Digitalization and innovation in the real estate and facility management sectors - an ecosystem perspective

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Abstract

Digitalization has become a topic of several presentations and discussions in real estate industry seminars in recent years. Often the speeches are about why the real estate industry needs digitalization, presenting threats and opportunities for the participants of the seminars. Still, real estate industry is conservative by nature and thus far property owners have not needed to innovate in order to stay in business. Therefore, a question arises that how do real estate owners react to the growing expectations about digitalization. On the other hand, relatively little is known about the innovativeness of real estate firms, as innovation research in built environment sector has largely focused on building project management phase organizations and facility management firms. Still, the real estate owners have a central role and a long-term perspective on the innovation in the built environment sector as a whole, as they are clients in all building life-cycle phases.

Thus, this thesis purpose is to increase understanding of digitalization as a phenomenon in the real estate and facility management sectors: 1) by distinguishing the phenomenon in relation to existing research and 2) by generating new knowledge on digitalization in the field by explorative research.

In order to distinguish the phenomenon in relation to existing research, the thesis provides a structured literature review that focuses on digitalization in the real estate and facility management sector. The main conclusion is that digitalization is a complex phenomenon, including multiple perspectives and conceptualizations, although, the literature converges on rather distinct topics of digital systems and methods, technology adoption and organization and management. Additionally, the review provides a discussion of opportunities for further research. An argument is made for sociotechnical perspective to provide opportunities for better managerial comprehension on the complex phenomenon.

In order to generate new knowledge on digitalization in the field, particularly, on the innovativeness of real estate firms, the thesis provides summaries of two papers. The first paper focuses on the innovation processes in the real estate owner organizations and the second paper focuses on the innovation ecosystem that comprises of actors that contribute towards common innovation goals. The papers are based on interviews with the various real estate industry actors and document analysis. The papers converge on results, concluding that the real estate owners have invested in resources and capabilities for innovation, but it is still challenging for them to act on the digital threats and opportunities. Additionally, the second paper develops an operationalizable definition and methodology for research on innovation ecosystems, which has relevance for the more general literature on innovation and strategy.

Thus, this thesis distinguishes digitalization as a phenomenon in the built environment management sectors and increases understanding on the innovativeness of real estate firms' and other actors that contribute to the innovativeness of the real estate sector as a whole.

Keywords:
business ecosystem; digitalization; digitization; digital transformation; facilities management; facility management; innovation; innovation ecosystem; property technology; proptech; real estate; social network analysis

Sammanfattning

Digitalisering har blivit ett ofta återkommande ämne för ett stort antal seminarier inom fastighetsbranschens under de senaste åren. En återkommande fråga har varit hur fastighetsbranschen hanterar digitaliseringen, samt om vilka hot och möjligheter digitaliseringen innebär för branschen. Fastighetsbranschen uppfattas ofta som konservativ och hittills har fastighetsägare inte tvingats vara särskilt innovativa för att kunna fortsätta sin verksamhet. En intressant fråga i sammanhanget är därför hur fastighetsägare reagerar på de växande förväntningarna om digitalisering från omvärlden. Relativt lite är känt om innovationsförmågan hos fastighetsföretag, eftersom innovationsforskningen inom byggd miljö till stor del har fokuserat på byggprojekt och fastighetsförvaltning. Fastighetsägarna har dock fortfarande en central roll och borde ha ett långsiktigt perspektiv på innovationer inom den byggda miljön som helhet, eftersom de är verksamma inom byggnadens alla faser i livscykeln.

Mot denna bakgrund är avhandlingens syfte att öka förståelsen för digitalisering som fenomen inom fastighetsförvaltningen: 1) genom att analysera fenomenet i förhållande till den befintliga forskningen och 2) genom att generera ny kunskap om digitalisering inom området genom intervjuer och dokumentanalys.

För att särskilja fenomenet digitalisering i förhållande till befintlig forskning innehåller avhandlingen en strukturerad litteraturöversikt som fokuserar på digitalisering inom fastighetsförvaltningen. Den huvudsakliga slutsatsen från denna litteraturöversikt är att digitalisering är ett komplext fenomen, som innehåller flera perspektiv och konceptualiseringar, även om litteraturen fokuserar på ett antal distinkta ämnen: digitala system och metoder, anpassning av teknik och organisation samt förvaltning. Dessutom innehåller översikten en diskussion om relevanta områden för vidare forskning. Vidare ger översikten vid handen, att genom att anlägga ett socio-tekniskt perspektiv ges bättre möjligheter att förstå digitalisering.

För att skapa ny kunskap om digitalisering, särskilt vad gäller fastighetsföretagens innovativitet, innehåller avhandlingen två artiklar. Den första artikeln fokuserar på innovationsprocesser inom fastighetsföretag och den andra artikeln fokuserar på innovationsekosystemet som består av ett antal olika aktörer som bidrar till gemensamma innovationsmål. Artiklarna bygger på intervjuer med olika aktörer inom fastighetsbranschen och dokumentanalys. Artiklarnas resultat pekar åt samma håll, och slutsatsen som kan dras är att fastighetsägarna har investerat i resurser och kapacitet för innovation, men det är fortfarande en stor utmaning för dem att agera på digitala hot och möjligheter. Dessutom utvecklar den andra artikeln en definition och metod för forskning om innovationsekosystem, som har relevans för forskning inom innovation och strategi.

Således särskiljer denna avhandling digitaliseringen som ett fenomen inom den byggda miljön och ökar förståelsen för fastighetsföretagens innovationsförmåga och andra aktörer som bidrar till innovationer inom fastighetssektorn som helhet.

Acknowledgements

"Odd objects make you well-rounded"
Simon Mäntylä, Crossfit Solid, 2018

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Olli Kytömäki
Stockholm, December 2019

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List of Acronyms

AR: augmented reality

BIM: building information management, building information modeling

FM: facility management, facilities management

GIS: geographic Information System

ICT: information and communication technology

IT: information technology

PDR: phenomenon-driven research

PropTech: property technology

SNA: social network analysis

List of papers

Paper 1:
Kytömäki, O., & Kadefors, A. (2018 September). Digitalization and innovation in the real estate sector. In ARCOM 34th Annual Conference. ARCOM.

Paper 2:
Kytömäki, O. (2019). An operationalizable definition and method for research on innovation ecosystems. A manuscript.

1. Introduction

1.1 “The new reality of property owners”

This thesis takes a starting point in an empirical observation. In Stockholm, in early 2017, several new and already established real estate industry seminars took digitalization on the agendas as one of the main themes. These seminars were aimed for real estate owners, suppliers and other actors interested in “the new reality of property owners”, as one of the most influential industry spokespersons expressed it. At the same time, several industry reports on digitalization were published (e.g. Westergren et al. 2017; Fastighetsägarna Stockholm 2018; Kairos Future 2018; Baum 2017).

Much of the discourse in the seminars and reports promised fundamental change, digital transformations or disruption, in the real estate industry. In one of the presentations the speaker used a metaphor of a melting ice cube to explain how real estate owners will lose business if they don’t act on new threats and opportunities related to digital technologies. Another speaker pointed out that the real estate sector is the last fortress, over which a tsunami of startup firms is running over. These claims were backed by examples from other industries, as well as a fact that a tremendous number of “PropTech” (property technology) firms have emerged in the real estate sector. These “PropTech” startups are often backed by venture capitalist funding, and equipped with a diversified pool of talent and digital technologies (Baum 2017).

One industry influencer pondered over the novelty of digitalization as a concept in the built environment sector: “I started wondering is digitalization something new or is it just a new word for an old phenomenon. I think it is both. Digitalization is a new word for ICT or IT, but it still contains something different. It is a new view of something, and in that case, it is about new business models, sharing economy and doing things in new ways instead of making old things more efficient.”

This thesis explores what is the nature of digitalization as a phenomenon; how has it changed the industry beyond this “seminar talk”; and how do firms in the traditional industry react to such claims of impending change.

1.2 Digitalization and innovation as a phenomenon

Today, digitalization is high on the agenda in many organizations. It is often included in organizational strategies, policies, goals, structures and roles, projects or investment plans, with implicit expectations of organizational transformations and increased overall efficiency (World Economic Forum 2019; European Commission 2018; The World Bank Group 2019,

OECD 2019). Digitalization is associated with other major change trends, such as globalization, sustainability, climate change or demographics, which all have fundamental impact on the daily lives of individuals in society, and societal development (European Commission 2018).

The interest in digitalization has to do with the fundamental nature of digital technologies. Today, an increasing number of products can collect and transmit digital data, which effectively turns them into a digital layer that is programmable, addressable, sensible, communicable, memorable, traceable, and associable (Yoo et al. 2010). These digital technologies allow products and services to become "smarter" and transform the way they are assembled, consumed and experienced, and the rapid development of digital technologies has reduced the cost of communication, collaboration and coordination in organizations (Yoo et al. 2012).

With these organizational and technical perspectives in mind, it is reasonable to view digitalization as a sociotechnical change process. Similarly, in an organizational context, innovation is defined as a process of invention, development, and implementation of new ideas (Garud et al. 2013). Thus, digitalization and innovation can be seen as the same phenomenon, with the exceptions that digitalization is particularly focused on digital innovations, and also that digitalization takes into consideration the broader societal implications of these digital innovations (Yoo et al. 2010).

In other words, *digitalization in an organizational context can be defined as a sociotechnical innovation process of invention, development and implementation of new ideas, which are focused on digital technologies*. Despite its importance for societal development, there is still little knowledge about how the modern digital technologies, and related digitalization processes, will transform organizations, and especially so in industries that have a low degree of digitization (McKinsey Global Institute 2015). Another condition that makes the transformative effect of digitalization difficult to analyze is when the effects lead to changes that are so broad, that it is difficult to relate the digital technology cause, and the organizational, or societal effect (Tilson et al. 2010).

1.3. Technology driven change and ecosystem perspective on organizational studies

While the modern digital technologies have changed the agenda for contemporary organizational development, the underlying topic of technology driven change has long roots in academic research. For Schumpeter (1942), change was a result of an evolutionary process of "creative destruction", where incumbent firms are challenged by entrant firms, which often use better technologies; instead of challenging the margins of existing firms, the entrants challenge "their foundations and their very lives". In a similar vein, Christensen (1997) argues that it is in many ways challenging for incumbents to defend their positions, as their business models are geared towards the traditional technologies and value proposals. The view that

incumbent firms rarely introduce radical innovations, and rather try to solidify current market positions with incremental innovations, has become known as the incumbent's curse (Chandy and Tellis 2000). Thus, Innovation research teaches us that innovativeness of organizations is essential for the long-term existence of firms.

Innovativeness of organizations has also been debated from the perspective of structures for innovation activities. The capabilities view focuses on firm-level structures and processes as essential for innovation in an environment of rapid technological change (Leonard-Barton 1992; Teece et al 1997). But, other research see innovation as not only a firm-level phenomenon, but a phenomenon that depends on interorganizational structures, such as networks (Håkansson and Snehota 1989) or ecosystems (Moore 1993). The ecosystems literature emphasize that ecosystems are a way to conceptualize business logics based on actors' shared goals, activities or other interdependence, rather than their existing network positions or industry boundaries (Moore 1993; Adner 2017; Jacobides et al. 2018).

1.4. Ecosystems and construction industry research

The ecosystems perspective is particularly interesting in the construction and built environment management industries, but surprisingly little used (Pulkka et al. 2016). This is surprising because the construction industry is typically characterized as having many actors that do different work tasks, but that work together towards common goals in many different kinds of construction projects. There is a high degree of dependence between collaborating actors, both in individual projects, and at a system level, because actors need to be able to rely on that there are other actors that they can collaborate with to get a project done. Buildings will not be built or managed, if firms can't agree on complex technical and organizational questions. Traditionally, the construction sector is described low in innovativeness, mainly as the focus on construction project performance hinders learning and innovation in the long term (Dubois and Gadde 2002) and the sector specific institutional logics and firm or project level processes make it difficult to adopt or sustain innovations (Winch 1998). The built environment ecosystem perspective can potentially make the construction sector more innovative, because it analyzes the construction sector as a part of a higher order ecosystems-level goal of increased efficiency in the built environment.

In the building management phase, innovation research has mainly focused on the intra-firm level and concluded that real estate owners and facility managers are typically powerless in their innovation activities (Engström and Hedgren 2012; Cardellino and Finch 2006; Goyal and Pitt 2007; Mudrak et al. 2005). In the construction sector context, the real estate owners are recognized as strategic decision makers and gatekeepers in all building life-cycle phases (Kulatunga et al. 2011), and thus their innovativeness can have a positive impact on the construction sector as a whole. Thus, adoption of innovation ecosystem perspective could

shed light on how interdependence between organizations may benefit or hinder innovation activities in the sector.

This thesis is an attempt to answer some of the questions related to innovativeness of real estate and facility management organizations. It attempts to find answers situated in particular contexts, namely, the contemporary innovation ecosystems that comprises of various actors aiming for digital development in the sector. This thesis engages in two broad and long-lasting debates in organizational studies. The first debate is about sociotechnical change processes, and on digitalization in particular. The second debate is about interorganizational structures that interact with the digitalization activities in organizations, and here the focus is on innovation ecosystems. An innovation ecosystem can be defined as *a system of actors that contribute towards a common system-level innovation goal.*

2. Research purpose, design and methods

This section presents the research purpose and the general approach to the research design, as well as discusses why certain research methods were selected, and how they were used.

2.1. Explorative, phenomenon-driven research

As the phenomenon of interest, digitalization in real estate and facility management organizations and related innovation ecosystems, is considered to have a high degree of novelty, this thesis adopts a phenomenon-driven research (PDR) approach, which focuses on identifying and conceptualizing novel phenomena (Schwarz & Stensaker 2014; 2016; Von Krogh et al. 2012).

PDR often begins with an interesting observation, rather than an insight from an existing theoretical debate (Von Krogh et al. 2012). By putting a phenomenon as a starting point of research, PDR may prevent the research to be too bounded on insights from an existing theory or to be too focused on advancing a theory (Schwarz and Stensaker 2014). Rather, theory is used for positioning the findings in comparison to current knowledge (Schwarz and Stensaker 2014), and then the empirical observation and findings are used for advancing an existing theory, or for building new theory (Eisenhardt and Graebner 2007). This theorizing may be inductive or deductive by nature (Von Krogh et al. 2012). Further, this form of research generates improvements in understanding the phenomenon and contribute to the body of knowledge in the research field (Schwarz & Stensaker 2016). It also may help researchers to overcome the relevance-rigor gap in management and organizational studies (Von Krogh et al. 2012).

The selection of research methods is also guided by the phenomenon, and several PDR researchers advocate for a pragmatic, instrumental mixed-methods approach (Schwarz & Stensaker 2014; 2016; Von Krogh et al. 2012; Eisenhardt and Graebner 2007). The research methods are selected based on the maturity of the research on a phenomenon; the choice is made in relation to the initial findings, and thus the research questions and research design are explorative in the beginning, but may sharpen when the research on the phenomenon matures (Von Krogh et al. 2012).

2.2. Purpose and research questions

The purpose of this thesis is to increase understanding of digitalization as a phenomenon in the real estate and facility management sectors. More precisely, this purpose can be divided into two research aims. In accordance with the PDR approach, the first aim (1) is to distinguish the phenomenon in relation to the existing body of knowledge by identifying inadequacies in

the body of knowledge and by identifying relevant concepts for research on digitalization in the field, and the second aim (2) is to generate new knowledge on digitalization in the field by explorative research.

For this purpose, two research questions are pursued:

1. How is digitalization as a phenomenon viewed in the existing body of knowledge, in the built environment management literature?
2. How do real estate owners manage innovations related to digitalization?

