Stimulating building industry transition through innovation and actor agency: an exploration of BIM adoption by building client organizations

Master thesis submitted to Delft University of Technology
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE
in **Complex Systems Engineering and Management**
Faculty of Technology, Policy and Management
by
Sydney Folsom
Student number: 4626214

To be defended in public on 30 November 2018

Graduation committee
Chairperson: Prof.dr.ir. J.W.F. Wamelink
Faculty of Technology, Policy and Management

First supervisor: Dr.ir. A. Straub
Faculty of Architecture and the Built Environment, Department OTB

Colophon

Author

Name	Sydney Folsom
Student number	4626214
Email	sydney.folsom@gmail.com

Graduation thesis

University	Delft University of Technology
Faculty	Faculty of Technology, Policy and Management (TPM)
Address	Jaffalaan 5 2628 BX, Delft
Master program	Complex System Engineering and Management (CoSEM)

Graduation Committee

First supervisor	Prof.dr.ir. J.W.F. Wamelink
Second supervisor	Dr.ir. A. Straub

Preface

> *"The most fundamental resource in the modern economy is knowledge and, accordingly, the most important process is learning"*
>
> – Bengt-Åke Lundvall

This master thesis represents an important milestone, the culmination of seven years of intensive growth and learning. Naturally, the months spent developing and executing this research contributed significantly my knowledge and experiences. Although the journey was meandering and involved the occasional tribulation, it has also yielded many rewards.

In carrying out research, I have become keenly aware of challenges facing the building industry and its adoption of building information modeling (BIM). Perhaps more importantly, I have become sympathetic to these challenges. The overwhelming amount of information and uncertainty surrounding BIM stymies researchers much in the same way as it does key industry stakeholders, like building client organizations.

As with any major undertaking, this thesis would not have been possible without the involvement and motivation of others. To my supervisors, thank you for your steering and guidance. To my friends and family, thank you for your kind words of encouragement and willingness to learn about BIM.

With this, I present my master thesis and conclude this chapter.

Sydney Folsom
Delft, November 2018

Table of Contents

1. Introduction

1.1 Demand for a more sustainable building industry

The building industry is a notorious energy and resource consumer. According to United Nations statistics, the manufacturing of building materials accounts for approximately 10% of all global energy end-use (UNEP, 2011) and energy consumption during the use and operation phase of buildings produces 30–40% of total global green house gas emissions (UNEP, 2007). Furthermore, evidence increasingly suggests that emissions resulting from activities during the building phase are as significant as during the use and operation phase (Wong & Zhou, 2015). In addition to intensive energy consumption, the creation and demolition of constructions contributes upwards of 40% of all waste in developed countries (UNEP, 2011). Although the construction industry has many negative impacts in terms of energy and resource consumption, it also plays a central role in national economies (Ozorhon et al., 2010) and increasing quality of life through the generation and sustainment of the built environment (Whyte & Sexton, 2011; Ye et al., 2009).

Sustainability and environmental welfare have risen to prominence in political agendas worldwide. Nearly all countries are working actively toward the development and implementation of new policy, which holds considerable implications that affect all industries. As a result of the Paris Agreement of 2016, numerous national initiatives have been implemented with the hope of mitigating the impacts of climate change. These efforts are reinforced further by the European Union Sustainable Development Goals, which require the policy of all member states to be reflective of these goals by 2030. There is also an increasing awareness that "system innovations for sustainability" or "transitions" of socio-technical systems are necessary in order to become more sustainable (Gaziulusoy & Brezet, 2015). Given the building industry's status as a notorious energy and resource consumer, it is therefore unsurprising that it has become a primary target for improvements. In short, the building industry is being pressured to dispense of its traditional practices in favor of more sustainable and long-term approaches for the design, construction, management, and eventual deconstruction of buildings.

Despite good intentions and actions on behalf of the building industry to respond to these demands, transition does not appear to be occurring rapidly enough. In point of fact, the overarching conclusion drawn in the 2017 Emissions Gap Report by UN Environment (UNEP, 2017) was that an urgent need exists for accelerated, short-term action and enhanced, long-term ambition in order to fulfill the mission and goals set out by the Paris Agreement and Sustainable Development Goals. Such an urgent need, however, comes into direct conflict with the conventional stronghold and slow-to-change nature of the building industry. Although the building industry's attitude towards challenge and change is often despondent, such developments also pose new opportunities.

1.2 The potential of BIM and building client organizations

In response to mounting pressure, many actors in the building industry are turning to innovation in an attempt to fulfill these new needs and demands. Arguably one of the most prominent innovations driving change in the building industry over the past decade is building information modeling (BIM). One of the most all-encompassing definitions of BIM found in literature is as follows: "Building Information Modeling (BIM) is a set of interacting policies, processes and technologies" (Succar, 2009) generating a "methodology to manage the essential building design and project data in digital format throughout the building's life-cycle" (Penttilä, 2006). Accordingly, BIM is an innovation well suited to enhance sustainability (Bynum, Issa, & Olbina, 2013) and drive the adoption of more holistic and lifecycle-oriented approaches to building projects (Eadie et al., 2013). Unsurprisingly, therefore, BIM has come to be seen as the common denominator for new and innovative approaches in the design, construction, maintenance, and operation of buildings (Bynum et al., 2013). BIM and its adoption by industry actors represent an important first step towards becoming a more sustainable building industry. In many ways, it appears that BIM may be capable of alleviating many of the building industry's new and long-standing challenges (Rezgui et al., 2009; Succar, 2009). Even actors at the national level see BIM's potential. In fact, several nations have already set deadlines or adhere to policy that requires BIM on new building projects (Akinade et al., 2017). The many promises of BIM have stimulated an unprecedented rate of adoption and implementation, especially in the design and construction phases of the building lifecycle. However, the full potential of BIM is not yet being realized and the sustainability benefits are thusly being limited.

