystems-as-flows approach may help by making business ecosystem phenomena, such as complementarities (Jacobides *et al*., 2018) or mutual agreements (Adner, 2017), explicit in actor-to-actor relationships. Based on this, it can explain how business ecosystem-level constructs may emerge from these micro-level flows.

Table 2 summarizes how the MLN model may contribute to microstructural perspectives in future ecosystem research. First, the MLN model provides definitions for multilayer network analysis (e.g. Dickison *et al*., 2016; Salehi *et al*., 2015; Kivelä *et al*., 2014) based on micro- and macro-level network structures, which may be useful in studies on multilayer ecosystems. Second, similar to previous SNA research on ecosystems (e.g. Shipilov and Gawer, 2020; Tsujimoto *et al*., 2018; Alvedalen and Boschma, 2017; Spigel and Harrison, 2018; Neumeyer and Santos, 2018), the MLN model offers avenues for dynamic network analysis, although this has not been operationalized here. The MLN model could be used to analyze past developments or to predict and steer ecosystem development, for example, by forecasting emergent system-level phenomena from actor-level interactions (Battistella *et al*., 2013) or identifying moments of continuity and discontinuity (Peltoniemi, 2006). Third, it establishes boundary conditions for ecosystem structures (Phillips and Ritala, 2019; Jacobides *et al*., 2018; Adner, 2006, 2017) and defines terminology for ecosystem layers, which is currently unsettled in the literature (Gulati *et al*., 2012; Mazzucato and Robinson, 2018; Carayannis and Campbell, 2009). Finally, it provides research avenues related to ecosystem strategy (Teece, 2007; Hannah and Eisenhardt, 2018; Dattée *et al*., 2018) and digital platform models (Gawer and Cusumano, 2014; Tiwana, 2014; Rochet and Tirole, 2003) by introducing concepts for distinguishing between actor-level and system-level phenomena, although strategies or platforms are not explicitly analyzed or discussed in detail in this article.

5.3 Benefits of event data for business ecosystem analysis

One important implication of the MLN model, as demonstrated in this article empirically, is that business ecosystem analysis can be done based on event data. Event data, particularly financial transaction data, offers advantages for analyzing business ecosystems. Using actual invoice data between buyers and sellers provides a more accurate, data-driven description of the microstructures of the ecosystem, compared to analyses where actors and ties are either assumed or derived from other sources. This has implications for which actors and ties are included in the analysis. For example, Battistella *et al*. (2013) base their analysis on the level of "types of actors," whereas our methodology focuses on actors themselves and does not assume any actor typology. Instead, our analysis relies on transaction data to define an actor's belonging to the ecosystem. Interestingly, this approach showed that a local food store is as part of the "digitalization" network, as it had invoiced cost centers related to "digitalization." Had we assumed that only certain types of actors, technologies, or services are relevant to "digitalization," we would have missed this finding. On the other hand, one might question the significance of this finding, but we believe it demonstrates well that ecosystems are complex systems that transcend industry or functional boundaries, with actors from various sectors providing essential products and services for ecosystem functioning. Nevertheless, we agree with Battistella *et al*. (2013) and Borgatti *et al*. (2013) that it is the researcher's responsibility to set boundary conditions for ecosystems, and with Phillips and Ritala (2019) that ecosystems are "open systems" in which actors join and leave. Other benefits of using event data in future research on business ecosystems include:

Comprehensiveness and scalability: Event data provides a comprehensive view of business ecosystem activities and relationships. It includes information about various aspects such as time, location, monetary value, volume, assets, and actors involved. Moreover, analysis methods applied to event data are scalable, efficient, and can be automated, making it suitable for large-scale studies, where data is accessible.

Types and sources of event data: There are diverse types and sources of event data that are valuable for business ecosystem analysis. Financial transaction data from firms, customers, banks, and service providers, as well as data related to orders, deliveries, invoices, contracts, and logistical transactions, offer insights into different aspects of business ecosystems.

Descriptive and predictive analysis: Event data analysis enables descriptive explanations of flows within business ecosystems throughout their lifecycle. It can also be used for forecasting and normative analysis. For instance, identifying dependencies and lock-ins in business ecosystem flow structures can inform ecosystem governance and optimization strategies, potentially breaking path dependencies.