2.3. Research methods

In this section, the selection of research methods and their use is discussed. Use of several methods, data sources and validation of findings with industry representatives, as well as the academic supervision and conference peer-review processes, have been used to validate the research design and findings during the research process (Yin 2013).

2.3.1 Initial exploratory interviews, observations in industry seminars and industry reports

The starting point for this research was the interest on digitalization raising from the real estate industry. To investigate what this interest was in particular, the author participated in several industry seminars (see table 1), where digitalization was on the agenda.

Table 1. List of industry seminars participated

Seminar	Organizer	City	Date
Business arena	Fastighetsnytt	Stockholm	21.9.2017
Cime	Epicenter Stockholm	Stockholm	15.-16.11.2017
Digitalisera för hållbarhet - så kan IT fungera som ett verktyg för hållbar utveckling!	Centre for Sustainable Communications, CESC, KTH	Stockholm	21.11.2017
Digital boendekommunikation	Fastighetsägarna	Stockholm	13.12.2018
Elastiska hem workshop	Kairos future, Kod Arkitekter	Stockholm	29.1.2019
Elastiska hem workshop	Kairos future, Kod Arkitekter	Stockholm	21.2.2019
Fastighetsmarknadsdagen Digitalisering	Fastighetssverige	Stockholm	8.5.2019
Future proptech UK	Future PropTech	London	13.-15.5.2019
Elastiska hem	Kairos future, Kod Arkitekter	Stockholm	3.9.2019

At the same time, several industry reports (see table 2) were published in Swedish real estate sector. The observations from industry seminars and reports were used for designing initial exploratory interviews with real estate owners. The initial interviews aimed at deepening the understanding of what are the relevant questions for further inquiry. This understanding was

further used in formulation of the research questions, choice of research methods and the choice of theory.

Table 2. List of industry reports aimed for real estate owners

Report name	Report ordered by	Published
Digital boendekommunikation	Fastighetsägarna	2018
Digitalisering och mobilitet - Ett förändrat affärslandskap för fastighetsbolag väntar runt hörnet	Fastighetsägarna	2017
Fastighetsägarens roll i leveranskedjan – Det nya ekosystemet	Fastighetsägarna	2019
Lysande utsikter för fastighetsbranschen	Fastighetsägarna	2018
PropTech 3.0: Framtiden inom fastigheter (Original in English: Baum 2017)	Fastighetsägarna (Swedish translation)	2018
The IoT guide: a business guide to the Internet of Things	Westergren et al.	2017
Digitalisering – mer än teknik: Kartläggning av svensk forskning och näringslivets behov	Vinnova	2018

The observations made in seminars, both from presentations and from informal discussions, as well as reading the industry reports, were essential for deepening the understanding on the specific research context (Schwarz & Stensaker 2016), as well as for recognizing which actors and topics in digitalization were relevant for the innovation ecosystem. Additionally, these seminars and reports addressed the topicality of the digitalization research in the sector, which indicate that the research has potential for practical relevance. Still, it should be noted, that even the seminars attracted a lot of participants, the participants were to a great extend from the largest real estate owner organizations. Therefore, people from smaller organizations were not necessarily exposed to the messages that were distributed at the seminars, and may therefore be missing out from the innovation activities in the sector.

2.3.2 A structured literature review

The research question one imposes the choice for research method to be a literature review. Here, a structured literature review is selected for several reasons. First, as the aim is to distinguish digitalization as a phenomenon in comparison to the existing body of knowledge, the review should cover adequately large part of the body of knowledge. This is done by integrating literature from multiple databases over a long time period and by using multiple search terms. Within these limitations, an exhaustive search was selected (Grant and Booth 2009; Cooper 1988) in order to capture the relevant literature. Second, based on initial database searches, a structured literature review was feasible method in terms of the number of articles on the topic. Third, existing literature in general, and existing literature review papers in particular, did not provide a review that would have addressed the research question. Fourth, as the number of research articles grows every year, there is a growing demand for structure research synthesis. Fifth, and finally, as Yoo et al. (2010) point out, there

is a great risk of research findings being unnoticed by scholars in other fields, especially so as the digitalization research is conceptually scattered. This is particularly relevant in built environment sector, which is highly scattered in multiple management disciplines. Thus, the literature review was integrative by nature (Torraco 2005), meaning that it synthesizes several literature streams on digitalization and innovation, in several management disciplines. The literature review, and a more in-depth discussion on its methods and limitations, is presented as the section 3.3.

2.3.3 Interview study and document analysis

The second research question focuses on organizational and managerial questions related to digitalization. For this purpose, an interview study, comprising of 33 interviews was conducted (see table 3). The firms for interviews were selected based on their relevance in the real estate industry development in Sweden. These interviews were complemented with document analysis, based on information from organizations' and their partners' web pages, published reports and other online sources. The interviewees were selected based on their roles in the organizations: each interviewee held managerial responsibilities on digital development.

Table 3. List of interviews

Organization	No of interviewees	Role(s)	Date	Interview length	Public / private	Type
AFA Fastigheter	1	Manager	12.12.2017	49 min	Private	Commercial property owner
Atrium Ljungberg	1	Manager	8.3.2019	1 hour 31 min	Private	Commercial property owner
Castellum	1	Manager	24.1.2019	47 min	Private	Commercial property owner
Hufvudstaden	1	Manager	2.10.2017	1 hour 16 min	Private	Commercial property owner
Ica fastigheter	1	Manager	29.5.2019	1 hour 7 min	Private	Commercial property owner
Hemsö	2	Managers	16.1.2018	1 hour 16 min	Private	Community service buildings owner
Akademiska hus	1	Manager	13.6.2018	1 hour 20 min	Public	Community service buildings owner
SISAB	1	Manager	8.2.2019	1 hour 7 min	Public	Community service buildings owner
BIM alliance	2	Managers	11.1.2018	44 min	-	Industry association
Fastighetsägarna Stockholm	1	Manager	6.12.2017	49 min	-	Industry association
SABO	1	Manager	1.11.2018	2 hours 18 min	-	Industry association
Real Estate Core	1	Manager	28.1.2019	1 hour 2 min	-	New supplier
Hembokad	1	Owner	11.6.2018	1 hour 11 miin	Private	New supplier
Iiootee	1	Manager	14.1.2019	1 hour 23 min	Private	New supplier
LokalLife	1	Manager	23.1.2019	57 min	Private	New supplier
Urban innovation	1	Manager	3.11.2017	1 hour 6 min	Private	New supplier
Zynka BIM	1	Manager	24.1.2019	1 hour 24 min	Private	New supplier
Byggvesta	4	Managers	18.12.2017	1 hour 33 min	Private	Residential property owner
Heba fastigheter	2	Managers	31.5.2019	47 min	Private	Residential property owner
HSB	1	Manager	21.11.2018	2 hours 6 min	Private	Residential property owner
Lennart Eriksson fastigheter	1	Manager	21.12.2018	1 hour 14 min	Private	Residential property owner
Riksbyggen	1	Manager	31.8.2017	1 hour 27 min	Private	Residential property owner
Stena Fastigheter	1	Manager	11.9.2017	1 hour 1 min	Private	Residential property owner
Wallenstam	1	Manager	4.6.2018	1 hour 12 min	Private	Residential property owner
Familjebostäder	1	Manager	5.6.2019	1 hour 25 min	Public	Residential property owner
MKB fastigheter	1	Manager	19.11.2018	1 hour 1 min	Public	Residential property owner
Örebro bostäder	1	Manager	6.11.2018	1 hour 26 min	Public	Residential property owner
Stockholms hem	2	Managers	18.8.2017	1 hour 3 min	Public	Residential property owner
Ericsson	1	Manager	11.1.2019	1 hour 32 min	Private	Traditional supplier
Siemens	1	Manager	6.2.2019	1 hour 40 min	Private	Traditional supplier
Sweco	2	Managers	31.5.2018	49 min	Private	Traditional supplier
Thyrens	1	Manager	17.9.2018	52 min	Private	Traditional supplier
Vitec	2	Managers	15.1.2019	48 min	Private	Traditional supplier
Count of interviews: 33						

The interviewees were contacted by email, and in cases where contacts did not lead to an interview, another person was selected from lists of companies, which were compiled for pre-selected firm type categories (see table 4). These categories are real estate owners, suppliers and industry associations. For each category, there was a preselected minimum threshold for number of interviews. Each interview was transcribed and analyzed using Nvivo 12 software.

Table 4. List of firms contacted, but not interviewed

List of nonrespondent organizations
Klövern
Hemfosa
Stångåstaden
Vasakronan
Linköpings Stadshus
Fastigo
Fastighetsnytt
Familijbostader
Niam
Rise
White Architects

Traditionally, the large real estate owners have been in forefront of adopting new business objectives and new technologies, and thus altogether 19 real estate owner organizations were interviewed. These firms were selected based on firm type categories: commercial property owners (5 interviews), which includes hotels, shopping centers and offices; community service building owners (3 interviews), a category that includes for example schools and health care facilities; and residential property owners (11 interviews). Additionally, in each category, the aim was to include both private and public sector actors. This was done in order to have understanding on the phenomenon on each organization in each of these categories. It should be noted, however, that these categories don't represent all building types, for example logistic centers are not represented. The selection of firms was based on their existing collaboration with the academia and based on the total taxable building floor area. Data on ownership was collected from Datscha database on 29.8.2018.

The second category of organizations is industry associations (3 interviews). The industry associations have traditionally had an important role in the industry development, and now these associations have new initiatives in digital development. Many of the interviewed real estate owners are members in these industry associations, and each of the associations are active in organizing industry seminars and in publishing industry reports on digitalization.

The third category is suppliers (11 interviews). In this category, five interviews we directed at traditional suppliers, which have accumulated experience on industry development over long time period. Three of these firms have broad experience on digitalization from other industries and two have experience on digitalization in the construction industry. Also, six interviews were directed at new suppliers, which each have been founded recently in order to pursue opportunities related to new digital technologies. The suppliers were selected based

on their relevance in the industry development and each of the suppliers have been in development projects with the real estate firms.

The interviews were explorative, semi-structure interviews, by nature. This approach was based on the PDR logic, in which the research process should not limit the study of an emergent phenomenon, as well as the findings from the initial interviews: each interviewee had different perspectives on digitalization depending on their own experience and organizational goals and context. Also, as the understanding on the phenomenon matured during the interview period, both of interviewees' and of interviewers, the interview guidelines were further developed. Still, all interviews had same themes in common; the interviews concerned the firms'

1. expectations about digitalization for their organization,
2. actions that their firms have planned or have taken,
3. impacts of these activities for the firm and stakeholders
4. and collaborations for innovation.

It should be noted, that a research focusing on innovation typically selects innovative organization and projects as a unit of analysis. This selection is thus biased and not representative for the real estate sector as a whole, and further research should complement the understanding on the phenomenon by engaging in research with other types of industry actors, such as small and medium sized real estate owners. Also, as the focus of this research is on building management phase, the real estate owner's role as an actor in building projects was not a pre-selected theme in the interviews, and despite the explorative nature of the interviews, few of the interviewees reflected on the theme.

2.4. Outline of the thesis

The table 5 summarizes the discussion on research design. The overall purpose of the research is to increase understanding on digitalization as a phenomenon in the real estate and facility management sectors. This purpose is divided into two aims. First, the aim is to distinguish the phenomenon in relation to existing body of knowledge, and second, to generate new knowledge on the phenomenon, based on an exploratory qualitative research. The section 3 presents the theoretical framework that is developed based on the findings from initial interviews and observations. Particularly, section 3.3. focuses on the first research question by presenting a structured literature review on the phenomenon. Section 4 presents the summary of the findings of the qualitative interview study. The section 4.3. presents analysis of how the research answers the research questions. The section 5 summarizes the research by conclusion.

Table 5. Summary of the research design

Aim	Research question	Method	Analytic framework	Section
Distinguish the phenomenon in relation to the existing body of knowledge.	How is digitalization as a phenomenon viewed in the existing body of knowledge?	A structured literature review	Grounded theory	Section 3.3.
Generate new knowledge on the phenomenon by explorative research.	How do real estate owners manage innovations related to digitalization?	Empirical analysis: interviews and document analysis	Innovation process Innovation ecosystem	Section 4 Paper 1 Paper 2

3. Theoretical framework

This section presents the theoretical framework and key concepts, which are used in later sections for analytical process and interpretation of the empirical findings. The selection of these theories and concepts is based on the initial empirical findings from interviews, observations and industry reports. The findings show that real estate owners actively seek for new collaborations in innovation activities and have formed interorganizational structures for collaboration. Thus, this section presents the relevant literature on interorganizational innovation in the field. Secondly, as the concept of innovation ecosystem has a good fit with the initial findings, the concept is briefly introduced. Finally, in order to distinguish digitalization as a phenomenon in the industry in relation to the existing body of knowledge, a structured literature review on the phenomenon is provided.

3.1. Interorganizational innovation in the built environment sector

Despite the rapid development of digital technologies in recent years, the business landscape of built environment sector has remained relatively constant, at least if compared with the high-tech sectors, which typically dominate the empirical examples in innovation research. Firms in built environment sector have had relatively little incentives to innovate as the business performance has largely been determined by other factors than innovation. In this context, there are two research streams on interorganizational innovation, which are relevant for the real estate and facility management firms.

The first literature stream focuses on interorganizational innovation in the construction industry. While innovation in construction sector can take many forms, interorganizational innovation research has largely focused on actors designing and constructing buildings. There is an extensive group of studies that view buildings as complex product systems (Blayse and Manley 2004; Gann and Salter 2000; Harty 2005) and focus on interorganizational innovation around design and construction of these product systems. Another perspective focuses more directly on relations between firms, for example on partnering in construction projects (Bresnen and Marshall 2000), building project value chains (Slaughter 2000) or construction industry networks (Bossink 2004; Bygballe and Ingemansson 2014; Dubois and Gadde 2002). In this literature, it is often noted that innovation is challenging due to the project-based nature of the work and that other institutional factors make it difficult to sustain innovations (Dubois and Gadde 2002; Winch 1998). Much of the digitalization research has focused on BIM.

The literature on interorganizational innovation in the construction sector, however, is only partially relevant for real estate and facility management firms. These firms are relevant stakeholders in building projects (Nam and Tatum 1997; Kulatunga et al. 2011; Gambatese and Hallowell 2011), as they will take over the management once the buildings are ready, and

they are subject to some of the institutional logics, such as standards or policies, that prevail in the built environment sector (Blayse and Manley 2004). Yet, the business logic of ownership and building management are arguably very different to those of firms' solely focusing on the design and production phases. The real estate firms, for example, are not project-based or temporal organizations, and thus innovation is bounded in different kinds of practices and structures compared to the rest of the construction sector (Harty 2008). It is worth noting that some of the firms are active in all building phases, as they both build and operate buildings, but nevertheless, due to the unique business logics of owning and managing buildings, innovation research should focus on questions relevant for building management phase.

The second literature stream focuses on innovation in the facility management, a topic that is covered more throughout in the section 3.3. Firstly, this literature is relevant for the building maintenance phase management, but rather rarely focuses on questions of real estate owner's strategy (Atkin and Bildsten 2017). This literature often criticizes real estate owners for being conservative (Engström and Hedgren 2012; Ivory 2005) and FM firms to be unable to sustain innovations (Mudrak et al. 2005; Cardellino and Finch 2006). Secondly, this literature largely focuses on innovativeness of facility management firms, but lacks research on interorganizational aspects of innovation. Thirdly, innovations in building management phase have potentially a large impact, as most of the buildings are already existing. An improvement that can be scaled at already existing building stock can potentially have a significant impact in the built environment as a whole: for building managers, service providers and users of buildings. Digital innovations may present a new way to scale innovations in buildings. Such innovations are for example digital platforms for services and communication.