Despite swift adoption and advances in BIM, a variety of barriers have arisen that have prevented an integrated, lifecycle-oriented BIM use from taking shape. Although BIM use has generally been limited to architects, designers, and contractors, this is not to say that these actors are the only ones who could benefit from BIM. In fact, recent research has indicated that downstream actors are poised to gain the most from BIM. In particular, building client organizations (BCOs) may be able to reap various benefits by implementing BIM in the use, operation, and management of buildings (Eadie et al., 2013). Consequently, BCOs may be a valuable actor group uniquely positioned to transcend some of these barriers. By driving the adoption, implementation, and use of BIM in later lifecycle phases, building clients could create a new demand capable not only of further developing lifecycle-oriented BIM use on building projects as an innovation but also of influencing transition in the building industry, whether directly or indirectly.

1.3 Limited insights and understanding

While building client organizations may be able to contribute to the transition to a more sustainable building industry by stimulating demand for BIM in later building lifecycle phases, a knowledge gap exists. Little is known, for example, about how BCOs are currently going about adopting BIM. From the few examples available in literature, it appears that BCOs are faced by various interrelated interdisciplinary challenges and are struggling to implement BIM in an effective manner (Lindblad, 2018; Vass & Gustavsson, 2017).

The research area itself poses another shortcoming. Although BIM is an increasingly popular research topic, the focus has primarily been on BIM as it relates to the design and construction phases. This can likely be attributed to the supply-driven nature of the building industry. As such, there is a dearth of literature emphasizing the demand-side and building clients in particular. Some frameworks aiming to stimulate the use of BIM have been made available, though the majority are directed to the supply-side and are thus too technical for practical use by building clients (Nepal et al., 2014; Succar, 2009; Xu et al., 2014). Conversely, other frameworks are quite generic and lack a specific course of action for pursuing BIM. Additionally, since the majority of research focuses on the supply-side, little has been said regarding the (potential) contribution of the demand-side on stimulating lifecycle-oriented use of BIM.

Furthermore, decision making processes that lead to the adoption of innovations in the building industry are a relatively underexplored research area (Sepasgozar & Bernold, 2012). Innovation and transition theory provide background for the causes and conditions that stimulate change and resulting transition. These theories have not been deeply explored within the context of the building industry, however. Thus, recommendations have been made that future investigation be made into factors affecting decision-making, adoption, and implementation of innovations in the building industry (Frambach & Schillewaert, 2002). To overcome this knowledge gap, Murphy et al. (2011) propose that future research in this field should develop innovation management models with the "potential to reduce the risk of abandonment of innovations in construction projects and increase innovation uptake in the construction industry."

1.4 Research aim and approach

Given the magnitude of this issue and the existing knowledge gaps, it is prudent to explore why building industry transition is occurring so slowly and how current initiatives could be augmented to quicken the pace. It is also, however, impracticable to attempt to explore every facet of these issues within the scope of one research project. This research, therefore limits its scope to focus on BIM and building client organizations.

The primary aim of this research is to explore the adoption of building information modeling by building client organizations and its potential to contribute to the transition to a more sustainable building industry. It is anticipated that fulfilling this aim will provide new insights into current BCO BIM adoption and also contribute to the existing knowledge of how innovation occurs in the building industry.

Taking context into consideration is especially important when doing research into complex socio-technical systems (Geels, 2004). There are a variety of reasons for this, though three stand out in particular. Firstly, BIM is implemented within a complex yet conventional industry that varies per country with a vast, interwoven stakeholder network. Secondly, BIM itself is a quickly evolving innovation with technological, social, and process aspects, which is growing in popularity despite lacking comprehension. Thirdly, lifecycle-oriented approaches in the building industry are infrequent, and thus not widely understood.

Given that this research therefore involves a duality of complex socio-technical systems and ventures beyond industry conventions, it was essential first to address a range of background information. Firstly, the building industry and its actors as they exist in developed countries are explored. Additionally, clarification is provided for what innovation in the building sector entails and where it typically occurs. Thereafter, pertinent developments impacting the building industry are reviewed according to the multi-level perspective. Lastly, this contextual information is compiled and used together with theory presented in Chapter 2 to characterize the current state of transition in the building industry. Thereafter, a complementary technological innovation system approach is applied. In this way, current pursuits of BCOs to adopt BIM are explored and system functions are analyzed. In closing, systemic problems are identified and suggestions based on innovation and transition theory are made for their improvement.

1.5 Research questions

Based on the research aim and objectives, the following research question is proposed:

Main research question

> *How can building client organizations improve their BIM adoption process, thereby contributing to the transition to a more sustainable building industry?*

In addition to the main research question, three sub-questions also serve to guide and structure the research.

Research sub-questions

1. *What is the current trajectory of transition in the building industry?*
2. *How could the adoption of BIM by building client organizations contribute to the transition to a more sustainable building industry?*
3. *What systemic problems in building client organizations BIM adoption can be identified?*

1.6 Research methodologies

To answer the aforementioned questions, this research employs a combination of literature study and case studies.