Advantages of financial transaction data: Financial transaction data, in particular, offers several advantages for network and business ecosystem analysis. Firstly, it provides exhaustive information on actor relations at a specific time, offering a comprehensive view of business ecosystem components. Secondly, its structured nature allows for comparisons within and across firms over time. Thirdly, standardized chart of cost accounts facilitates comparability between firms. Fourthly, while it primarily represents buyer-seller relations, it unveils broader network structures and actor roles. Lastly, it contains attributes such as date and monetary value that are relevant for ecosystem analysis.

Limitations and considerations: One limitation of financial transaction data is the challenge of accessing data from multiple organizations within a business ecosystem. However, our analysis demonstrates that data from a few cases can yield valuable insights. Additionally, while transaction data focuses on reported flows between suppliers and buyers, it offers valuable opportunities to explore broader ecosystem structures.

6. Conclusion

The study proposed the MLN model for studying business ecosystems. Analysis of two case studies showed complex enterprise architectures among real estate owners, characterized by numerous suppliers. The findings highlight the importance of comprehensively understanding existing enterprise architectures. Further research should concentrate on enhancing enterprise architectures. Moreover, the MLN model provides opportunities for future research on enterprise architectures and business ecosystems. Since the article focused on understanding and theorizing about business ecosystems based on case studies, its main limitation is that it does not address the business ecosystem as a whole.

References

Adamides, E.D. and Mouzakitis, Y. (2009), “Industrial ecosystems as technological niches”, *Journal of Cleaner Production*, Vol. 17 No. 2, pp. 172-180, doi: 10.1016/j.jclepro.2008.04.003.

Adner, R. (2006), “Match your innovation strategy to your innovation ecosystem”, *Harvard Business Review*, Vol. 84 No. 4, pp. 98-148.

Adner, R. (2017), “Ecosystem as structure: an actionable construct for strategy”, *Journal of Management*, Vol. 43 No. 1, pp. 39-58, doi: 10.1177/0149206316678451.

Aguinis, H. and Molina-Azorín, J.F. (2015), “Using multilevel modeling and mixed methods to make theoretical progress in microfoundations for strategy research”, *Strategic Organization*, Vol. 13 No. 4, pp. 353-364, doi: 10.1177/1476127015594622.

Alvedalen, J. and Boschma, R. (2017), “A critical review of entrepreneurial ecosystems research: towards a future research agenda”, *European Planning Studies*, Vol. 25 No. 6, pp. 887-903, doi: 10.1080/09654313.2017.1299694.

Amit, R. and Schoemaker, P.J. (1993), “Strategic assets and organizational rent”, *Strategic Management Journal*, Vol. 14 No. 1, pp. 33-46, doi: 10.1002/smj.4250140105.

Atkin, B. and Bildsten, L. (2017), "A future for facility management", *Construction Innovation*, Vol. 17 No. 2, pp. 116-124, doi: 10.1108/ci-11-2016-0059.

Bäcklund, K., Vigren, O. and Carlsson, J. (2024), "Implementing digital innovations: overcoming organizational challenges", *Developments in the Built Environment*, Vol. 18, 100436, doi: 10.1016/j.dibe.2024.100436.

Barbosa, A.O., Santana, A., Hacks, S. and Von Stein, N. (2019), "A taxonomy for enterprise architecture analysis research", *ICEIS 2019 - Proceedings of the 21th International Conference on Enterprise Information Systems*, SciTePress, Setúbal, Portugal, pp. 493-504.

Barney, J. (1991), "Firm resources and sustained competitive advantage", *Journal of Management*, Vol. 17 No. 1, pp. 99-120, doi: 10.1177/014920639101700108.

Barney, J.A.Y. and Felin, T. (2013), "What are microfoundations?", *Academy of Management Perspectives*, Vol. 27 No. 2, pp. 138-155, doi: 10.5465/amp.2012.0107.

Basole, R.C., Russell, M.G., Huhtamäki, J., Rubens, N., Still, K. and Park, H. (2015), "Understanding business ecosystem dynamics: a data-driven approach", *ACM Transactions on Management Information Systems*, Vol. 6 No. 2, pp. 1-32, doi: 10.1145/2724730.