3.2. From firm's innovativeness to innovation ecosystems

Research on firm's innovativeness has largely been based on the resource-based view of a firm (Barney 1991), which emphasizes firm's resources and capabilities as a source for competitive advantage, and thus argues that innovation is an intra-firm managerial process Tidd et al. (2005). Particularly, managers should focus on firm's dynamic capabilities, that are its abilities to reconfigure competences according to firm's changing environment (Teece et al. 1997). These dynamic capabilities are often seen to be embedded in the organizational routines and processes (Eisenhardt and Martin 2000), and thus they are a subject of hierarchical managerial control.

However, the increasing complexity of interorganizational innovation activities has challenged this intra-firm perspective, but while there have been multiple attempts to build theories on interorganizational innovation, these have only been partially successful, probably due to lack of theoretical understanding of these complex systems or conceptual divergence in describing

these systems. Further, research that would theoretically link these firm-level micro factors to system-level macro factors is scarce.

In the past two decades, the concept of business ecosystem, term borrowed from biology, has received attention both from management researchers and practioners (Jacobides et al. 2018). The interest is largely due to an increasing need for understanding complex business communities and networks, and from a perceived inadequacy of other concepts to provide sufficient explanation for the business logic in these communities (Moore 1993). Generally, it is seen that value creation is depended on multiple actors that need to cooperate (Adner and Kapoor 2010), and herein ecosystem concept is relevant, as it provides a product/service system focused framework for analysis, which is not limited to geography or contractual arrangements, and involves also non-business actors (Tsujimoto et al. 2018). Today, the term ecosystem is generally used of a group of firms that are dependent on each other's activities (Jacobides et al. 2018).

Since 1991, more than 500 articles on "business ecosystem" have been published (search on Web of Science on 6.12.2019). This breadth of scholarly contributions and lack of conceptual clarity has led to multiple confusions in scholarly discourse (Adner 2017; Ritala and Almpanopoulou 2017; Oh et al. 2016; Ritala and Gustafsson 2018; Tsujimoto et al. 2018).

Nevertheless, scholars have found ecosystems as a useful analogy or metaphor, and some recognize it as a promising scholarly field on its own worth within innovation, entrepreneurship and strategy research (Ritala and Gustafsson 2018; Adner 2017). A recent literature review by Tsujimoto et al. (2018) identifies four literature streams, where ecosystem concept is used: first focuses on industrial ecosystems, second on business ecosystems and organizational boundaries, third on platform management, and fourth on multi-actor network perspective, which expands the analysis from groups of firms to a wide variety of actors, including governmental actors, investors and user communities. Additionally, Jacobides et al. (2018) differentiates a literature stream on innovation ecosystems, which focus on particular innovations or new value proposals, and Clarysse et al. (2014) distinguishes knowledge ecosystems, which are geographical hotspots, where universities and public research organizations greatly influence the innovation activities. The main debates in the ecosystem literature have been on ecosystem structures and boundaries (Jacobides et al. 2018; Gulati et al. 2012; Adner 2017), value creation and value capture mechanisms (Adner and Kapoor 2010), ecosystem types (Valkokari 2015), rigor of ecosystems research (Ritala and Gustafsson 2018) and conceptual overlap with other concepts used in strategy literature (Adner 2017).

As the aim of this thesis is to investigate real estate owners' innovation activities, the concept of innovation ecosystem is of relevance. It is here defined as *a system of actors that contribute towards a common system-level goal.* This conceptualization has several implications. First, it draws the ecosystem boundaries around a group of actors based on their contributions

towards a shared goal. It thus follows Adner's (2017) approach, which determines the ecosystem boundaries based on flows of actions, rather than formal ties between the actors. This view emphasizes ecosystems as a dynamic, rather than a static concept. Second, it focuses on activities and mechanisms related to value creation, rather than on value capture. Third, as an analytical framework, it allows multilevel and multi-actor analysis. That is to say, both actor and system level analysis are required for comprehensive understanding of the ecosystems as social structures (Giddens 1984). Fourth, contrary to most ecosystem studies (Jacobides et al. 2018), this definition does not assume a focal actor or platform, around which the ecosystems are formed. Fifth, it allows ecosystems to be self-organizing or to be deliberately formed and hierarchically managed, and because of that, ecosystem strategies can be both deliberate or emergent. Sixth, it does not limit the ecosystem based on the types of actors or geographical location. Finally, based on initial empirical analysis, this conceptualization has shown to have a good fit with the empirical findings. This discussion, and the definition of innovation ecosystems in particular, is used to guide the analytical process in this thesis.

3.3. A structured literature review on digitalization and innovation in the real estate and facility management sectors

3.3.1. introduction

In recent years, digitalization has emerged as a major topic in the real estate industry discourse. There is an abundance of industry seminars that have taken digitalization as one of the main themes, and various industry reports are focusing on certain aspects of digitalization (Baum 2017; Westergren et al. 2017; Fastighetsägarna Stockholm 2018; Kairos Future 2018). While much of digitalization has remained on the level of discourse, more and more organizations have incorporated aspects of digitalization as a part of their business development activities and strategies (Kytömäki and Kadefors, 2018 September). Within the movement, there is an urge to reform the way people work in organizations and how firms offer services to their customers. This emerged interest on digitalization has created a need for a more comprehensive understanding on digitalization as a phenomenon, but still research on the recent developments on digitalization has remained scarce.

At the core of the phenomenon of digitalization is digitization, implementation of digital technologies, which is a technical process of replacing analog technologies with digital ones (Tilson et al. 2010). It is worthwhile to distinguish this technical process from digitalization, that is a sociotechnical process with broader social and institutional implications (Tilson et al. 2010). With this definition of digitalization, research should consider both the nature of a technology being used, as well as the organizational context where a technology is being used. The emergence of new digital technologies has increased the need to study the organizational implications in different contexts. Today an increasing number of physical products can have

a digital layer that turns them programmable, addressable, sensible, communicable, memorable, traceable, and associable (Yoo et al. 2010). These digital layers form the digital infrastructure, that is an inseparable part from the physical infrastructure, and together they form complex adaptive sociotechnical systems. In such systems, innovations often emerge through combinatory (evolutionary) logic (Yoo et al. 2010; Henfridsson and Bygstad 2013). Therefore, it is reasonable to research digitalization and innovation as largely overlapping phenomena.

While technological change processes have been studied in the field of real estate before, there are reasons why digitalization is little explored. First, as new digital technologies have emerged recently, their implications have not yet been further investigated. Second, much of the previous research has focused on rather technical questions leaving managerial and organizational implication less covered. Third, the real estate industry is a mature industry with limited R&D resources and conservative culture, which may prevent firms and researchers from investing time and money on new initiatives. Also, as much of digitalization related research is from high-tech sectors, real estate sector provides an interesting context for further investigations on the phenomenon.

Therefore, the purpose of this paper is to review the existing literature and develop a comprehensive understanding on the current research on digitalization and innovation in real estate, property and facility management sectors, the building maintenance phase. As an integrative literature review (Torraco 2005), it synthesizes literature streams on digital technologies and innovation from a long time period, an approach that has not been adopted in earlier research in the sector. An integrative review may provide comprehensive understanding for development of firms and other organizations, which is especially important in interdisciplinary fields, such as innovation management (Tidd et al. 2005) and a rigorous literature review can be of great worth speeding up the theoretical progress in a research field (Webster and Watson 2002). Also, review articles serve the purpose of synthesizing the body of knowledge in a field. As Yoo et al. (2010) point out, when terminology is not settled, there is a risk that findings in one field go unnoticed by scholars in other fields due to the scattered nature of research on digitalization. This is particularly relevant in the built environment sectors, which are highly scattered by nature. Also, the need for research synthesis grows due to the increasing number of research articles published every year (see figures 5 and 6).

More specifically, this paper aims at identifying the articles that focus on innovation and digitalization in the real estate and facility management, and at analyzing and categorizing these articles based on their topics and concepts. Finally, it presents a synthesis of the literature and discusses potential avenues for further research. Thus, it contributes to the body of knowledge on innovation and technology management in the construction sector.

This review differs from a previous review article by Wong et al. (2018) by focusing on building maintenance phase, instead of representing the whole construction industry, and by integrating innovation, management and organizational perspectives with technology focused literature streams, instead of focusing narrowly on digitization and digital technologies as such. Similarly, it differs from reviews by Araszkiewicz (2017) and Ullah et al. (2018), which focus on digital technologies in real estate and facility management sectors, and from a review by Shen et al. (2010), which focuses on systems integrations and interoperability in architecture, engineering, construction, and FM sectors. Also, this review complements and expands the analysis of the history of digitalization in FM provided by Bröchner et al. (2019). Additionally, compared to previous review articles, this paper deploys different methods of analysis and synthesis.

It is also notable, that the recent review by Nielsen et al. (2016), which focuses on sustainability on facility management, does not consider the impact of digitalization on sustainability, which indicates that digitalization and sustainability have been rather distinct topics in the literature. Bröchner et al. (2019) does consider both as major drivers for change in the FM field, opening up a discussion on the connection between the two topics.

The paper is structured as follows: First, the general approach of conducting the review is explained. Second, the step-by-step process of searching, selecting and analyzing the literature is described. Then, the results are presented, and finally, the implications of the results are discussed.

3.3.2. Method

3.3.2.1. Approach to literature review

A rigorous structured literature review can serve many purposes in academic research: it may facilitate theory development by synthesizing the literature and proposing classification systems or conceptual frameworks, close topics, where much of research has already accumulated, and uncover new themes by pointing out issues and opportunities (Wolfswinkel et al. 2013; Webster and Watson 2002; Torraco 2005; Grant and Booth 2009). On a topic that has accumulated a body of research for a longer period, a literature review can provide analysis and synthesis that extends the existing research, or if the topic is more emergent, a literature review can contribute by exposing theoretical foundations of the emergent literature (Webster and Watson 2002). This review aims at serving both of these purposes by pointing out theoretical roots and active debates in the literature over a long time period, and linking them with the more recent developments in digitalization and innovation research.

As the motivation for this research is to increase understanding on an emerging phenomenon, this research adopts a phenomenon-based research approach. This allows a selection of

research methods based on the phenomenon, and use the findings to build new theory (Schwarz and Stensaker 2016; Von Krogh et al. 2012). This inductive logic of reasoning is compatible with the grounded theory approach (Glaser and Strauss 1967), and thus a grounded theory literature review approach proposed by Wolfswinkel et al. (2013) is followed, except where specified otherwise. According to Wolfswinkel et al. (2013) and Grant and Booth (2009) the key concepts, or categories, may surface during the process of reading and analyzing the literature and writing the review. Both Wolfswinkel et al. (2013) and Webster and Watson (2002) agree that a concept-centric review, in contrast to author-centric review, is better for synthesizing and presenting the literature.

Wolfswinkel et al. (2013) propose a five-stage iterative model for conducting a literature review:

1. Define: Definition of criteria for inclusion and exclusion, identification of the field of research, determination of the appropriate sources and dedication on the search terms,
2. Search: Search the literature based on selected criteria,
3. Select: Refine the sample,
4. Analyze: Open, axial or selective coding,
5. Present: Represent and structure the content and structure the article.

Here, following a phenomenon-driven research approach, an attempt is made to let the literature speak for itself, free of pre-selections based on theory or the author's own preferences for specific papers. This is taken into consideration in two ways. First, the method of searching and selecting the relevant literature is exhaustive coverage, which aims at comprehensive presentation of relevant works on the topic (Grant and Booth 2009; Cooper 1988). Second, the results are presented by using the concepts of the original authors (Cooper 1988). Thus, the method for analyzing and presenting the results is largely based on descriptive statistics. Only when all sides of an argument are presented, may the reviewer take a position based on the cumulative evidence (Cooper 1988).

Another important factor for conducting a literature review is transparency of the review process and methodological consistency in conduction of the review (Wolfswinkel et al. 2013). On the other hand, the analytic process always involves exploration of finding a good fit between the method and the literature being reviewed, as well as plain errors in the analytical process. Thus, the review process involved multiple iterations and revisions in selection of keywords, organization and analysis of the data and choosing the way to present the results. These iterations helped in validating the earlier decisions made and correcting errors in processing the data. The consistency and transparency of the process was ensured by double-checking and documenting every step of the process, as suggested by Wolfswinkel et al. (2013).

3.3.2.2. Define

An efficient and rigorous literature review needs clear definitions of inclusion and exclusion criteria (Wolfswinkel et al. 2013). The scope of this study is to gain a comprehensive understanding of real estate and facility management, and on a specific topic, innovation and digitalization. Thus, a structured literature review on the topic was selected as the research method (Webster and Watson 2002). The main restrictive factor for the scope of the review is the selection of search words. The selection of keywords was based on reading on the topic, both new and old articles, several initial keyword searches in Scopus, Web of Science and Google scholar databases and discussion with senior academics, who have been active in combining information system research to research in the real estate and facility management context. This was done in order to reach an exhaustive coverage on the topic. The approach took multiple rounds of iterations, mainly as the understanding of the emerging phenomenon of digitalization took time to shape, both in the review process, as well as in the reviewed literature. Then, a strict keyword search on Scopus and Web of science databases was conducted. With this approach, as suggested by (Webster and Watson 2002), the search as such does not limit the results to certain journals, research methodology or geography, but includes any scholarly articles relevant to the topic and is multidisciplinary by nature.

3.3.2.3. Search

The list of database searches and keywords is presented in the table 6. Altogether 36 searches were made in Scopus and Web of Science Core Collection databases, which in combination have a good coverage on academic literature. Search codes were in the format of “(TITLE-ABS-KEY ("real estate management") AND TITLE-ABS-KEY ("digit*"))” for Scopus and “TOPIC: (""real estate management"" AND ""digit*"") Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI. Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.” for Web of science. The searches combined "real estate management”, "facilit* management" and "propert* management" with the search terms "digit*", "information technology" "information system*", "information and communication technology", "internet" and "innovation" with AND operator.

Combination of several search terms on digital technologies and innovation and on different managerial functions well covers the chosen research area. The words real estate management, property management and facility management are often used as synonyms, and thus all of them are included in the search. This strengthens the interdisciplinary approach, as the words cover most building maintenance phase management functions. Also, other search terms were tested, but were left out as they didn’t have a good fit to the research scope. The words “facilit*”, “propert*”, “digit*” and "information system*” were used, instead of “facility”, “property”, “digitalization” and “information systems”, to capture different format of the words. All searches were made on Title, Abstract or Keywords, in order

to capture all relevant search results. No further filters were used. Altogether, this produced 2558 search results, of which 756 were from Web of science database and 1802 from Scopus database. Results were exported as CVS files to Excel, where the two were combined into one worksheet based on the common column headings.

Hereby, there is no explicit definition of digitalization or innovation to guide the selection of the articles, but the selection is based on the selected keywords; the inclusion is thus based on the decisions of the author's, who have decided to include the chosen keywords related to digitalization or innovation in their paper title, keywords or abstract.