The basis of this research is formed upon a literature study, consisting of three parts parts. The first portion of the literature study explores innovation and transition theories. Specifically, the Multi-Level Perspective from Geels (2002) and a new theoretical framework for actors in transformative change by de Haan and Rotmans (2018) are studied. The second portion of the literature study looks into the nature of the building industry. Lastly, the third portion investigates currently available information on the current adoption of BIM by building client organizations. Together, these literature studies provide considerable background information to support and a new perspective from which to conduct the remainder of the research.

The remainder of the research employs case studies. For this, three large-scale building client organizations were interviewed. This information was processed and evaluated according to principles and an evaluation framework derived from the literature study. The results of these case studies contribute new knowledge on the current status of BIM adoption by building client organizations and the systematic problems that are currently being faced. Combining these results with the theoretical underpinnings it is then possible to draw conclusions addressing the main research question.

1.7 Report outline

Because research into innovation and transition in the building industry is limited, this research first establishes a foundational background in Chapter 2 based upon established and state-of-the-art theory. In researching socio-technical systems, and even more so when conducting transition research, the context is crucial to understanding. Therefore, Chapter 3 is dedicated to capturing the context of the building industry as it generally exists within developed countries, and in the Netherlands in particular. The chapter concludes by combining the theory covered in Chapter 2 with contextual information to characterize the current state of transition in the building industry, thereby addressing research sub-question 1. Chapter 4 pulls from existing literature to address research sub-question 2 about the potential contribution of BIM adoption by BCOs to transition of the building industry. In Chapter 5, the framework for the case study evaluation is derived based upon three innovation evaluation frameworks and a multi-disciplinary BIM maturity model. With this evaluation framework having been developed, Chapter 6 embarks on a case study of three large-scale building client organizations, which addresses sub-questions 3. Finally, in Chapter 7 the research is recapped and formal answers the research sub-questions are provided. The research concludes by answering the main research question and a discussion of the research limitations, results, and future possibilities.

2. Transition and innovation

2.1 Multi-level perspective (MLP)

The multilevel perspective (MLP) is a model that was developed in order to garner a better understanding of regime shifts, specifically the shift from one stable regime to another, in socio-technical systems. The multi-level perspective is composed of three nested, hierarchical levels — namely the landscape, patchwork of regimes, and niches (Geels, 2002) (Fig. 1). Although it is referred to as a nested hierarchy, it is important to keep in mind that socio-technological transition is not the result of a single, linear or vertically integrated process. Rather, the process is iterative and interwoven. Thus, the outcome of socio-technological change is the result of a dynamic relationship between all three levels over a period of time (Raven, 2005).

Following along with the hierarchy, the stability of the levels varies, with high stability at the landscape-level, relative yet variable stability as the regime-level, and low stability at the niche-level. Additionally, the greater the stability, the greater the structuration (Geels, 2002). Furthermore, the resulting interplay between the three levels determines the overall stability and structuration of the niche itself (Witkamp, Raven, & Royakkers, 2011).

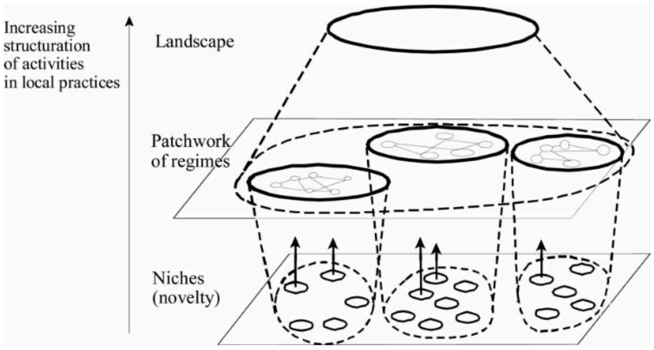


Figure 1. Multiple levels as a nested hierarchy (Geels, 2002)

Figure 2 offers a standardized visualization of the multi-level perspective. The visualization of the multi-level perspective seeks to show that socio-technical regimes (patchwork of regimes) and innovations (niches) both occur within a larger context, the landscape, which consists of deeply embedded trends (Raven, 2005). This visual representation also depicts the nature of the systems as various streams and flows. The regime-level in particular can be likened to an ebbing and flowing stream, the turbulence of which varies according to landscape and niche level pressures.

The MLP as a methodology and visualization tool are still evolving. Earlier interpretations, for example, included different regime specifications within the socio-technical regime-level (Geels, 2002). Newer versions, like the one in Figure 2 have added additional arrows to signify new findings on the interaction between the three levels. In this case, the arrows are representative of the influence of broader landscape- and regime-level developments on the perceptions of niche actors and the size of support networks (Geels & Schot, 2007).

At the top of the nested hierarchy in the multi-level perspective is the landscape, which consists of societal, institutional, and other background factors that enable and constrain regime and niche developments (Raven, 2005). Of the three levels, the landscape is the most structure. Thus, by definition, the landscape lies beyond the influence of individual actors yet has a major influence upon them (Geels, 2004;Raven et al., 2010).