Battistella, C., Colucci, K., De Toni, A.F. and Nonino, F. (2013), "Methodology of business ecosystems network analysis: a case study in Telecom Italia Future Centre", *Technological Forecasting and Social Change*, Vol. 80 No. 6, pp. 1194-1210, doi: 10.1016/j.techfore.2012.11.002.

Borgatti, S.P., Everett, M.G. and Johnson, J.C. (2013), *Analyzing Social Networks*, Sage, London.

Bröchner, J., Haugen, T. and Lindkvist, C. (2019), "Shaping tomorrow's facilities management", *Facilities*, Vol. 37 Nos 7/8, pp. 366-380, doi: 10.1108/f-10-2018-0126.

Brozovsky, J., Labonnote, N. and Vigren, O. (2024), "Digital technologies in architecture, engineering, and construction", *Automation in Construction*, Vol. 158, 105212, doi: 10.1016/j.autcon.2023.105212.

Burt, R.S. (1992), *Structural Holes: The Social Structure of Competition*, Harvard University Press, Cambridge, MA.

Carayannis, E.G. and Campbell, D.F.J. (2009), "'Mode 3' and 'Quadruple Helix': toward a 21st century fractal innovation ecosystem", *International Journal of Technology Management*, Vol. 46 3/4, p. 201, doi: 10.1504/ijtm.2009.023374.

Cennamo, C. (2021), "Competing in digital markets: a platform-based perspective", *Academy of Management Perspectives*, Vol. 35 No. 2, pp. 265-291, doi: 10.5465/amp.2016.0048.

Clarysse, B., Wright, M., Bruneel, J. and Mahajan, A. (2014), "Creating value in ecosystems: crossing the chasm between knowledge and business ecosystems", *Research Policy*, Vol. 43 No. 7, pp. 1164-1176, doi: 10.1016/j.respol.2014.04.014.

Constantinides, P., Henfridsson, O. and Parker, G.G. (2018), "Introduction—platforms and infrastructures in the digital age", *Information Systems Research*, Vol. 29 No. 2, pp. 381-400, doi: 10.1287/isre.2018.0794.

Csardi, G. and Nepusz, T. (2006), "The igraph software", *Complex Systems*, Vol. 1695, pp. 1-9.

Dattée, B., Alexy, O. and Autio, E. (2018), "Maneuvering in poor visibility: how firms play the ecosystem game when uncertainty is high", *Academy of Management Journal*, Vol. 61 No. 2, pp. 466-498, doi: 10.5465/amj.2015.0869.

de Vasconcelos Gomes, L.A., Facin, A.L.F., Salerno, M.S. and Ikenami, R.K. (2018), "Unpacking the innovation ecosystem construct: evolution, gaps and trends", *Technological Forecasting and Social Change*, Vol. 136, pp. 30-48, doi: 10.1016/j.techfore.2016.11.009.

Dickison, M.E., Magnani, M. and Rossi, L. (2016), *Multilayer Social Networks*, Cambridge University Press, Cambridge.

DiMaggio, P.J. and Powell, W.W. (1983), "The iron cage revisited: institutional isomorphism and collective rationality in organizational fields", *American Sociological Review*, Vol. 48 No. 2, pp. 147-160, doi: 10.2307/2095101.

Dubois, A. and Gadde, L.E. (2002), “The construction industry as a loosely coupled system: implications for productivity and innovation”, *Construction Management and Economics*, Vol. 20 No. 7, pp. 621-631, doi: 10.1080/01446190210163543.

Eisenhardt, K.M. and Graebner, M.E. (2007), “Theory building from cases: opportunities and challenges”, *Academy of Management Journal*, Vol. 50 No. 1, pp. 25-32, doi: 10.5465/amj.2007.24160888.

Engström, S. and Hedgren, E. (2012), “Sustaining inertia? Construction clients’ decision-making and information-processing approach to industrialized building innovations”, *Construction Innovation*, Vol. 12 No. 4, pp. 393-413, doi: 10.1108/14714171211272180.