Table 6. List of database searches

No.	Database	Search term	Results
1	Scopus	REM & digit*	16
2	Scopus	REM & information technology	9
3	Scopus	REM & information system*	31
4	Scopus	REM & information and communication technology	1
5	Scopus	REM & internet	10
6	Scopus	REM & innovation	21
7	Scopus	FM & digit*	281
8	Scopus	FM & information technology	187
9	Scopus	FM & information system*	411
10	Scopus	FM & information and communication technology	37
11	Scopus	FM & internet	142
12	Scopus	FM & innovation	179
13	Scopus	PM & digit*	101
14	Scopus	PM & information technology	60
15	Scopus	PM & information system*	86
16	Scopus	PM & information and communication technology	9
17	Scopus	PM & internet	61
18	Scopus	PM & innovation	160
19	Web of Science Core Collection	REM & digit*	12
20	Web of Science Core Collection	REM & information technology	4
21	Web of Science Core Collection	REM & information system*	21
22	Web of Science Core Collection	REM & information and communication technology	1
23	Web of Science Core Collection	REM & internet	1
24	Web of Science Core Collection	REM & innovation	9
25	Web of Science Core Collection	FM & digit*	125
26	Web of Science Core Collection	FM & information technology	47
27	Web of Science Core Collection	FM & information system*	149
28	Web of Science Core Collection	FM & information and communication technology	7
29	Web of Science Core Collection	FM & internet	54
30	Web of Science Core Collection	FM & innovation	61
31	Web of Science Core Collection	PM & digit*	64
32	Web of Science Core Collection	PM & information technology	17
33	Web of Science Core Collection	PM & information system*	42
34	Web of Science Core Collection	PM & information and communication technology	4
35	Web of Science Core Collection	PM & internet	21
36	Web of Science Core Collection	PM & innovation	117
			Total: 2 558

3.3.2.4. Select

The figure 1 presents the process of selecting the literature for analysis and presentations. The 2558 search results were screened to find out if the searches match the scope of the research and sorted to prepare the data for further steps in the selection process. Then, exclusion criteria were applied. As some of the results had incomplete information stored in the databases, those results were removed. First, 101 results did not have the name of the author(s) and 37 results missed an abstract, and were thus removed. Second, 103 results were removed as the language was other than English. Third, 75 documents were removed based on the document type. The document types that were removed were “Article; Retracted Publication”, “Book”, “Book Chapter”, “Conference Review”, “Editorial Material”, “Note” and “Short survey”, leaving document types “Article”, “Article; Early Access”, “Article; Proceedings Paper”, “Conference Paper”, “Proceedings Paper” and “Review” in the sample. With these 316 removals 2242 results remained. Fourth, 719 duplicate values were removed based on the title of the paper. This was done separately for search results on digitalization and innovation, in order to keep full records in both categories. Fifth, the titles, abstracts and keywords of the remaining 1523 results were screened and 802 results were removed as they were not relevant for the scope of the research, as they did not concern digitalization, innovation or real estate, property and facility management. Finally, 721 results remained.

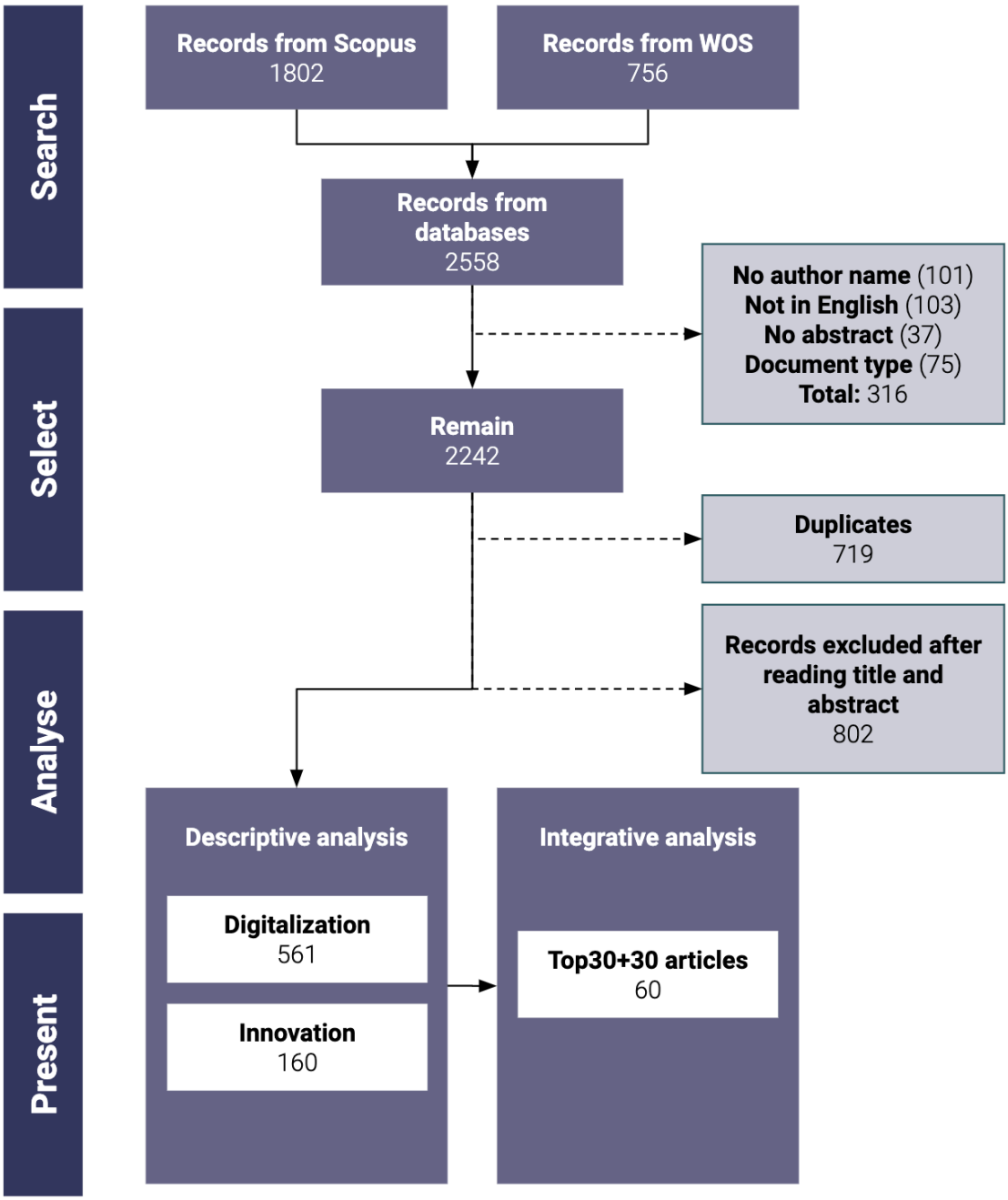
To prepare the data for the analysis phase, these 721 results were divided into categories “digitalization” and “innovation” based on the original search terms. The results including search terms “digit*”, “information technology”, “information system*”, “information and communication technology” and “internet” were grouped into a category “digitalization”, containing 561 results, and here on these results represent the body of knowledge on digitalization. Respectively, the results including the search term “innovation” were grouped into a category “innovation”, containing 160 results, and here on these results represent the body of knowledge on innovation. Together these categories form a sample for descriptive statistics, and this sample is from now on called “complete literature”.

This search, selection and grouping strategy aims at exhaustive collection of relevant results on digitalization and innovation across different management disciplines in the building maintenance phase. As Cooper (1988) argues, with an exhaustive search, the author may base their conclusions and discussions on all-inclusive information base. The strategy adopted here deviates from Wolfswinkel et al. (2013) by aiming for exhaustive collection of relevant research by relying on multiple keyword searches, instead of forward and backward tracking articles based on citations. In this paper the full data from innovation and digitalization categories were used for descriptive statistics. The inclusion criteria were not limited to certain journals, but the literature includes for example the most influential conference papers (Webster and Watson 2002), and as the aim is to track the historical development in

the field, the timeframe was the longest possible: the earliest article in Scopus dates back to 1977 and to 1984 in Web of science database.

Finally, another sample was prepared from the "complete literature" sample. 60 most cited papers, 30 from innovation and digitalization categories, were selected for reading and integrative analysis. This group is henceforth called "Top30+30" sample. As the aim was to collect most influential research, the selection was based on number of citations. This selection decision was informed by the analysis and screening of the "complete literature".

Figure 1. The process of selecting the literature for analysis and presentations



3.3.2.5. Analyse and present

Here, the analysis process and decisions regarding the presentation of the results is introduced, whereas the interpretation of the results is discussed in the next section. Inspiration for organizing and visualizing the results was found from Cooper (1988), Wolfswinkel et al. (2010) and Wolfswinkel et al. (2013). The analysis was done in two parts, first on "complete literature" sample and then on "top30+30" sample. All presentations are concept-centric as suggested by Wolfswinkel et al. (2013) and Webster and Watson (2002). The concepts presented are those of the original authors, except where specifically stated otherwise. This method differs from a pure grounded theory approach, as here the concepts emerges from the data through quantification, instead of interpretation by the reviewer. Wolfswinkel et al. (2013) do agree that the categories may come from the data, previously recognized categorization or from the reviewer, and that a presentation of results may be based on quantification on the number of publications. The decision for the approach was made after the descriptive analysis on the "complete literature", which showed large conceptual divergence in the concepts used.

As the aim of this research is to gain a comprehensive overview on the digitalization and innovation research in the real estate and FM sector, the data on "complete literature" was sorted and prepared so that a historical overview could be made. For the figure 5 "Growth of digitalization research - Number of papers per year", the data was sorted in Excel based on publication years and number of publications per year. For the table 7 "Journals", the data was sorted based on most publications per journal. Respectively, the same analyses were done for the innovation category (figure 6 and table 8). For the figure 7, "Top5 most popular concepts in digitalization research", the data was organized based on year and count of top5 most used keywords over time. This descriptive form of analysis and presentation brings up the trends in research over time and points out the journals, where this research is published.

The analysis on the "Top30+30" sample is wider. Wolfswinkel et al. (2013) proposes that a grounded theory analysis process should start by picking up a random paper and highlighting excerpts that seem relevant for the scope of the research and continue until all articles are read. The analysis on the "Top30+30" sample was done by reading the articles in full, in alphabetical order, and coding relevant excerpts in Nvivo 12 software. As the purpose of this review is to gain an overview of the literature, the relevant information was coded in predetermined nodes: "Definitions", "Research gap addressed", "Unit of analysis", "Theory or key concepts", "Method", "Suggestions for further research", "Implications for organizations", "Key findings" and "Views on digitalization". While many of the authors didn't reflect on all of these aspects, "Research gap addressed", "Theory or key concepts", "Method" and "Unit of analysis" were more or less explicitly addressed by all authors, and those nodes are coded for all articles.

Then, key concepts from each paper were listed and compared to each other. At this point, concepts that were close relatives to each other were combined through open coding Wolfswinkel et al. (2013). For example, “3D laser range finder”, “3D laser scan” and “3D visualization” were combined into a higher-level concept “3D visualization”. These concepts were grouped according the unit of analysis used in the paper and the category “digitalization” or “innovation”, where they belong to in the “complete literature”. The results are presented in the figure 8 and figure 9. The advantage of this presentation is that it exposes gaps in research by showing what concepts have been used in relation to different units of analysis, as well as in relation to digitalization and innovation literature streams. Further, figure 10 and table 9 are results of axial coding, where concepts from figure 8 and figure 9 are grouped based on their unit of analysis and perspectives on digitalization and innovation Wolfswinkel et al. (2013), and finally, the discussion is based on selective coding, where relations between the concepts and categories are discussed Wolfswinkel et al. (2013).

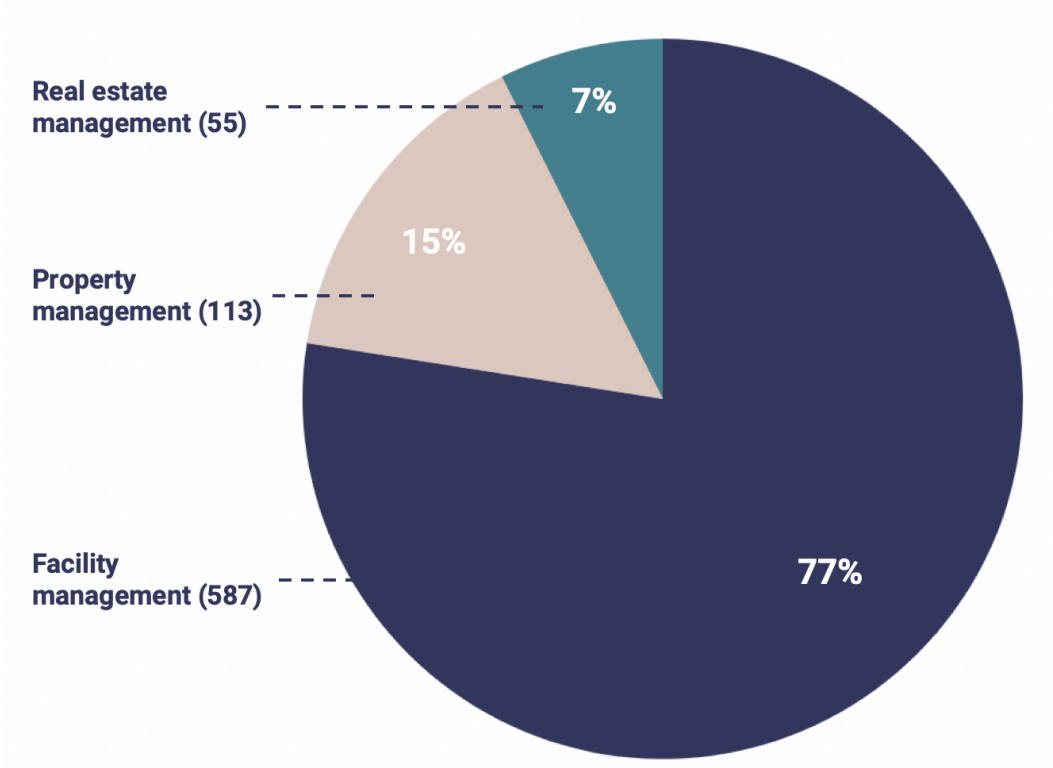
3.3.3. Results

This section presents the results of the literature review as follows. First, analysis on the “complete literature” data set gives an overview of the topic, and then, a review based on reading of “top30+30” literature provides insights on how digitalization and innovation is viewed in the literature.

3.3.3.1. Overview of the digitalization and innovation literature in the building maintenance phase – descriptive statistics

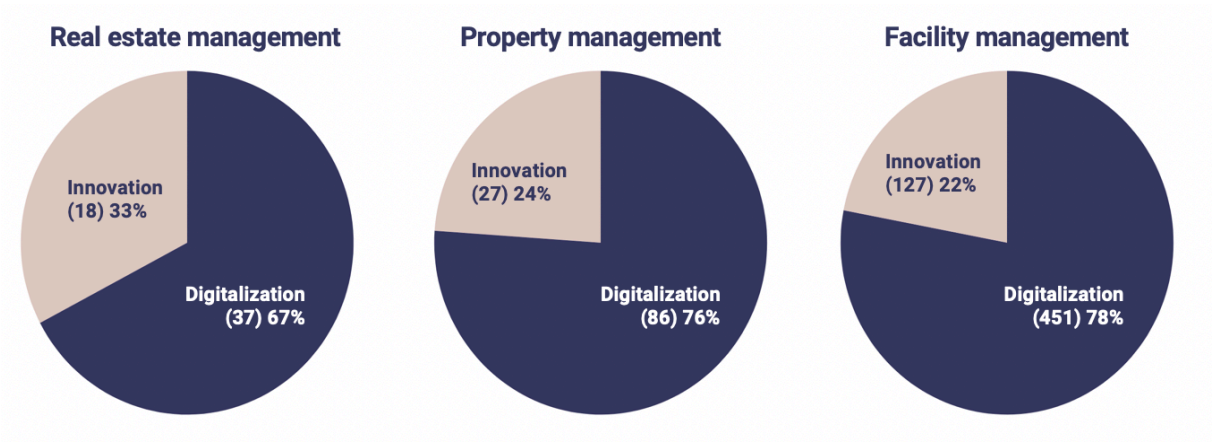
The figure 2 and figure 3 present the share of research on digitalization and innovation per management discipline. Please note that in figure 2 and 3 the analysis is based on the “complete literature”, but as the categories are based both on management disciplines (3 categories) and digitalization and innovation (2 categories), the number of duplicates removed is different. Figure 2 shows that majority of the results, 77%, focus on facility management, whereas property management (15%) and real estate management (7%) have attracted less research. Reading of the literature shows that facility management has developed into a more coherent field of academic discourse, with specific journals, whereas contributions on real estate management and property management are more scattered. Also, authors have different definitions and traditions in using the words facility (or facilities) management, property management or real estate management, and this causes divergence in the literature.