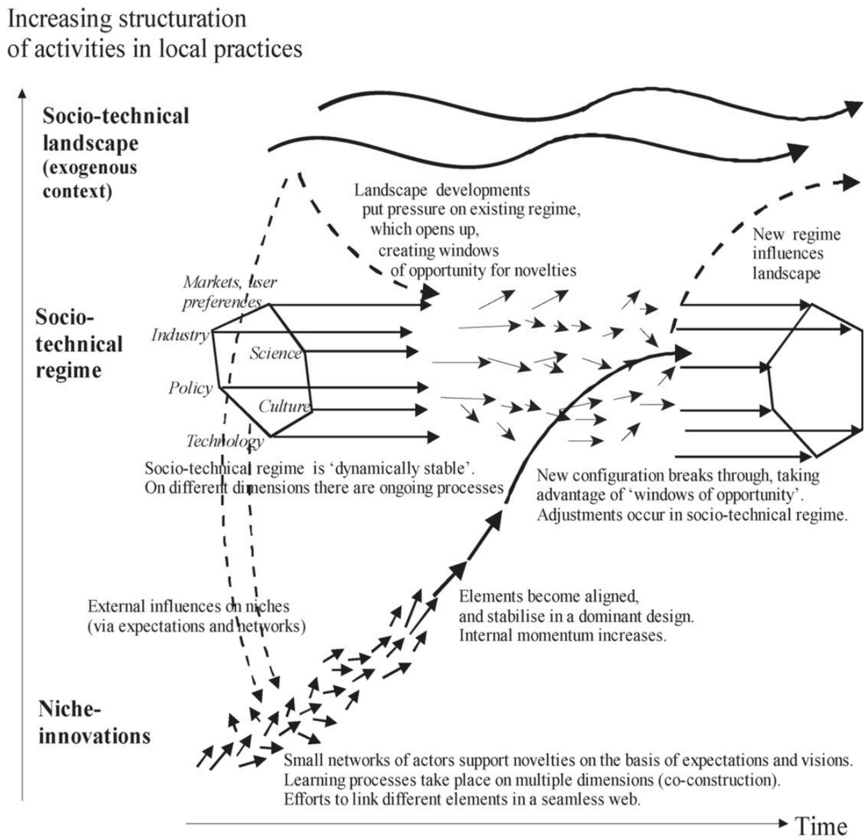


Figure 2. Standardized multi-level perspective of transition (Geels & Schot, 2007)

Embedded into the landscape is the regime-level. Simply stated, the regime is the incumbent, mainstream way that things are done in a socio-technical system. The regime-level is reflective of a socio-technical system and is comprised of a "patchwork of regimes". Within the multi-level perspective on transitions, six key regimes are identified: market/user preferences, industry, policy, technology, culture, and science (Geels & Schot, 2007) (Fig. 2). Although other regimes exist, these six provide a sufficient overview and address key aspects of institutional theory.

The third level is niche-innovations. This level is comprised of "embryonic nuclei for future" that are still is the developmental stage and have yet to achieve strong enough institutionalization to emerge into the regime-level (Fuenfschilling & Truffer, 2014). Niche-level developments can vary in size and degree of potential change. Of the three levels, the niche-level has the least structuration.

If broken down further, the MLP could actually be said to contain a fourth "level", that of experiments (Raven, 2005). Early efforts in generating the MLP distinguish between experiments and niches. This distinction helps to describe the process by which local experiments connect and develop over time leading to the development of a regime (Fig. 3). It also demonstrates the importance of the creation and transfer of knowledge and experiences gained from innovation experiments in the creation of structuration that supports further niche development and regime emergence.

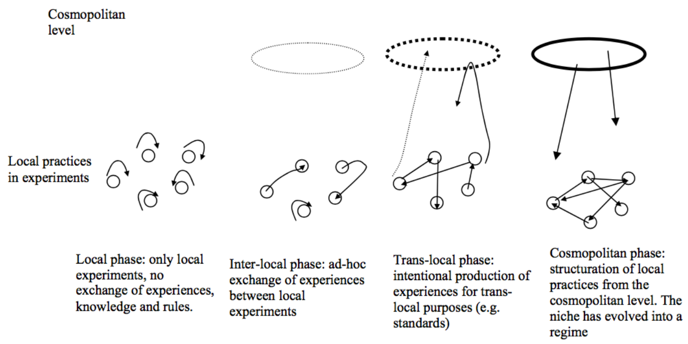


Figure 3. Emerging level of niches in relation to local practices in experiments (Raven, 2005)

An additional feature added later by de Haan and Rotmans (2011) is the “niche-regime”. As the name suggests, the characteristics lie somewhere between that of niches and the regime. For a niche-level innovation to be promoted to a “niche-regime”, it must provide a viable or competitive advantage compared to the incumbent regime(s) of the greater socio-technical-regime. Niche-regimes are therefore poised for breakthrough into the regime-level should the correct conditions transpire to form a window of opportunity. Should breakthrough occur, the niche-regime then proceeds to compete actively within the incumbent regime. The niche-regime therefore compares roughly to the trans-local phase in Figure 3.

2.2 A new theoretical framework for actors in transformative change

One of the greatest criticisms of existing transition frameworks like the multi-level perspective is that they tend to glaze over the role of actors in transition, focusing instead on transition as it pertains to innovation and technology (de Haan & Rotmans, 2018). The MLP suggests undertones of actor involvement and influence, but it is not clear how actors relate to specific a level or interaction between the three levels. These shortcomings are largely a result of the complexities of the state-of-the-art status of innovation and transition research. In response to these criticisms Markard, Hekkert, and Jacobsson (2015) note that understanding of the agency of different actor groups is an important direction for future research.