Engwall, M. (2003), “No project is an island: linking projects to history and context”, *Research Policy*, Vol. 32 No. 5, pp. 789-808, doi: 10.1016/s0048-7333(02)00088-4.

Eriksson, K., Wikström, K., Hellström, M. and Levitt, R.E. (2019), “Projects in the business ecosystem: the case of short sea shipping and logistics”, *Project Management Journal*, Vol. 50 No. 2, pp. 195-209, doi: 10.1177/8756972818820191.

Felin, T., Foss, N.J. and Ployhart, R.E. (2015), “The microfoundations movement in strategy and organization theory”, *The Academy of Management Annals*, Vol. 9 No. 1, pp. 575-632, doi: 10.1080/19416520.2015.1007651.

Foss, N.J., Schmidt, J. and Teece, D.J. (2023), “Ecosystem leadership as a dynamic capability”, *Long Range Planning*, Vol. 56 No. 1, 102270, doi: 10.1016/j.lrp.2022.102270.

Freeman, L.C., Roeder, D. and Mulholland, R.R. (1979), “Centrality in social networks: II. Experimental results”, *Social Networks*, Vol. 2 No. 2, pp. 119-141, doi: 10.1016/0378-8733(79)90002-9.

Gawer, A. and Cusumano, M.A. (2014), “Industry platforms and ecosystem innovation”, *Journal of Product Innovation Management*, Vol. 31 No. 3, pp. 417-433, doi: 10.1111/jpim.12105.

Gawer, A. and Phillips, N. (2013), “Institutional work as logics shift: the case of Intel’s transformation to platform leader”, *Organization Studies*, Vol. 34 No. 8, pp. 1035-1071, doi: 10.1177/0170840613492071.

Granovetter, M.S. (1985), “Economic action and social structure: the problem of embeddedness”, *American Journal of Sociology*, Vol. 91 No. 3, pp. 481-510, doi: 10.1086/228311.

Granstrand, O. and Holgersson, M. (2020), “Innovation ecosystems: a conceptual review and a new definition”, *Technovation*, Vol. 90, 102098, doi: 10.1016/j.technovation.2019.102098.

Gulati, R. (1998), “Alliances and networks”, *Strategic Management Journal*, Vol. 19 No. 4, pp. 293-317, doi: 10.1002/(sici)1097-0266(199804)19:4<293::aid-smj982>3.0.co;2-m.

Gulati, R., Puranam, P. and Tushman, M. (2012), “Meta-organization design: rethinking design in interorganizational and community contexts”, *Strategic Management Journal*, Vol. 33 No. 6, pp. 571-586, doi: 10.1002/smj.1975.

Hacks, S., Brosius, M. and Aier, S. (2017), “A case study of stakeholder concerns on EAM”, *IEEE 21st International Enterprise Distributed Object Computing Workshop (EDOCW)*, pp. 50-56, doi: 10.1109/edocw.2017.17.

Hannah, D.P. and Eisenhardt, K.M. (2018), “How firms navigate cooperation and competition in nascent ecosystems”, *Strategic Management Journal*, Vol. 39 No. 12, pp. 3163-3192, doi: 10.1002/smj.2750.

Henderson, R.M. and Clark, K.B. (1990), “Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms”, *Administrative Science Quarterly*, Vol. 35 No. 1, pp. 9-30, doi: 10.2307/2393549.

Jacobides, M.G., Cennamo, C. and Gawer, A. (2018), “Towards a theory of ecosystems”, *Strategic Management Journal*, Vol. 39 No. 8, pp. 2255-2276, doi: 10.1002/smj.2904.

Kivelä, M., Arenas, A., Barthelemy, M., Gleeson, J.P., Moreno, Y. and Porter, M.A. (2014), “Multilayer networks”, *Journal of Complex Networks*, Vol. 2 No. 3, pp. 203-271, doi: 10.1093/comnet/cnu016.

Koch, C., Hansen, G.K. and Jacobsen, K. (2019), "Missed opportunities: two case studies of digitalization of FM in hospitals", *Facilities*, Vol. 37 Nos 7/8, pp. 381-394, doi: 10.1108/f-01-2018-0014.