Figure 2. Number of articles and share of research per management discipline



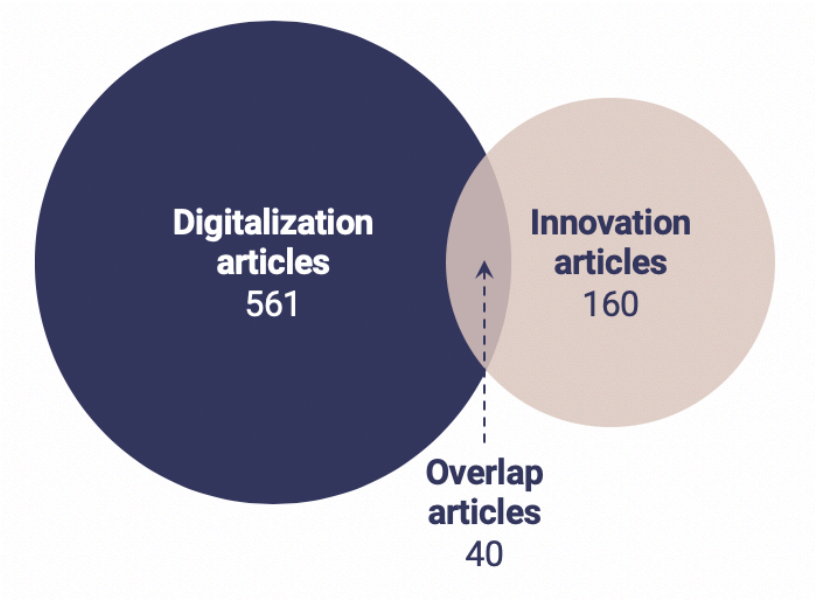
The figure 3 further divides the number of research articles to innovation and digitalization categories per management discipline. This shows that the share of digitalization literature counts for 78% of the FM literature on digitalization and innovation, and respectively, for 76% of property management literature and 67% of real estate management literature. The proportions indicate that research on digitalization, as it is here comprised, is more abundant than research on innovation. A closer review of the literature shows that innovation literature focuses more on managerial and organizational questions, whereas digitalization literature focuses more on technical systems.

Figure 3. Number of articles and share of digitalization and innovation research per management discipline



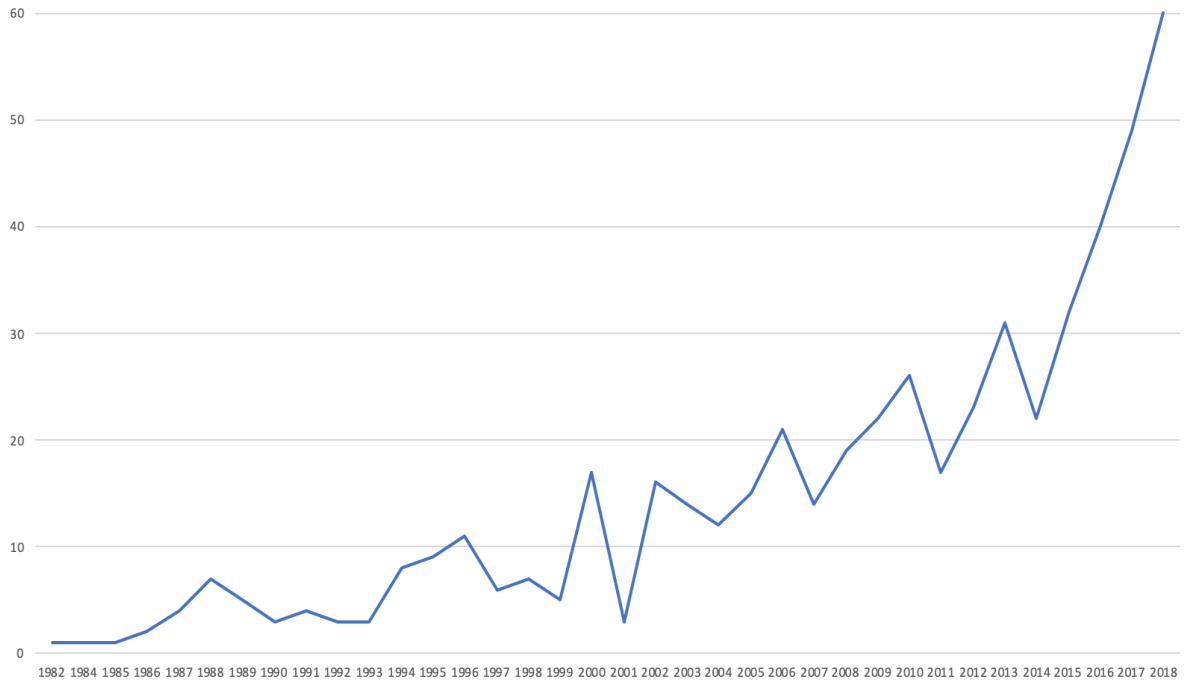
Further, the figure 4 presents the number of articles in the "complete literature" data set and the number of digitalization and innovation articles in both categories, as well as the overlap between these categories. A closer look into the overlapping articles show that many of them are cross-disciplinary by nature (16 out of 40, 40%) (f.e. Gholizadeh et al. 2017), as they discuss specific developments across the industry or take a multi-actor approach or building lifecycle approach. Also, three of them are review articles (Atkin and Bildsten 2017; Wong et al. 2018; Ullah et al. 2018), which discuss the expected implications of various digital technologies across the built environment disciplines. Notably 18 (45%) of overlapping articles are published after 2015, indicating that research combining innovation and digitalization perspectives is on the rise. Still, the majority of the papers does not concern both digitalization and innovation.

Figure 4. Number of articles in digitalization and innovation categories



The figure 5 extends the analysis with historical perspective by showing the growth of digitalization research over time, between 1982 and 2018. The curve shows moderate growth in published articles per year between 1982 (1 publication) and 2014 (22), and rapid growth between 2014 (22) and 2018 (60). The rapid growth of digitalization literature research in the sector is not surprising, given that digitalization has been recognized as a major change force in society at large and is widely discussed also in the industry media (Atkin and Bildsten 2017). A strict keyword search on abstracts of these articles show that only 22 articles have specifically used the words “digitalization”, “digitalisation”, “digitisation” or “digitization”, but the usage is on the rise, as 19 of these articles are from 2017 or 2018.

Figure 5. Growth of digitalization research – number of published papers per year



Respectively, the figure 6 shows the historical perspective on innovation research over time, between 1992 and 2018. Overall, the curve shows rather linear growth in number of published articles per year between 1992 (1 publication) and 2018 (17 publications, 12 on linear trendline). Still, the annual variation in number of publications is rather high. Notably, research on innovation peaked between 2005 and 2008, and again between 2015 and 2018, which could be a coincidence or a trend cycle in research.

Figure 6. Growth of innovation research – number of published papers per year

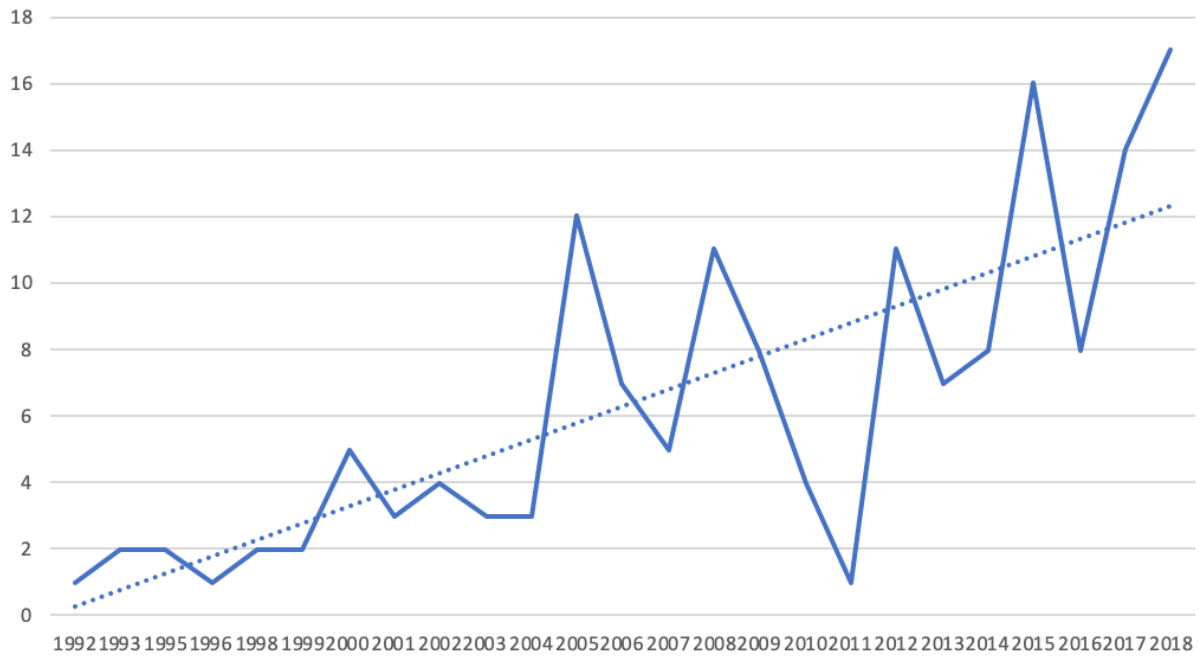
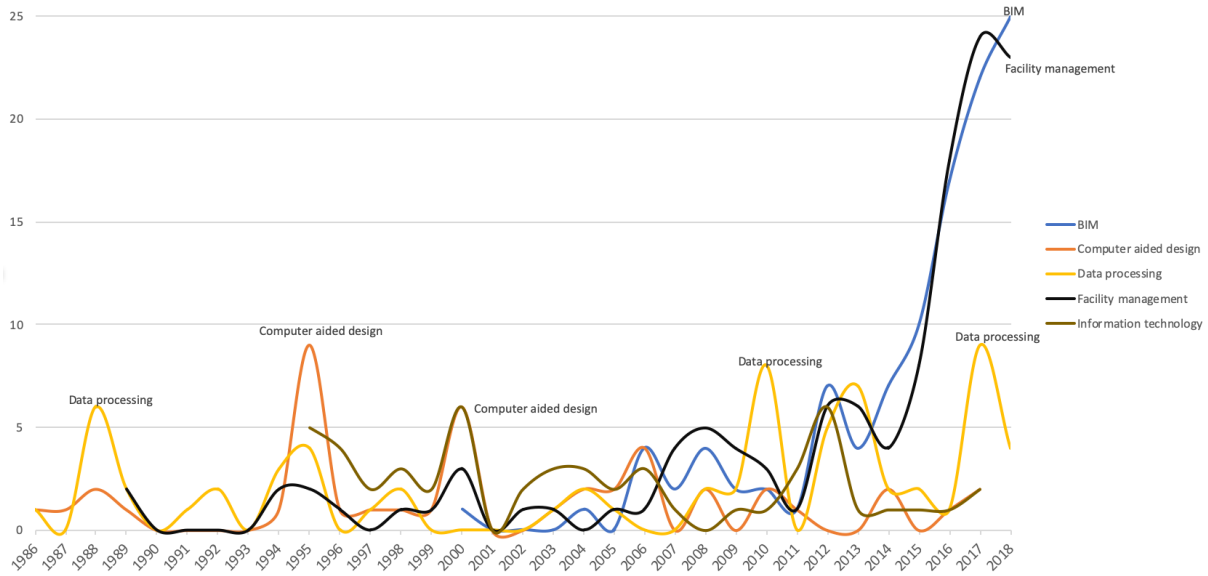


Figure 7 provides a closer look into the top5 most popular concepts used in the digitalization literature between 1985 and 2018. The figure was combined based on how often each concept occurs in the keywords of all 561 articles in the digitalization category. The figure shows that the number of publications on facility management and BIM, the all-time top2 most popular topics among the authors, exploded from 2015 onwards. In a longer perspective, the beginning of the BIM trend takes place between 2004 (1 publication) and 2008 (4), whereas the annual number of publications on facility management has been rather stable between 1989 (2) and 2006 (1), and in slightly higher between 2007 (4) and 2014 (4). Other popular topics have been computer aided design, data processing and information technology, which all have had rather stable number of publications each year. These concepts, however, represent only a fraction of the total number of concepts here associated with digitalization, and thus a more comprehensive analysis is later provided.

Figure 7. Top5 most popular concepts in digitalization research – number of published papers per year



Finally, table 7 presents the top10 journals based on number of publications, where articles on digitalization have been published, and respectively, table 8 presents the journals, where articles on innovation have been published. As same journals are on top of the list in both categories, the research on digitalization and innovation most likely reaches the same academic audience. This concludes the presentation of the results based on "complete literature".

Table 7. Journals, where articles on digitalization were published

Journal	Number of publication
Facilities	32
Automation in Construction	27
Journal of Facilities Management	11
Electronic Journal of Information Technology in Construction	7
Applied Mechanics and Materials	6
Journal of Computing in Civil Engineering	6
Journal of Corporate Real Estate	6
Built Environment Project and Asset Management	5
ISPRS International Journal of Geo-information	5
Journal of Construction Engineering and Management	5

Table 8. Journals, where articles on innovation were published

Journal	Number of publication
Facilities	30
Journal of Facilities Management	9
Journal of Corporate Real Estate	6
Property Management	4
Automation in Construction	3
Building Research and Information	3
Construction Management and Economics	3
International Journal of Strategic Property Management	3
Sustainability	3
Built Environment Project and Asset Management	2

3.3.3.2. Integrative review on digitalization and innovation literature

This section presents the results of the analysis based on reading of the "top30+30" list of articles, which contain 30 most cited digitalization and 30 most cited innovation articles from the "complete literature" data set. The figures 8 and 9 present the concepts authors used in the "top30+30" literature in relation to categories digitalization and innovation, as well as the relations between the concepts and the unit of analysis. The number in box after a concept shows how many articles used the concept in the literature. The presentation is divided into two figures. In the figure 8, the unit of analysis is "technology or system" and "individual". In the figure 9 the unit of analysis is "organization" and "industry or society". Overall, the number of used concepts is broad and varied, and these concepts vary depending on the author's level of abstraction when describing the concept. This presentation indicates how research in the field is divided and point out potential research gaps. The following review focuses on dominant views on digitalization and innovation in systems and organization literature.