De Haan and Rotmans (2018) have recently undertaken steps to further this research area by addressing the matters of actors and agency in transition. They deviate from a purely innovation and technology focus to propose a new theoretical framework that highlights the formation and breakdown of systems based on network formation processes, interaction between various actor typologies, and adaptation of system dynamics over time. In their perspective, transitions are “the consequences of [a] myriad [of] actions and interactions of actors and the alliances they form in their pursuit of systemic changes.” Although de Haan and Rotmans (2018) affirm that their proposed framework has limitations and that the concepts still need to be firmly underpinned, it represents a first step towards creating a stronger awareness of and appreciation for the role of actors and agency in transition studies.

Figures 4 and 5 provide visualizations of two typical transformation dynamics according to the proposed framework. In each of these figures is a representation of actors, streams (societal value sets), and systems. Unlike earlier research, this framework adds in the elements of connection, affiliation, alliance, and the resultant support associated with actor networks. Using these elements, the proposed framework explains system change in terms of deliberate or strategic actions and interventions carried out by actors and their consequences (de Haan & Rotmans, 2018). Perhaps the most unique aspect of this framework is its emphasis on actors as strategic, value-driven entities that connect and affiliate with other strategic, value-driven actors to form alliances.

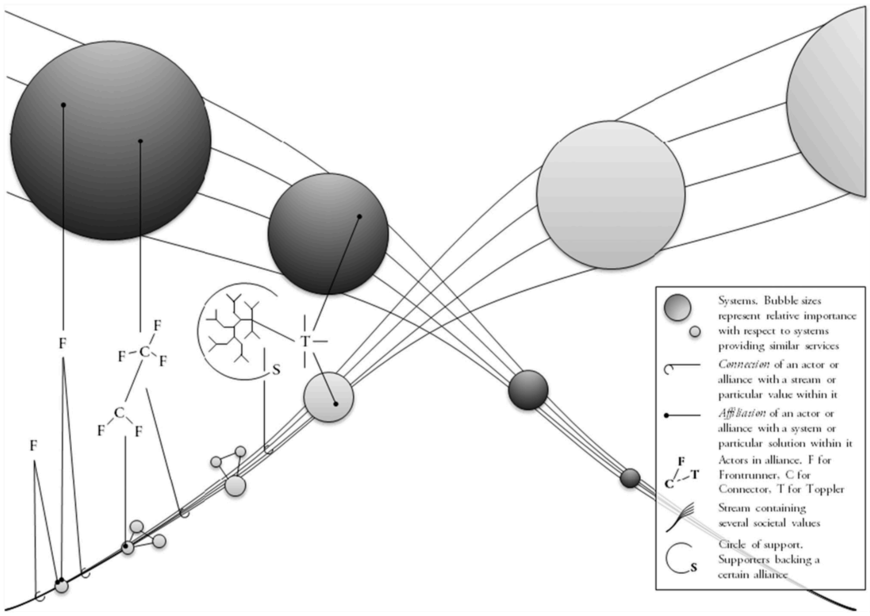


Figure 4. Dynamics on a transformative stage, with an incumbent system being replaced by an emerging system (de Haan & Rotmans, 2018).

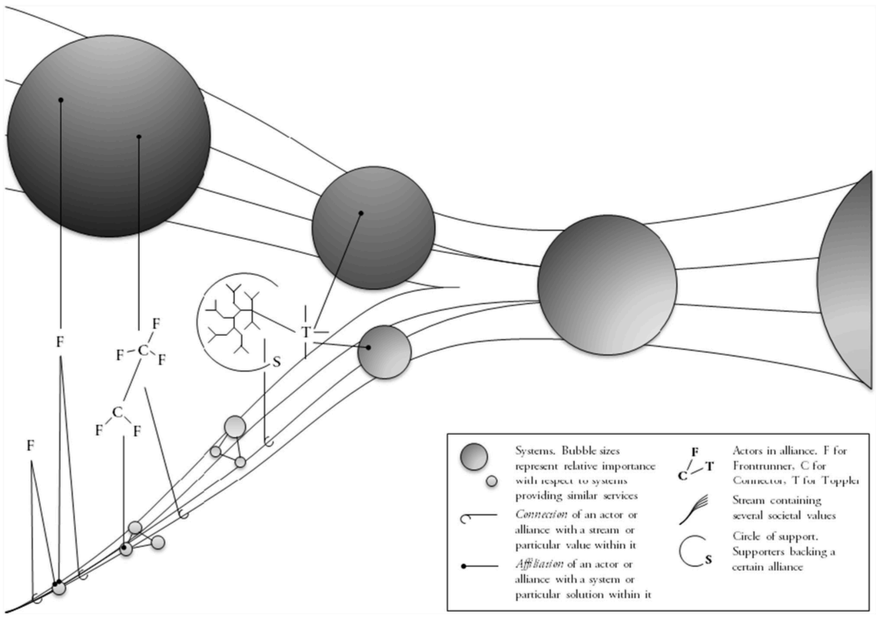


Figure 5. Dynamics on a transformative stage, with an incumbent system merging with an emerging system (de Haan & Rotmans, 2018).