Koirala, B., Cai, H., Khayatian, F., Munoz, E., An, J.G., Mutschler, R., Sulzer, M., De Wolf, C. and Orehounig, K. (2024), "Digitalization of urban multi-energy systems – advances in digital twin applications across life-cycle phases", *Advances in Applied Energy*, Vol. 16, 100196, doi: 10.1016/j.adapen.2024.100196.

Kotusev, S., Singh, M. and Storey, I. (2015), "Consolidating enterprise architecture management research", *System Sciences (HICSS), 2015 48th Hawaii International Conference on*, pp. 4069-4078, doi: 10.1109/hicss.2015.489.

Kulmala, H.I., Paranko, J. and Uusi-Rauva, E. (2002), "The role of cost management in network relationships", *International Journal of Production Economics*, Vol. 79 No. 1, pp. 33-43, doi: 10.1016/s0925-5273(00)00061-x.

Levin, S.A. (1998), "Ecosystems and the biosphere as complex adaptive systems", *Ecosystems*, Vol. 1 No. 5, pp. 431-436, doi: 10.1007/s100219900037.

Malecki, E.J. (2018), "Entrepreneurship and entrepreneurial ecosystems", *Geography Compass*, Vol. 12 No. 3, e12359, doi: 10.1111/gec3.12359.

Mazzucato, M. and Robinson, D.K.R. (2018), "Co-creating and directing Innovation Ecosystems? NASA's changing approach to public-private partnerships in low-earth orbit", *Technological Forecasting and Social Change*, Vol. 136, pp. 166-177, doi: 10.1016/j.techfore.2017.03.034.

McIntyre, D.P. and Srinivasan, A. (2017), "Networks, platforms, and strategy: emerging views and next steps", *Strategic Management Journal*, Vol. 38 No. 1, pp. 141-160, doi: 10.1002/smj.2596.

Moore, J.F. (1993), "Predators and prey: a new ecology of competition", *Harvard Business Review*, Vol. 71 No. 3, pp. 75-86.

Nambisan, S. and Sawhney, M. (2011), "Orchestration processes in network-centric innovation: evidence from the field", *Academy of Management Perspectives*, Vol. 25 No. 3, pp. 40-57.

Neumeyer, X. and Santos, S.C. (2018), "Sustainable business models, venture typologies, and entrepreneurial ecosystems: a social network perspective", *Journal of Cleaner Production*, Vol. 172, pp. 4565-4579, doi: 10.1016/j.jclepro.2017.08.216.

Nyoni, V., Broberg Piller, W. and Vigren, O. (2023), "Sustainability action in the real estate sector — an organizational and institutional perspective", *Cleaner Production Letters*, Vol. 5, 100049, doi: 10.1016/j.clpl.2023.100049.

Oh, D.S., Phillips, F., Park, S. and Lee, E. (2016), "Innovation ecosystems: a critical examination", *Technovation*, Vol. 54, pp. 1-6, doi: 10.1016/j.technovation.2016.02.004.

Peltoniemi, M. (2006), "Preliminary theoretical framework for the study of business ecosystems", *Emergence: Complexity and Organization*, Vol. 8 No. 1, p. 10.

Phillips, M.A. and Ritala, P. (2019), "A complex adaptive systems agenda for ecosystem research methodology", *Technological Forecasting and Social Change*, Vol. 148, 119739, doi: 10.1016/j.techfore.2019.119739.

Pome, A.P., Tagliaro, C. and Ciaramella, G. (2021), "A proposal for measuring in-use buildings' impact through the ecological footprint approach", *Sustainability*, Vol. 13 No. 1, p. 355, doi: 10.3390/su13010355.

Rochet, J.C. and Tirole, J. (2003), "Platform competition in two-sided markets", *Journal of the European Economic Association*, Vol. 1 No. 4, pp. 990-1029, doi: 10.1162/154247603322493212.

Roundy, P.T. and Bayer, M.A. (2019), "Entrepreneurial ecosystem narratives and the micro-foundations of regional entrepreneurship", *The International Journal of Entrepreneurship and Innovation*, Vol. 20 No. 3, pp. 194-208, doi: 10.1177/1465750318808426.