Figure 8. Key concepts per unit of analysis and innovation and digitalization categories

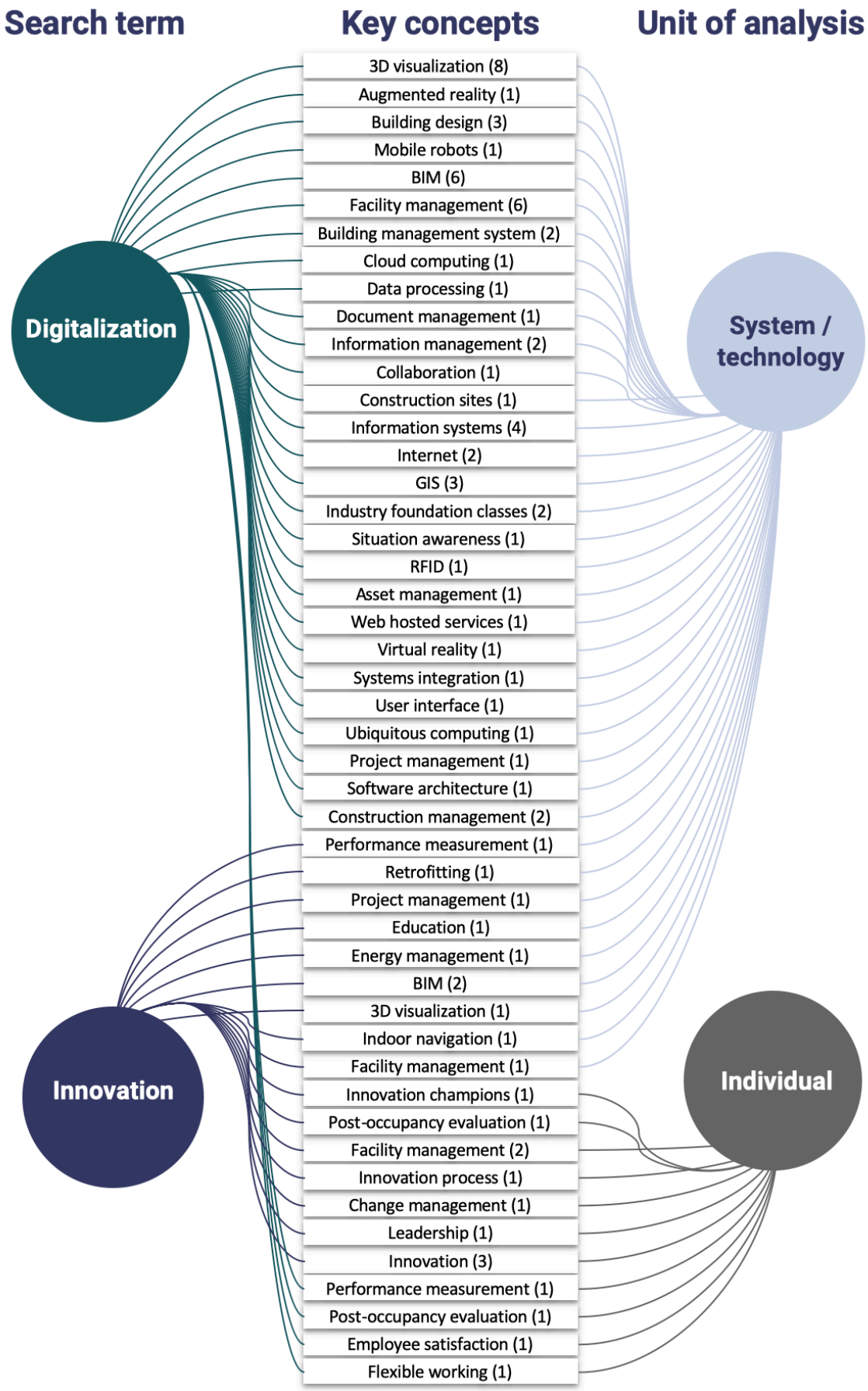
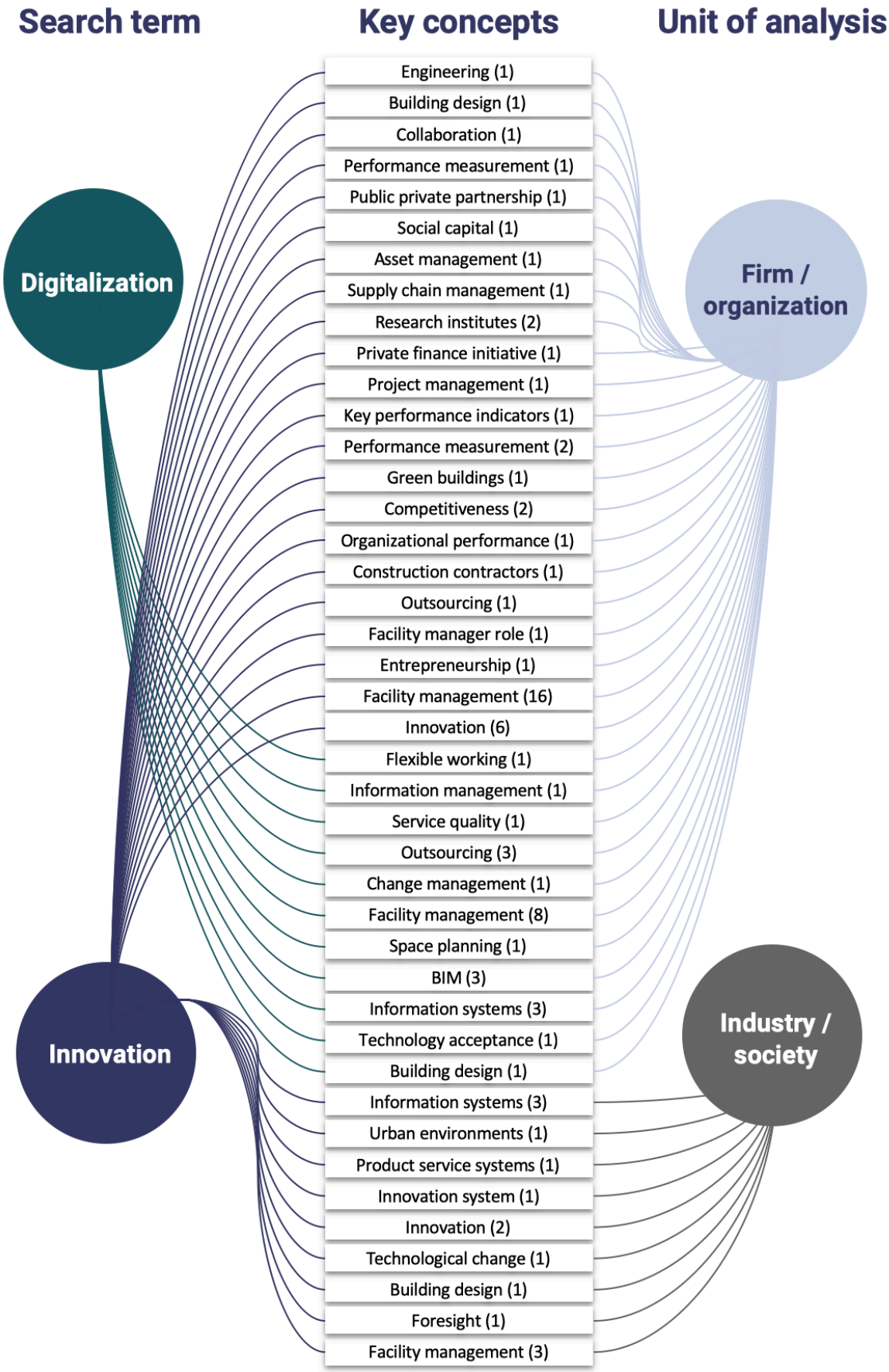


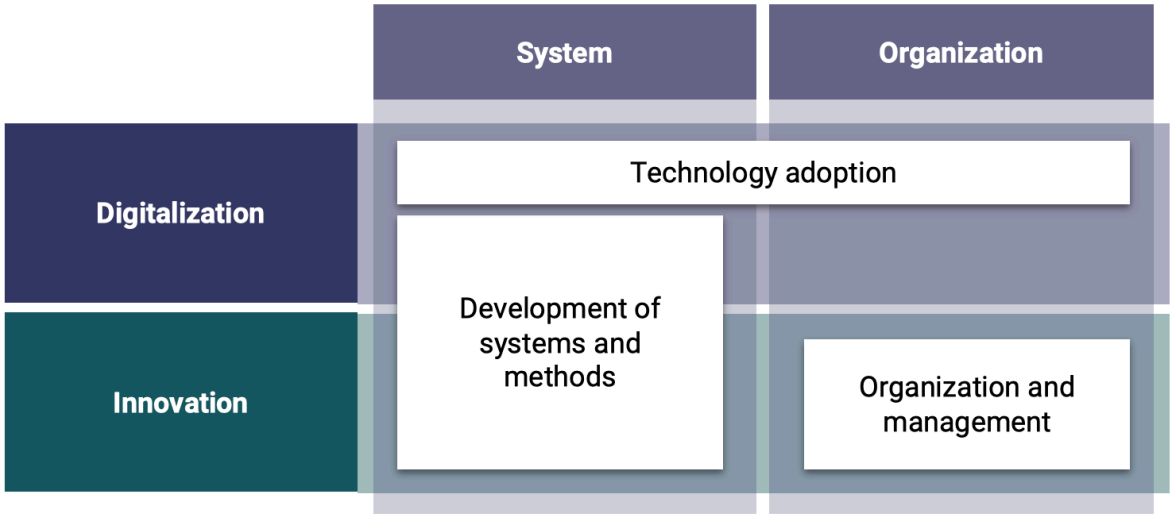
Figure 9. Key concepts per unit of analysis and innovation and digitalization categories



Literature review – perspectives on innovation and digitalization

The figure 10 shows the main debates in the "top30+30" literature. First, there is no noticeable difference in perspectives to innovation and digitalization in those papers that have system or technology as unit of analysis ("Development of systems and methods" -box). Second, there is an ongoing debate, which crosses systems and organization categories, on how technologies and systems are being adopted in organizations ("Technology adoption" -box). Third stream of literature concerns various aspects of innovations as organizational and managerial phenomenon ("Organization and management" -box), but this discussion is rather detached from the earlier two. The review here follows these three debates.

Figure 10. Debates on digitalization and innovation in building maintenance phase



The papers that have a technology or a system as a unit of analysis ("Development of systems and methods" -box), regardless if they are from digitalization or innovation category, often start by an author noticing a new application area for a new digital technology. Many of these are general-purpose technologies that have been developed in other industries and are now being applied in the construction industry. For example, Augenbroe (2004) point out that the availability of software innovations, such as building simulation software, has made them daily instruments in the industry. Another example is digital imaging of spaces. Golparvar-Fard et al. (2011) and Brilakis et al. (2005) point out that popularity of cheap high-quality digital cameras has provided an abundance of building site images, which can improve construction management processes. As a response to such opportunities, Kersten et al. (2004), Bhatla et al. (2012), Golparvar-Fard et al. (2011) and Brilakis et al. (2005) have developed methods for documentation of existing buildings, infrastructure and constructions sites with digital cameras, and for generating 3D models from these images. Similarly, Surmann et al. (2003) have developed a method for creating 3D models of indoor environments with autonomous mobile robots.

These technologies produce a lot of data, which has led to emergence of new demand for innovations in information processing, system development and system integrations (Golparvar-Fard et al. 2011; Brilakis et al. 2005), and many have addressed this challenge. For example, Kang and Hong (2015) have worked on integration of BIM and GIS systems for facility management, Wang and Xie (2002) on integrations between building management systems and facility management systems, Caldas et al. (2005) on integration of construction project documentation with project management databases and Schevers (2007) on a facility management model based on BIM. Schevers (2007) point out the rationale: the value of information grows, when it is made accessible to others. Review articles on systems integrations is provided by Shen et al. (2010) and Sanhudo et al. (2018).

In areas where systems and data has been organized, the discussions have turned towards new applications, and many authors have proceeded to develop and test their models and prototypes. Four of the authors have developed BIM related applications. Liu and Issa (2012) have proposed use of 3D models for facility maintenance workflows, Wyatt (1997) for property valuation, Bosche et al. (2008) for construction project process tracking and Isikdag et al. (2013) for indoor navigation. Others have turned to developing other technology applications, such as augmented reality (AR) (Irizarry et al. 2013), Radio Frequency Identification (Ko 2009), outdoor information screens (Linden et al. 2010) or intelligent tutoring systems (Kaklauskas and Gargasaitė 2006). Some of these applications have been more successful than others. In a review article, Chi et al. (2013) see that AR technologies are reaching maturity and have recently started affecting our daily lives. Yet, today, the use of AR technologies in practice is more of an exception than a convention in the construction sector.

The dominant view is that once these technologies are harnessed in the construction sector, they open up completely new application areas or make existing processes more efficient. As Shen et al. (2010) encapsulates it, information systems provide “a consistent set of solutions to support the collaborative creation, management, dissemination, and use of information through the entire product and project lifecycle, and further to integrate people, processes, business systems, and information more effectively.” But as these papers focus mainly on developing systems and methods, they rarely elaborate on organizational implications.

Other authors have shifted the focus from systems or technologies towards the challenges and other implications organizations face when implementing these technologies (“Technology adoption” -box in figure 10). For example, Johnson and Clayton (1998) recognize 25 different digital technologies, that are, with a varying impact, influencing the way business is done in organizations in construction industry. Ways of working are changing, much due to increasing use of IT, and thus there is a growing demand for flexibility, for example, related to forms of employment or property (Gibson 2003). More recent debates have been circled around BIM. Lee et al. (2015), Kassem et al. (2015) and Becerik-Gerber (2011) point out that the popularity of BIM in research is based on the perception that it can facilitate information

sharing in the management of buildings over their lifecycles. They argue that this view is too optimistic, as it is still unclear what factors affect successful BIM implementations or why it is adopted (Lee et al. 2015; Kassem et al. 2015). Several authors have taken up this topic: Lee et al. (2015) proposes an acceptance model for BIM in construction organizations, Kassem et al. (2015) provides a case study on the value of BIM in FM and Becerik-Gerber (2011) surveys BIM-benefits for FM practices. Findings show that while BIM has been an improvement to information management processes, there still are substantial challenges, mainly caused by lack of skills and interoperability between different systems (Kassem et al. 2015). Still, here too, the dominant view is that information technology serves as an enabler for organizational change and that these technologies create new opportunities for innovation (Johnson and Clayton 1998).

In organization research ("Organization and management" -box in figure 10), there are several studies on innovation, but these studies rarely reflect on the nature of the technological systems or the organizational needs for new technologies; rather, the focus is limited on organization and management. Notably, much of this research dates back to 2000 – 2008, and only four papers have individual as a unit of analysis. For example, Paglis and Green (2002) focus on managers' motivation for leadership of change and Leiringer and Cardellino (2008) on rhetoric strategies of innovation champions. Others focus on firms, and mainly on FM.

In FM, there has always been a broad debate about the boundaries and role of FM function, which is also evident in the literature reviewed. FM firms often originate from other service sectors and have expanded their service portfolio when opportunities have occurred (Bröchner 2008) and there are many organizations that perform FM functions in-house. Thus, there is a large variety of people and organizations performing FM. Shohet and Lavy (2004) and Duffy (2000) see that the challenge for facility managers is to balance between demands for lower operational costs and quality and performance of the facilities, and innovation. Heng et al. (2005) point out that FM has an important role as a broker between different functional units and thus can add value to the core business of an organization. The debate on FM roles expand to questions on outsourcing (Hui and Tsang 2004; Grover et al. 1996), such as contracting (Burdon and Bhalla 2005), as well as partnering between FM service providers and various stakeholders (Okoroh et al. 2001; Javed et al. 2013; Bröchner 2003; Nutt 1999; Akintoye et al. 2003; Erdener 2003; Cook et al. 2012). On the other hand, Andersen et al. (2014) extend the discussion to sectoral innovation systems and foresight.

Generally, in the FM literature, the dominant view on innovation is that how can FM function add value to the client organization (Okoroh et al. 2001; Heywood and Kenley 2008), for example through collaboration (Nazali Mohd Noor and Pitt 2009B), or how can an in-house FM function support the strategic objectives of the organization, for example through securing business continuity in all situations (Pitt and Goyal 2004). Nazali Mohd Noor and Pitt (2009A)

argue, that in order for innovations to come about, it is essential that the FM goals are tied with the overall goals of the client organization.