In proposing a theoretical framework for actors in transformative change, De Haan and Rotmans (2018) include four actor role typologies, namely frontrunners, connectors, topplers, and supporters, which are discussed in more depth in Section 2.4. Additionally, the proposal addresses three types of actor alliance dynamics: initiatives, networks, and movements. These three dynamics represent the ways in which actors can work together on the basis of a shared aim and/or values to invoke change and system transition. This emphasis on alliances and cooperation between actors is succinctly described by Peppard and Breu (2003): "Organizations do not lead isolated lives but, instead, are linked inextricably with others. The success of one organization may, thus, be as much a function of what other organizations do as what the organization itself does."

The proposed framework and its actor focus are also in line with other recent research. An example of this can be found in the three main insights derived in research conducted by Wittmayer et al. (2017). Firstly, a single role always relates to one or more other roles, and that change in one role therefore affects the others. Secondly, the temporal nature of roles can be analyzed for either a specific moment in time as they contribute to (de)stabilization or as an evolutionary process with focus on how roles change over time. Thirdly, the roles can be purposefully utilized to influence the transition process.

This research makes one critique of the typology of de Haan and Rotmans (2018), in which niche-level innovations are referred to as "solutions." Although the authors defend their use of the word, the word "solution" implies that a problem is effectively solved or managed. This is in direct conflict with the nature of niche-level developments. Innovations at the niche-level have neither proved capable of uptake at the regime-level nor can they guarantee a solution to existing problems. It can even be debated as to whether breakthrough and use within the regime-level qualifies a development as a solution; hence the various transition pathway typologies that result in failed transitions. For the purpose of this research, the word "solution" was therefore replaced by "innovation." Additionally, the descriptions of the three typologies have been modified slightly to improve discussion between the proposed framework and the multi-level perspective. Lastly, definitions and the usage of terminology are not always consistent across transition and innovation research. An example of this is that the framework by de Haan and Rotmans (2018) refers to "transformative change" although it is consistent with the more generic term "transition" used by other authors. It is also easily confused with one of the transition pathway typologies proposed in their 2011 work, which has the same name despite having a different connotation. Such inconsistencies require care contemplation to ensure that terminology and theory are not misconstrued.

2.3 Transformative actor roles

The interest of transition research in socio-technical systems and actor alliances requires understanding of the relationships between actors over the course of the transition pathway. Part of this entails exploration into the role that actors play in transitional and other transformational processes. In research and in practice, actors capable of affecting their agency in a way that contributes to transition and other types of transformational processes are frequently referred to as "change agents." This term, however, is inconsistently applied thereby making its meaning ambiguous. Moreover, various types of actor roles can be distinguished.

In an attempt to simplify the complex chains of interaction that occur during transitions, researchers have been working towards more simplified typologies and definitions that can improve pattern recognition and analysis (de Haan & Rotmans, 2018, 2011; Wittmayer et al., 2017). De Haan and Rotmans (2018) specify four typologies are relevant to the beginning of a transformative change: frontrunners, connectors, topplers, and supporters. Additionally, even within the early transformation stage other typologies can and do exist. In order to provide a more comprehensive overview, three additional actor roles attributed to other researchers are also included, namely boundary spanners, boundary shakers, and free actors.

"Frontrunners" are frequently mentioned when discussing change and innovation, and the term has come to be used as a catchall for any type of pre-breakthrough actors (Loorbach & Rotmans, 2010). While this has benefited people's familiarity with the term, the distinction of frontrunners from other types of transformational roles is essential for researching transition. The role of frontrunners is the generation of new, alternative innovations (de Haan & Rotmans, 2018). In general, this role is discrete in nature with the actor working to fulfill its self-defined set of goals according to its own set of values, motives, and interests. Frontrunners can also become part of an alliance. This step is often beneficial as it expands their network and promotes alignment of their innovation with the endeavors of other similar actors.

"Connectors" serve a dual role. Firstly, connectors can play a role in connecting innovations to the system or embedding/anchoring innovations in an institutional context. Connectors play a role in the institutionalization of innovations, thus assisting their uptake within the regime. Secondly, connectors can help join together other actors and assist with alignment and the formation of alliances (de Haan & Rotmans, 2018).

"Topplers" play a role in the mobilization of innovations in order to assist with breakthrough into the regime (de Haan & Rotmans, 2018). This process entails introducing the innovation to the regime-level and the change and phasing out of barrier institutions. Topplers can assume a liaison function, and are tasked with articulating the innovation in such a way as to attract supporters.

"Supporters" play a more passive role in the transformation process. Their role entails supporting an innovation as it undergoes the process of institutionalization and transformation. By offering their support, these actors contribute to the legitimization of the innovation and express a vested interest in its uptake (de Haan & Rotmans, 2018).

Another actor role is "boundary spanners". The role of a boundary spanner is to engage in "strategies to manage cross-boundary connections" (Zietsma & Lawrence, 2010). Boundary spanning can occur across any of the three MLP levels, however boundary spanners fulfilling transformative roles operate between the niche and regime levels. Actors fulfilling a boundary spanning role can be affiliated to the niche level, the regime level, or both simultaneously (de Haan & Rotmans, 2018). Complimentary to this role is boundary shaking. "Boundary shakers" fulfill a similar role to boundary spanners, though their transformation role is carried out within organizations (Smink et al., 2015).

"Free actor" is more of a standing than a formal role. Wielinga and Geerling-Eiff (2009) describe free actors as having "the position and the capacity to do what is necessary to create a network conducive to innovation." This designation resonates strongly with the proposed framework by de Haan and Rotmans (2018) given that one of their preconditions is the freedom and ability of actors to work together in order to make and allow alliances to flourish. As such, all of the transformative actor roles discussed in this section could also be characterized as free actors.