Roundy, P.T. and Fayard, D. (2019), "Dynamic capabilities and entrepreneurial ecosystems: the micro-foundations of regional entrepreneurship", *Journal of Entrepreneurship*, Vol. 28 No. 1, pp. 94-120, doi: 10.1177/0971355718810296.

Roundy, P. and Lyons, T. (2021), "EXPRESS: where are the entrepreneurs? A call to theorize the micro-foundations and strategic organization of entrepreneurial ecosystems", *Strategic Organization*, Vol. 21 No. 2, pp. 447-459, doi: 10.1177/14761270211056240.

Salehi, M., Sharma, R., Marzolla, M., Magnani, M., Siyari, P. and Montesi, D. (2015), "Spreading processes in multilayer networks", *IEEE Transactions on Network Science and Engineering*, Vol. 2 No. 2, pp. 65-83, doi: 10.1109/tnse.2015.2425961.

Sanchez-Puchol, F. and Pastor-Collado, J.A. (2017), "A first literature review on enterprise reference architecture", *The Mediterranean Conference on Information Systems (MCIS) Proceedings*, Vol. 15 No. 1, 120.

Scaringella, L. and Radziwon, A. (2018), "Innovation, entrepreneurial, knowledge, and business ecosystems: old wine in new bottles?", *Technological Forecasting and Social Change*, Vol. 136, pp. 59-87, doi: 10.1016/j.techfore.2017.09.023.

Scott, J. (1988), "Social network analysis", *Sociology*, Vol. 22 No. 1, pp. 109-127, doi: 10.1177/0038038588022001007.

Scott, J. (2013), *Social Network Analysis*, 3rd ed., Sage, London.

Senyo, P.K., Liu, K. and Effah, J. (2019), "Digital business ecosystem: literature review and a framework for future research", *International Journal of Information Management*, Vol. 47, pp. 52-64, doi: 10.1016/j.ijinfomgt.2019.01.002.

Shaw, J. (2020), "Platform real estate: theory and practice of new urban real estate markets", *Urban Geography*, Vol. 41 No. 8, pp. 1037-1064, doi: 10.1080/02723638.2018.1524653.

Shenton, A.K. (2004), "Strategies for ensuring trustworthiness in qualitative research projects", *Education for Information*, Vol. 22 No. 2, pp. 63-75, doi: 10.3233/efi-2004-22201.

Shipilov, A. and Gawer, A. (2020), "Integrating research on interorganizational networks and ecosystems", *The Academy of Management Annals*, Vol. 14 No. 1, pp. 92-121, doi: 10.5465/annals.2018.0121.

Sloane, A. and O'reilly, S. (2013), "The emergence of supply network ecosystems: a social network analysis perspective", *Production Planning and Control*, Vol. 24 No. 7, pp. 621-639, doi: 10.1080/09537287.2012.659874.

Spigel, B. and Harrison, R. (2018), "Toward a process theory of entrepreneurial ecosystems", *Strategic Entrepreneurship Journal*, Vol. 12 No. 1, pp. 151-168, doi: 10.1002/sej.1268.

Stam, E. (2015), "Entrepreneurial ecosystems and regional policy: a sympathetic critique", *European Planning Studies*, Vol. 23 No. 9, pp. 1759-1769, doi: 10.1080/09654313.2015.1061484.

Sulzer, M., Wetter, M., Mutschler, R. and Sangiovanni-Vincentelli, A. (2023), "Platform-based design for energy systems", *Applied Energy*, Vol. 352, 121955, doi: 10.1016/j.apenergy.2023.121955.

Sydow, J., Schreyögg, G. and Koch, J. (2009), "Organizational path dependence: opening the black box", *Academy of Management Review*, Vol. 34 No. 4, pp. 689-709, doi: 10.5465/amr.34.4.zok689.

Tagliaro, C., Bellintani, S. and Ciaramella, G. (2021), "R.E. property meets technology: cross-country comparison and general framework", *Journal of Property Investment and Finance*, Vol. 39 No. 2, pp. 125-143, doi: 10.1108/jpif-09-2019-0126.

Teece, D.J. (2007), "Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance", *Strategic Management Journal*, Vol. 28 No. 13, pp. 1319-1350, doi: 10.1002/smj.640.