Some authors have focused research efforts more specifically on innovativeness of FM organizations. Cardellino and Finch (2006), Goyal and Pitt (2007) and Mudrak et al. (2005) point out that generally innovations in FM organizations are often one-shot commitments and sustaining innovations has been a challenge, and Eley (2001) see that FM organizations tend to be bad at responding to proposals that would require changes to their daily routines. To overcome these challenges, Goyal and Pitt (2007) recommend that principles of innovation management should be a part of daily activities for employees at all levels in FM organization, whereas Pitt and Tucker (2008) suggests that the FM innovation process should be governed with right performance measurement and benchmarking. On another note, Leiringer and Cardellino (2008) point out that much of the academic literature that rely on accounts from key individuals may be pro-innovation biased. Nevertheless, FM sector, still today, is largely perceived to have a low level of innovativeness.

Another line of debate concerns the relation between the workplace and the success of the organization (Then 2005). Authors have studied if ‘green’ buildings (Heerwagen 2000), innovative work settings (Dozie Ilozor et al. 2002), flexible workplaces (Van Der Voordt 2004) or location of the workplace (Dettwiler et al. 2006) can make the difference. Also, Haley (2009) discusses how management of research facilities can contribute to the overall success of a research institute. Then (2005) points out that the problems typically arise from a mismatch between organization culture and workplace strategies. In this debate, the dominant view on innovation is that how the workspace affects the productivity or innovativeness of organizations (Dozie Ilozor et al. 2002; Van Der Voordt 2004).

While several classifications on different perspectives to innovation exists (see f.e. Tidd et al. 2005), to the best of the author's knowledge, there are no classifications on digitalization perspectives in construction sector literature. Thus, the table 9 summarizes the results section by providing a classification of different perspectives on digitalization in the building maintenance phase. For each perspective, a description of the view and a representative quote are presented. This concludes the results presentation.

Table 9. A classification of perspectives on digitalization – based on “top30+30” literature

Perspectives on digitalization	Description	A representative quote
Buildings as integrated information systems	Buildings, and built environment at large, form loosely coupled information systems, that need integrations and interoperability between sub-systems. Focus on system optimization.	Vanlande et al. (2008): "we consider the building as an information system"
Digitalization as process efficiency	Digital processes, compared to analog or non-integrated processes, are superior in efficiency. Focus on process optimization.	Kersten et al. (2004): "Due to the digital data flow architectural photogrammetry has now become an efficient alternative to the classical building measurement and reconstruction methods."
Digitalization as a driver of organizational change or industry transformation	Digital technologies, when implemented in organizations, or construction industry at large, enable or drive change. Focus on change processes or system requirements for changing environments.	Gibson (2003): "ICT has been key in facilitating the staff flexibility." Shen et al. (2010): information systems provide “a consistent set of solutions to support the collaborative creation, management, dissemination, and use of information through the entire product and project lifecycle, and further to integrate people, processes, business systems, and information more effectively.”
Technology implementations or acceptance in organizations	Digital technologies are implemented in organizations in implementation projects. Acceptance of new technologies is based on expected utility for users or pilot projects.	Lee et al. (2015): "BIM acceptance and use remains a central concern of BIM research and practice. Therefore, we propose an acceptance model for BIM in construction organizations"
New application areas or use cases	Digital technologies enable completely new applications or use cases. These views are often based on pilot projects or authors' expectations about the future.	Surmann et al. (2003): "3D information available in real-time enables autonomous robots to navigate in unknown environments, e.g., in the field of inspection and rescue robotics."

3.3.4. Discussion - Towards an integrated view on digitalization and innovation

This section presents discussions on potential new research avenues, limitations of the research and contributions of the paper.

3.3.4.1. Potential new research avenues

As the results show, FM has been a dominant research focus in the building maintenance phase management, whereas research on property management or real estate management has received less research. Hence, different perspectives relevant to other than FM domain, may suffer from slower generation of knowledge. For example, real estate owner’s perspective appears only once in the reviewed “top30+30” literature and real estate asset management was entirely missing. Also, those papers that have taken individuals, teams, other organization types than firms, industry or society at large, as a unit of analysis, are more of exceptions than common. For example, employees may have very different perception on

innovations than managers, or users of the buildings may have very different view on building technologies than the facility managers, or, as the results show, there are no papers that discusses the societal implications of digitalization.

Also, only a few of the papers discuss the relations between different units of analysis. How do innovations and digitalization efforts are organized between employees, teams and managers, or how does firm level actions influence the networks, business ecosystems, industry, or society at large? Or the other way around: how does innovation policies impact the digitalization of the industry, or how do collaboration between companies impact their decisions of which technologies they invest in? Such questions are rarely asked. It would be desirable that researchers look at the phenomenon from the perspectives of many different actors.

The fact that research on innovation and digitalization is quickly growing provides many opportunities and challenges for researchers. Also, a long-term tendency in research has been towards further specialization of research topics, towards context-specificity. This is especially true in the construction sector, which is scattered by nature (Dubois and Gadde 2002). The specialization has an advantage of progressing domain or technology specific knowledge, but comprehension on the body of knowledge that crosses multiple management domains and technology-siloes, is difficult to achieve. This type of knowledge is especially important for managers, who try to make long term decisions related to innovation and digital technologies (Kytömäki and Kadefors, 2018 September). As Tidd et al. (2005) argue, "it is not sufficient to focus on single dimension of innovation: technological, market and organizational change interact", or as Ensor wrote already in 1988: an organization that suffers from "The functional silo syndrome – has a very damaging learning disability – it has not learned how to learn". Therefore, it makes sense to view digitalization and innovation from sociotechnical perspective (Tilson et al. 2010; Yoo et al. 2010; Henfridsson and Bygstad 2013), and investigate the broader social and institutional implications of digitalization (Tilson et al. 2010).

The scattered nature and growth of research papers being published create the need for review papers and methodologically better literature reviews in all research papers. This should be considered both in research projects, as well as in the editorial processes. It is also so that the scattering of the field creates more opportunities for interdisciplinary research, especially in the quickly growing digitalization category (Yoo et al. 2010). Though, the results point out that the overlap between digitalization and innovation categories has grown lately, indicating that more researchers are taking an interdisciplinary approach to digitalization and innovation.

Another remark on the historical trend is that both digitalization and innovation research have long history in building maintenance phase management fields. The researchers who take innovation and digitalization as topics for their research, should consider both the theoretical

and empirical applicability of the earlier research to their specific research project, but as Bröchner et al. (2019) points out, for example earlier studies on perceived effects of FM and workplace design could lose their relevance, as new digital technologies are adopted in office work; and similarly, digitalization may challenge the relevance of previous research in other topics as well, due to the combinatory logic of digital innovations (Yoo et al. 2010; Henfridsson and Bygstad 2013).

A cross-comparison of concepts used in the "top30+30" literature in relation to unit of analysis and categories "digitalization" and "innovation", as well as review on dominant perspectives on digitalization and innovation in each of the categories, shows gaps for further research.

First, as the dominant perspective in papers, where the unit of analysis is a system or a technology, is to see systems as product innovations, there is potential for researchers to adopt other innovation perspectives. There is a long tradition to view buildings as complex product systems (Davies and Brady 2000), and similarly, to view buildings as information systems (Vanlande et al. 2008), approaches that focuses on organizational and technological aspects of constructing these systems, but for example concepts, such as service innovation (Tidd and Montgomery 2003), service dominant-logic (Vargo and Lusch 2008) or business model innovation (Chesbrough 2010), could help authors to expand the perspective towards co-creation of value in processes, where users are involved. Many of the authors in the papers reviewed do mention that the systems and methodologies were "validated" in pilot projects, but the true validation does come only after a user takes the system into use, beyond the pilot phase. Thus, the focus on technical validation is not sufficient for innovation. This is particularly relevant in the building maintenance phase, where service providers confront the users of the buildings, and especially so in literature on BIM for FM, as the real-world examples of information system integrations over the life-cycle of the building has remained scarce (Bröchner et al. 2019). A way forward could be that papers that take systems as the unit of analysis would present better descriptions on the organizational contexts, with actions and implications, which could help in developing understanding on the context specific reasons why technologies and methods are successful or why they fail. This could be taken into consideration in research designs, as well as in editorial processes or research finance policies.

Another remark is that BIM dominates the systems literature compared to other technologies. As Lee et al. (2015), Kassem et al. (2015) and Becerik-Gerber (2011) point out, this is largely so for the reason that BIM is perceived to transform the way information is managed and used over the building life-cycle. As this vision has still failed to materialize, authors could turn to research other technologies that are currently being used or implemented. As Atkin and Bildsten (2017) point out, some of these debates on new technologies are largely done in industry media, instead of academic journals.

The dominant perspective in innovation research, where the unit of analysis is organizations, focuses on managerial and organizational questions, mostly related to FM. This perspective could benefit the systems literature by better describing the technologies that are being used in organizational processes, as well as the consequences of these technologies. Thereby, it could help in providing a feedback to the systems developers. Also, an approach that considers the technological systems, would not so easily neglect disruptions caused by new digital technologies (Christensen 1997) or would not miss the specific features of different types of technologies, for example in procurement decisions. On the other hand, Heng et al. (2005) point out that too much focus on technical efficiency in FM could prevent from seeing the relational dynamics in organizations that FM is to support, and thus argue for a more balanced view. Here too, a sociotechnical perspective (Tilson et al. 2010; Yoo et al. 2010; Henfridsson and Bygstad 2013), could be fruitful.

Perhaps, too strict focus on theory (Schwarz and Stensaker 2016), or too strict focus of the journals, prevents the authors from reporting interesting insights on the contexts or technologies in case. Also, as mentioned, this literature could benefit of adopting other units of analysis than firms, or of pursuing multi-actor research designs. Finally, as the results show, and pointed out by Atkin and Bildsten (2017), most of the well-cited innovation literature on FM was published more than 10 to 15 years ago, so update on the same themes could be necessary. As well, new themes, such as artificial intelligence or internet of things (Atkin and Bildsten 2017), should be brought to FM debates.

3.3.4.2. limitations of the research

There are at least three main limitations of this research. First, a review on a topic that aims to be exhaustive, is still limited by the chosen keywords for database searches, as well as in selection of the relevant databases. In this paper, this limitation is addressed by an iterative selection of keywords and data searches, where each iteration gives validation for the chosen search approach (Wolfswinkel et al. 2013). An alternative selection of keywords could provide new insights on digitalization and innovation.

Second, the topic itself could be redefined. Another topic for a review could include sustainability, that is increasingly seen as a major driver for change in FM field (Bröchner et al. (2019), and should thus be a fruitful topic for a review paper, perhaps in combination with innovation and digitalization literature streams. Also, a review could extend over other management disciplines, for example including real estate owners' and facility managers' roles in building design and construction phases. Of course, different combinations of these are possible.

Third limitation is in the analysis and presentation of the results. This review provides only limited presentation on the methods, theories used or empirical findings in the reviewed

literature, and a more in-depth review on these could provide a topic for another review. Similarly, this paper provides only a brief overview of the debates in the reviewed literature, as the aim is to integrate several topics in one review; the focus has been on drawing conclusions about the nature of digitalization and innovation discussions and point out relations between these debates. As this focuses on most cited papers and dominant logic of innovation and digitalization, it may miss out viewpoints that are more critical or have more specific audience. More in-depth reviews on particular topics are provided by Wong et al. (2018), Araszkiewicz (2017), Ullah et al. (2018), Shen et al. (2010), Bröchner et al. (2019), Nielsen et al. (2016) and Atkin and Bildsten (2017).

3.3.4.3. Contributions of this review

There are five contributions this paper provides for the debates on innovation and digitalization in the building maintenance phase management. First, this review is the only exhaustive structured literature review on the topic of digitalization and innovation, and it deploys different methods of analysis and synthesis compared to previous reviews. Thus, it extends the analysis and results of the previous review articles about management in the building maintenance phase by integrating digitalization and innovation literature.

Second, it provides descriptive statistics on the historical roots of digitalization and innovation research in building maintenance phase management, and points out that there are two growth periods in digitalization research and one rather linear growth trend in innovation research. Also, it points out that majority of research on digitalization and innovation concern FM, whereas other management disciplines have received less attention. Third, it provides a concept-centric presentation of the most cited innovation and digitalization research articles and provides a classification of different perspectives on digitalization in this literature. Further, it recognizes the main debates on digitalization and innovation per different unit of analysis, and points out potential research gaps between these debates.

Fourth, these analysis and presentations lead to conclusions about possible directions for future research. This may help authors in choosing a relevant digitalization and innovation perspective for their research projects and in positioning their research in relevant debates. Fifth, and finally, this review argues for sociotechnical perspective (Tilson et al. 2010; Yoo et al. 2010; Henfridsson and Bygstad 2013) in viewing the phenomenon of digitalization and innovation, a perspective which is not widely adopted. This perspective may help researchers to use innovation, organization and information systems theories to understand digitalization as a phenomenon, and further develop arguments based on empirics from construction sector towards empirical or theoretical debates in construction sector, innovation or information systems fields.

3.3.5. Conclusions

This paper presents the results of a structured literature review on digitalization and innovation in the building maintenance phase management. It combines literature related to digitalization and innovation from facility, property and real estate management disciplines.

Descriptive statistics show that FM has been a dominant topic in the literature, whereas property management and real estate management have received less attention. Another remark is that the growth of digitalization and innovation literature has been rapid in recent years. Also, the literature that combines digitalization and innovation perspectives is on the rise.

On the other hand, analysis on the top 30 most cited papers from digitalization and innovation categories show that there is much confusion on what digitalization and innovation are about, as well as scattering in the number of concepts related to digitalization and innovation. From this literature, three main debates are recognized based on the category "digitalization or "innovation" and unit of analysis: "technology or system" or "organization". First debate concerns development of digital technologies and systems, second concern technology adoption in organizations, and third concerns organizational and managerial questions related to innovation. Notably, these debates are rather distinct from each other. Further, this paper discusses the main perspectives for innovation and digitalization in each of these debates and provides a classification of different views on digitalization.

Based on these analyses, several research gaps are recognized. First, authors have mainly focused on systems and firms as units of analysis, and it is argued that other units of analysis would benefit the knowledge generation in the field. Similarly, researchers could make analysis on relations between researched units of analysis. For example, papers that discuss the societal implications of digital technologies are absent. Second, as the digitalization and innovation literatures are conceptually fragmented, and as the number of research papers is quickly rising, there is a growing need for review papers and interdisciplinary research strategies. This understanding that covers multiple digital technologies is especially important for managers, who currently struggle in making decisions related to innovation and digital technologies (Kytömäki and Kadefors, 2018 September). The growing need for interdisciplinary knowledge should be acknowledged in editorial processes.

The research focusing on systems and technologies often view digital systems as product innovations. It is argued that other innovation perspectives could benefit the systems developers in recognizing the user needs. Currently, many technology implementations are unsuccessful as they fail to identify user needs or deliver systems that would meet these needs. Also, it is argued, that papers that take systems as unit of analysis could better specify the

organizational context where the technical validations are made, and try to explain why the implementations have been successful or why they fail. This could be requested by journal editors or research finance institutions. Further, as BIM has been dominating the systems literature in recent years, and it has still failed to produce significant impacts in the FM field, researchers could investigate the potential and impact of other technologies on real estate, property and facility management. On the other hand, in organizational research on innovation, the main focus has been on FM. It is argued that this literature could benefit from acknowledging technological specificity when explaining organizational change in FM. At the same time, it could help systems developers by providing feedback on the system implementations and implications of these technologies.