2.4 Transition patterns and pathways

Transition can occur in a variety of ways. Based on prior transition research, Geels et al. (2016) classify four types of transition pathways: "substitution", "transformation", "reconfiguration", and "de-alignment and re-alignment." While these classifications are useful for analyzing transformation, reality does not adhere to clear-cut classification. Based upon the nature of transitions as continuous and contested change processes between a variety of actors, the conceptualization of transition pathways has expanded to include "shifts between pathways" (Geels et al., 2016). Geels et al. (2016) also identify that shifts between transition pathways are influenced by a wide range of developments including: changes in actor coalition composition and strength, learning processes and experiences, and landscape developments (Geels et al., 2016). While these pathways help to support the new theoretical framework discussed in Section 2.3, they are too simplistic to support a qualitative narrative of a transition for analysis.

De Haan and Rotmans (2011) offer another perspective on transition pathway typology. Interestingly, this publication predates that of Geels by five years yet explores transition typologies in greater depth. Just as Geels (2016) refers to shifts between pathways, de Haan and Rotmans (2011) describe transitional change as a "chain of patterns" driven by conditions for change, such as tensions, stress, and pressure. Three types of transition patterns are defined as follows by de Haan and Rotmans (2011):

- Reconstellation (top-down) – "A new constellation emerges, or an existing one gains power by influences from outside the societal system., reconstellation and adaptation."
- Empowerment (bottom-up) – "A new constellation emerges, or an existing one gains power, either by itself or through interacting or merging with other constellations within the societal system."
- Adaptation – "A constellation alters its functioning either through interacting or merging with other constellations within or from outside the societal system."

The next step undertaken in their research was to create transition pathway typologies for these typologies. For this, the reconstellation and empowerment patterns were carried over directly. Adaptation, however, proved more complicated. Whereas the two other patterns have clear top-down or bottom-up characteristics, adaptation appears to be more internally induced. Instead of creating one category for adaptation, the researchers opted instead to create two separate categories. Transformation pathways are characterized as adaption dominated. Although they introduce transformation pathways into their research, de Haan and Rotmans (2011) challenge the notion that change can occur within a vacuum by disputing whether this type of internally induced change qualifies as a "proper transition". This is a highly relevant point for this research as it emphasizes the complexity and interconnectedness of socio-technical systems. The second category is the squeezed transition pathway, which is effectively simultaneous reconstellation and empowerment. The squeezed pathway is in keeping with previously established transition research, such as the multi-level perspective.

Also taken into consideration in the creation of the transition pathway typologies were the influence of the incumbent regime or the ultimate success or failure of the transition effort with respect to change in the existing, dominant regime. In total, eleven transition pathways are included in the typology (Table 1). The researchers acknowledge that a myriad of transition pathways are possible, they believed that the typology sufficiently addresses the distinguishable criteria.

Table 1. Transition pathway typologies (de Haan & Rotmans, 2011)

Transition pathway typology				**Type of regime change**
Top-down	*Bottom-up*	*Squeezed*	*Transformation*	
Radical reform	Reconfiguration	Teleological	Transformation	*(with regime adaptation)*
Revolution	Substitution	Emergent	-	*(without regime adaptation)*
Collapse	Backlash	Lock-in	System breakdown	*(failed transition)*

Combining the multi-pattern approach and transition pathway typologies together with descriptions of the transition conditions, it becomes possible to develop a narrative of the transition at hand that can then be qualitatively analyzed.

2.5 Conditions for transition

As mentioned previously, the regime-level is an ebbing and flowing steam in a constant state of flux. The most basic condition capable of initiating transition is destabilization of the regime level (Fuenfschilling & Truffer, 2014). Destabilization of the regime level creates windows of opportunity for niche-level and niche-regime developments to challenge the existing, dominant regime. According to the multi-level perspective, destabilization occurs as a result of interactions between processes occurring within each of the three levels. The processes can be attributed as follows (Geels & Schot, 2007):

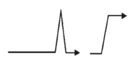
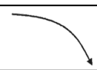
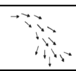
- Landscape: changes that lead to creation of pressure on the regime
- Socio-technical regime: destabilization that results in windows of opportunity for niche emergence
- Niche: buildup of momentum and support of an innovation by powerful alliances

Similarly, De Haan and Rotmans (2011) assert that conditions for transitional change arise when the societal system is compromised in some way, making the status quo unsustainable. As socio-technical systems are composite, open, and contextually influenced, they can be compromised by factors internal or external to the system. Three general conditions for transitional change according to de Haan and Rotmans (2018) are tensions, stress, and pressure. Tensions refer to flux between the system and its environment that are dependent upon complementary structural and cultural aspects and symmetry. Stress and pressure are both considered as internal factors that compromise the system therefore creations conditions for transition. Stress occurs when the dominant regime is inconsistent or inadequate in its performance. This often transpires as a result of mismatch between needs, structure, and culture. Lastly, pressure is system compromise resulting from direct competition between the dominant regime and niche or niche-regime developments. From the MLP perspective, it could be argued that pressure is internal to the regime-level and also originates from the landscape and niche levels.

Further, transition is a process of change from one state to another. Change can come in a variety of forms, four dimensions of which are highlighted by Suarez and Olivia (2005):

1. Frequency: number of environmental disturbances per unit of time
2. Amplitude: magnitude of deviation from initial conditions caused by a disturbance
3. Speed: rate of change of disturbance
4. Scope: number of environmental dimensions that are affected by simultaneous disturbances.