Teece, D.J., Pisano, G. and Shuen, A. (1997), "Dynamic capabilities and strategic management", *Strategic Management Journal*, Vol. 18 No. 7, pp. 509-533, doi: 10.1002/(sici)1097-0266(199708)18:7<509::aid-smj882>3.0.co;2-z.

Thomas, L.D. and Ritala, P. (2022), "Ecosystem legitimacy emergence: a collective action view", *Journal of Management*, Vol. 48 No. 3, pp. 515-541, doi: 10.1177/0149206320986617.

Thomas, L.D., Autio, E. and Gann, D.M. (2014), "Architectural leverage: putting platforms in context", *Academy of Management Perspectives*, Vol. 28 No. 2, pp. 198-219, doi: 10.5465/amp.2011.0105.

Tilson, D., Lyytinen, K. and Sørensen, C. (2010), "Research commentary—digital infrastructures: the missing IS research agenda", *Information Systems Research*, Vol. 21 No. 4, pp. 748-759, doi: 10.1287/isre.1100.0318.

Timm, F., Sandkuhl, K. and Fellmann, M. (2017), "Towards a method for developing reference enterprise architectures", *Proceedings of 13th Internationalen Tagung Wirtschaftsinformatik (WI 2017)*, St. Gallen, pp. 331-345.

Tiwana, A. (2014), *Platform Ecosystems: Aligning Architecture, Governance, and Strategy*, Elsevier, Massachusetts.

Troje, D. (2023), "Path dependencies and sustainable facilities management: a study of housing companies in Sweden", *Building Research and Information*, Vol. 51 No. 8, pp. 965-978, doi: 10.1080/09613218.2023.2216795.

Tsujimoto, M., Kajikawa, Y., Tomita, J. and Matsumoto, Y. (2018), "A review of the ecosystem concept—towards coherent ecosystem design", *Technological Forecasting and Social Change*, Vol. 136, pp. 49-58, doi: 10.1016/j.techfore.2017.06.032.

Tsvetkova, A. and Gustafsson, M. (2012), "Business models for industrial ecosystems: a modular approach", *Journal of Cleaner Production*, Vol. 29, pp. 246-254, doi: 10.1016/j.jclepro.2012.01.017.

Ullah, F., Sepasgozar, S.M. and Wang, C. (2018), "A systematic review of smart real estate technology: drivers of, and barriers to, the use of digital disruptive technologies and online platforms", *Sustainability*, Vol. 10 No. 9, p. 3142, doi: 10.3390/su10093142.

Vigren, O. (2022), "Digitalization, sustainability, and ecosystems: an application of social network analysis to the real estate sector", Doctoral Thesis, KTH Royal Institute of Technology, Stockholm.

Vigren, O., Kadefors, A. and Eriksson, K. (2022), "Digitalization, innovation capabilities and absorptive capacity in the Swedish real estate ecosystem", *Facilities*, Vol. 40 Nos 15/16, pp. 89-106, doi: 10.1108/f-07-2020-0083.

Wareham, J., Fox, P.B. and Cano Giner, J.L. (2014), "Technology ecosystem governance", *Organization Science*, Vol. 25 No. 4, pp. 1195-1215, doi: 10.1287/orsc.2014.0895.

Wasserman, S. and Faust, K. (1994), *Social Network Analysis: Methods and Applications*, Cambridge University Press, Cambridge.

Wetter, M. and Sulzer, M. (2023), "A call to action for building energy system modelling in the age of decarbonization", *Journal of Building Performance Simulation*, Vol. 17 No. 3, pp. 383-393, doi: 10.1080/19401493.2023.2285824.

Winter, R. and Fischer, R. (2006), "Essential layers, artifacts, and dependencies of enterprise architecture", *2006 10th IEEE International Enterprise Distributed Object Computing Conference Workshops (EDOCW'06)*, p. 30, doi: 10.1109/edocw.2006.33.

World Green Building Council (2021), *Annual Report 2021*, World Green Building Council Publications, available at: https://worldgbc.org/wp-content/uploads/2022/08/WorldGBC-2021-Annual-Report.pdf

Yin, R.K. (2009), *Case Study Research: Design and Methods*, Sage, California.

Corresponding author
Olli Vigren can be contacted at: olliky@kth.se