Thus, this review makes several contributions to the debates on innovation and digitalization in facility, property and real estate management. It contributes earlier review papers by integrating innovation and digitalization perspectives in a structured literature review. Also, it provides descriptive statistics on historical roots of the phenomenon and a presentation of the most used concepts in the literature. Further, it identifies the main debates on digitalization and innovation and classifies the dominant perspectives on digitalization in each debate. Based on these analyses, several research gaps are discussed. Finally, it argues for a sociotechnical perspective for researching digitalization and innovation.

As digitalization and innovation are complex phenomenon, including multiple actors and multiple technologies, there is a growing need for interdisciplinary research designs. On the other hand, this complexity causes problems for managerial comprehension and thus makes decision making challenging for years to come.

4. Discussion – an analysis of how the licentiate thesis answers to the purpose of the thesis

4.1. Summary of paper 1 – Digitalization and innovation in the real estate sector

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

Digitalization in the real estate sector is a multifaceted phenomenon with potential impact on a wide range of actors and processes. Here, property owners are strategic decision makers and gatekeepers (Kulatunga et al. 2011). Real estate owners are generally considered to be slow to take up new technology and new services (Engström and Hedgren 2012), much due to an absence of competition and innovation drivers in a sector where traditional business models have delivered substantial and stable returns for decades (Palm 2015). Due to the development in digitalization, however, they increasingly find themselves exposed to a multitude of challenging predictions and propositions. Thus, more or less all property owners have to decide how to respond to this novel and complex environment.

In this research, we report the result of an interview study primarily targeting large real estate owners, but also industry associations that act as knowledge brokers and change agents in the real estate sector. We investigate the strategies for seeking information, the actions taken and planned, how these were selected, and the experiences. We further discuss how digitalization initiatives relate to existing structures and roles for managing business development and innovation within these companies, and discuss implications for future development.

The interviews showed that digitalization is high on the agenda for all interviewed firms. The interviewees recognized various opportunities and threats, and all firms had taken actions in the field of digitalization. The findings show that developing digitalization strategies in real estate firms is a process, and as an outcome new organizational roles, strategies and structures had been formed. These added resources for innovation search, selection and implementation activities can lead to better absorptive capacity on both firm level and in the real estate and construction industry at large (Cohen and Levinthal 1990), and that is a key determinant for future development in this area.

On the other hand, the interviews show that currently most real estate firms have limited resources for business development, and most interviewees have struggled with project delivery and change management in their digitalization projects. Limited resources may imply that digitalization initiatives crowd out resources from other types of development work. Also, the interviewed knowledge brokers raise a general concern for the quality of the digitalization activities, since firms may take initiatives in this area mainly for marketing and legitimacy reasons and lack commitment to fully engage in development work. Thus, questions arise

whether real estate firms can execute innovative digitalization projects in this conservative business environment and if they are able to sustain already launched products and services. Another risk is that existing cognitive and organizational barriers may lead to innovation search strategies that focus only on current business contexts and thus lead to status-quo decisions (Engström and Hedgren 2012; Tidd et al. 2005), but this said, digitalization has raised the awareness about the risks of focusing exclusively on the current business models.

Further, the interviewees reported that as a part of their innovation process the real estate firms had engaged with various information sources and established new relationships to competitors, suppliers and customers. The role of industry knowledge brokers seems crucial to complement lack of firm resources and facilitate knowledge sharing in this field. As questions in digitalization seem to cross departmental, organizational and industry sectoral boundaries, digitalization affects the collaborations in the industry at large. On the other hand, digitalization enables new forms of indirect competition that may spur from established technology firms and PropTech startup companies.

4.2. Summary of paper 2 - An operationalizable definition and method for research on innovation ecosystems

Kytömäki, O. (2019). An operationalizable definition and method for research on innovation ecosystems. A manuscript.

This paper focuses on the interorganizational structures for innovation in the real estate sector. Particularly, it investigates an innovation ecosystem, focused on digital development in the industry. Innovation ecosystems have received a lot of attention in the organizational and managerial research (Jacobides et al. 2018), but interestingly, it has not been much adopted to research in built environment sector (Pulkka et al. 2016). The surge of interest in ecosystems research, as well as the multitude of definitions and methodological approaches in the research, has made the literature stream chaotic. Several authors have called for more clarity and coherence (Oh et al. 2016; Ritala and Almpanopoulou 2017). One challenge in the literature has been the lack of commonly accepted definitions, and another, the lack of methodological approaches that would sufficiently address the complexities involved in innovation ecosystems (Phillips and Ritala 2019). Authors commonly use ecosystem as an overarching concept, including multiple actor types, ending up describing a sector or firms' business environment as a whole.

To address these issues, this paper offers an operationalizable definition of innovation ecosystem - *a system of actors that contribute towards a common system-level innovation goal* – which aims at capturing the essence of what ecosystem concept can be about. It focuses on ecosystem-level goals, which separates it from other concepts in firms' interorganizational collaborations (for comparison, see Granstrand and Holgersson 2019). It also allows for

recognition of actors based on their contributions to these goals, instead of preassigned group of actors: therefore, contribution to system-level goal determines the boundary condition of the ecosystem. It also allows for recognition of actor-level and system level attributes in an innovation ecosystem, as well as identification of multiple innovation ecosystem layers based on actor and system level attributes.

Further, the paper operationalizes the concept in a study of a real estate innovation ecosystem. Thus, it provides a methodological approach for multi-level and multi-layer ecosystem research; it describes how innovation goals in an ecosystem can be identified, how this sets the inclusion/exclusion criteria and how different innovation goals form layers of innovation ecosystem. This methodology relies on explorative qualitative interview study, document analysis and social network analysis (SNA). SNA as a method have many advantages for ecosystem research: first, SNA offers already existing methods for qualitative and quantitative research, second, SNA provides visualization on the ecosystem. This paves the way for functional ecosystem analysis, such as performance analysis.

Thus, the paper makes contributions to the innovation ecosystem literature by providing a new definition and methodology for practical ecosystem research. It also complements the previous literature on built environment innovation by offering empirical evidence on a real estate owners' innovation ecosystem. Thus, it complements the "complex adaptive systems agenda" on innovation ecosystem research, proposed by (Roundy et al. 2018; Ritala and Gustafsson 2018; Phillips and Ritala 2019).

4.3. Analysis of how the literature review, paper 1, and paper 2 answers to the purpose of the thesis

The starting point for this thesis was an empirical observation that digitalization has been raised on the agenda in the real estate industry discourse as "the new reality of property owners". Based on this observation, a phenomenon driven research project was initiated, aiming at increasing understanding on digitalization as a phenomenon in the real estate and facility management sectors. Further, this purpose was divided into two research strategies, research questions and methods, as presented in the table 10. This section presents a reflection on how the research answers to the purpose of the thesis.

Table 10. The research design and research questions

Aim	Research question	Method	Analytic framework
Distinguish the phenomenon in relation to the existing body of knowledge.	How is digitalization as a phenomenon viewed in the existing body of knowledge?	A structured literature review	Grounded theory
Generate new knowledge on the phenomenon by explorative research.	How do real estate owners manage innovations related to digitalization?	Empirical analysis: interviews and document analysis	Innovation process Innovation ecosystem

4.3.1. How is digitalization as a phenomenon viewed in the existing body of knowledge, in the built environment management literature?

The first aim of the thesis was to distinguish the phenomenon in relation to the existing body of knowledge. The discussion here proceeds as follows: first, a short description of the phenomenon is provided, second, perspectives on digitalization in the built environment management literature is discussed, and third, these perspectives are compared to the description of the phenomenon in order to distinguish the phenomenon in relation to the existing body of knowledge.

The phenomenon of digitalization has been multifaceted in the real estate industry discourse. This discussion has highlighted various threats and opportunities related to digitalization, but it has also caused misunderstandings, confusion and uncertainty. The increased uncertainties related to new technologies, partners and competition has made decision making challenging. Still, in organizational context, managers are faced with “the new reality of property owners”. In this context, perceiving digitalization as a sociotechnical innovation process of invention, development and implementation of new digital technologies is a pragmatic step forward, as it highlights the opportunity for managerial action.

To answer the research question one: “How is digitalization as a phenomenon viewed in the existing body of knowledge, in the built environment management literature?”, exploration on relevant theory and structured literature review was conducted. The literature review was done in order to clearly define the body of knowledge on digitalization (561 articles) and innovation (160 articles). The search protocol processed digitalization and innovation first as two separate streams of literature, providing descriptive statistics on both, and then integrated these streams to provides insights on how digitalization and innovation is viewed in the literature.

This review concludes that digitalization in the real estate and facility management field is a complex phenomenon. It is noteworthy that research on digitalization and innovation comprises of a large number of concepts. This has an implication, as Yoo et al. (2010) point out, that the conceptual scatter of digitalization research will most likely result in a dispersion of research contributions. Thus, this complexity will presumably continue to cause problems for comprehension, both in academic and practitioner debates. Still, there are three themes to which much of the debates converge. These are development of digital systems and related methods, technology adoption in organizations and innovation in organization and management perspectives. However, these discussions are rather distinct from each other, and rather limited in use of innovation theories. An argument for sociotechnical research is made in the discussion of the literature review, as it may provide basis for a comprehensive interdisciplinary research design. Further, by recognizing the concepts and debates in relation to different units of analysis, the literature review points out several research gaps.

The review of existing literature in relation to recent discussions on digitalization shows that there are several limitations in knowledge on digitalization in the real estate and facility management sector. On one hand, these limitations provide research opportunities for researchers interested on real estate owners or digitalization and innovation in the sector. On the other hand, the low number of relevant research contributions and dispersion of the research complicate production of knowledge. For this reason, there is a need for knowledge compilation, for example in forms of literature reviews.

Also, there are several questions raising from the recent discussion on digitalization, which are not well reflected in the extant body of knowledge. One aspect is technology management. Much of the literature is focused on development of systems and methods or on technology adoption, but rarely it is questioned what happens to the information systems over time in organizations. Talks on digitalization show that some of these systems have gone through changes, some can’t be changed and some become a burden to the organizations. There is also a growing dissatisfaction on the existing information systems, as they may not always serve the purpose of the user. Managers are burdened with administrating multiple IT systems, many of which are underutilized. Over time, dissatisfaction on existing IT systems may contribute to overly high expectations for new digital technologies. In any case, the unsuitable IT systems cause inefficiencies.

Another question related to technology management is uncertainties related to new technologies. At the moment, several real estate owners expect others to invest in digital technologies in order to learn from the examples. The problem is that if most keep waiting, the leadership for change is in the hands of a few, and if the problem is prolonged, it may lead to a low level of overall investment in the sector. Third aspect of technology management is related to partner uncertainty. For real estate owners, it may be difficult to find and establish

collaborations with new partners, many of which are newly founded PropTech startup companies.

Another aspect relevant in the digitalization discussion, but missing from the extant body of knowledge, has to do with new forms of competition and collaboration. As the real estate firms are increasingly performing innovation activities on ecosystem level, research should consider these new forms of collaborations. One advantage of ecosystems is that they are an effective form of organizing in highly complex business environment. This is a relevant theoretical insight that may help in understanding these collaborations. Another uncertainty is related to changing competitive landscape. Today, competition can quickly arise from completely new actors outside of the sector, and therefore, research should cover the antecedents of such competition. In turn, digitalization can open up new markets, and ways to address these markets, for real estate and facility management firms, as well as for startups that brew in built environment sector innovation ecosystems.

Thus, several questions raised in the debates related to "the new reality of property owners" are currently not covered in the body of knowledge on digitalization and innovation in the built environment management sector.

4.3.2. How do real estate owners manage innovations related to digitalization?

The second aim of the thesis was to generate new knowledge on the phenomenon in the field by explorative research. The research in the paper one and paper two address the second research question: "How do real estate owners manage innovations related to digitalization? Particularly, the papers approach the question from two perspectives: 1) empirically analyzing the innovation process in the real estate firms, and 2) by identifying the relevant actors in the real estate innovation ecosystem. This part discusses how the two perspectives complement each other and how they answer the research question about innovation management.

The innovation process perspective focuses on the innovation activities in the real estate firms. These activities are divided into three categories: innovation search, selection and implementation activities. By investigating these categories, the paper one uncovers the interviewees aims and challenges in the innovation activities in the sector. This can be contrasted with the "seminar talk" on digitalization, which addresses "the new reality of property owners", focusing largely on digital disruption.

The reality of property owners, to a large degree, is that they have invested in resources and capabilities for innovation, by establishing new roles, functions and collaborations, but still are challenged to act on the digital opportunities discussed in these seminars. On the other hand, digitalization is something that they have been doing for years, when focusing on implementation of building management systems, optimization of energy efficiency or

investing in administrative systems. Yet, a small group of real estate owners, together with industry associations and suppliers, have been active for example on establishing new businesses. Many of these digitalization activities may challenge the traditional view on real estate owners as conservative actors, in a conservative built environment sector.

This perspective is complemented with an innovation ecosystem perspective, which extends the discussion from intrafirm innovation activities to innovation ecosystem-level activities. The analysis of multiple innovation goals, actor-system level attributes and different layers of the ecosystem, provide understanding on the innovativeness of the sector as a whole. Therefore, the use of multiple methods and perspectives generate new knowledge on the phenomenon of digitalization in the built environment sector.

Further, the paper two extends the discussion from explorative, descriptive research to theoretical and methodological questions related to the innovation ecosystem research. This contribution is of relevance for the more general literature on innovation and strategy. Such theorization based on descriptive research is one of the aims of phenomenon-driven research. Still, as the scope of this thesis sets the limits to a study of one innovation ecosystem, the research is limited in generalizability for other innovation ecosystems in built environment sector, or other sectors. Further research could aim at studying innovation ecosystems in other contexts, for example by adopting the innovation ecosystem definition and methodology provided in the second paper, and extend the new theoretical and empirical knowledge generated in this thesis

Together the two papers contribute to the understanding on innovativeness of real estate firms. In particular, this research extends the existing knowledge on innovativeness of real estate organizations and provide new knowledge on digitalization in the real estate sector. Additionally, the paper two demonstrates the usefulness of innovation ecosystem concept in built environment sector research.

5. Conclusion

This thesis is an exploration of the phenomenon of digitalization in the context of the real estate industry. The purpose of the thesis is to increase the understanding of the phenomenon, particularly by distinguishing the phenomenon in the existing research and by generating new knowledge on digitalization in the field using an explorative approach. For this purpose, the thesis contains a structured literature review and two research papers which cover the research objectives.

The thesis contributes to research on innovation in the building maintenance phase by distinguishing the literature on innovation and digitalization. While previous literature review articles have touched on the topic, this review integrates literature from technically focused and managerially focused literature streams, as well as literature from different building maintenance phase managerial sub-disciplines. Therefore, it provides a holistic view on research on digitalization and innovation in the sector. However, due to the scattered nature of the research, building comprehension on the phenomenon will be a challenge also in the future.

Also, the thesis contributes to the research on innovation in the built environment sector, by providing new insights on the innovativeness of real estate firms, a perspective that is less common in research within the built environment. The two papers specify real estate owners' goals, actions, challenges and collaborations from two analytical perspectives: the first paper focuses on innovation processes inside the real estate firms and the second paper on the collaborations within the innovation ecosystem. The papers conclude that despite the added resources to the innovation functions in real estate firms, managing change in the conservative environment remains challenging. Additionally, the second paper provides a definition and methodology for innovation ecosystem research, which is of interest for research within innovation and strategy.

Digitalization offers multiple opportunities and threats for the actors in the real estate sector. It remains to be seen to what extent these actors will be able to defend their existing businesses against the new potential competitors and to create new businesses growth from the initiatives by the most active real estate firms and other actors within the industry. Digitalization promises resource efficiency and better services for tenants and building users. Thus, it remains to be an interesting topic for discussion and a rewarding business area for many.

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