Table 2. Dimensions and typologies of change (Suarez & Oliva, 2005)

Frequency	Amplitude	Speed	Scope	Type of environmental change	Demarcation
low	low	low	low	Regular	
high	low	high	low	Hyperturbulence	
low	high	high	low	Specific shock	
low	high	low	low	Disruptive	
low	high	high	high	Avalanche	

Based upon these dimensions, Suarez and Oliva (2005) derive five types of environmental change (Table 2) with respect to management and organizational adaptation. A one-to-one relationship does not exist between the type of change and amount of regime-level destabilization that occurs. However, it could be generally stated that the higher the frequency, amplitude, speed, and/or scope of the change, the greater the regime-level destabilization is likely to be. Consequently, the type of change experienced by a socio-technical system affects the conditions for transition. It is, therefore, the circumstances or the nature of the change, or both, that distinguish normal change from the transformative (de Haan & Rotmans, 2011).

For as much as destabilization of the regime is necessary for niche breakthrough to occur, (re)stabilization plays an equally important part (Loorbach, 2010). As de Haan and Rotmans (2018) put it, "Transformation is as much about breaking down as it is about building up." Re-stabilization of the regime level can come in a variety of forms, as indicated by the transition patterns and pathways discussed in Section 2.4 in which the regime does or does not adapt. These two concepts are represented by Figures 4 and 5, respectively. In the case of a failed transition, instability continues and, in theory, new windows of opportunity are created for niche-level developments to emerge, thus initiating a new potential stabilization process.

Relating change to re-stabilization is a trickier matter given that the system response to change is unpredictable. For example, a specific shock may lead to quick reactionary measures and swift re-stabilization whereas hyperturbulance may create uncertainty and an unwillingness to (re)act, therefore prolonging re-stabilization. Considering the aforementioned system dynamics, it can therefore be deduced that regime-level destabilization is intensified when multiple regimes undergo transition simultaneously.

Furthermore, the destabilization, change, and re-stabilization of a regime are not the result of one single experiment. The importance of creation and transfer of knowledge and experiences with respect to the development and emergence of niche-regimes was highlighted earlier in Section 2.1. One additional condition captured by both transition theory perspectives is aptly summed up by Raven (2005) who describes regime change as requiring "a long trajectory of many experiments and the emergence and stabilization of a niche level." Another important condition for transition is, thus, time.

2.6 Chapter summary

This chapter has highlighted two perspectives on transition in complex socio-technical systems. Though the focal points of the two perspectives differ, the conditions for transition are generally comparable. In brief, transition occurs as the result of change that destabilizes the dominant regime and subsequent re-stabilization. The extent of destabilization relates to the frequency, amplitude, speed, and scope of changes that occur at any of the three levels, though internal regime-level change is usually negligible. The pressure, tension, and stress at the regime-level caused by such changes results in destabilization, which creates windows of opportunity for viable niche-regimes to break through into and compete with the regime. Various outcomes dependent on the presence or absence of regime adaptation are possible, which in turn dictate the re-stabilization of the regime level and transition pathway.

Although outright transition is unattainable in socio-technical regimes, adaptation and transformation are possible. However, neither can efficiently nor effectively occur in the absence of sufficient stability. Thus, for a regime to progress further along its transition pathway, the stability of the regime must first return to a certain acceptable level. Because of the nature of socio-technical regimes and regardless of the source and extent of change, it is the actors and actor alliances that ultimately shape and direct the transition path.

3. Building industry transition

3.1 Building industry as a socio-technical regime

3.1.1 Characteristics

The building industry is a mature industry that holds strongly to its conventions (Takim, Harris, & Nawawi, 2013; Ye et al., 2009). As it currently exists, the building industry is largely supply-driven despite having little control over demand-side factors placed upon it (Davidson, 2013). Furthermore, the building industry is a highly stable, which implies that technologies and market conditions are tend to change slowly (Von Tunzelmann & Acha, 2009). Moreover, it is representative of a socio-technical system. This system can be characterized as a project-based "multi-industry" (Davidson, 2013) that relies upon temporary, project-based supply-side organizations (Bakker, 2010) to execute building projects that fulfill the requirements and expectations of demand-side actors. This heterogeneous nature results in considerable fragmentation within the industry, a consequence of which is the industry's notoriety for being generally inefficient (Ahbabi & Alshawi, 2015; Becerik-Gerber & Kensek, 2009; Ozorhon et al., 2010). The building industry is also distinguished by its generally risk-averse stance, strong values represented by the "iron triangle" of time, cost, and quality (Davis, 2017; Ye et al., 2009), and a tendency to stick to the status quo.

Taken as a whole, the characteristics of the building can be further associated with and reflected by a strong preference and tendency toward maintaining the status quo. Unsurprisingly therefore, the building industry is frequently characterized as being "low-technology" (Von Tunzelmann & Acha, 2009) and reluctant to innovate (Ozorhon et al., 2010; Sepasgozar & Bernold, 2012). In general, the building industry does not regard innovation as a productive activity because it requires the development and new knowledge and skills as well as new processes and systems (Davidson, 2013). Combined, these characteristics have led the building industry to lag significantly behind other industries (Dutta, 2015) When innovation does occur in the building industry, the process is generally slow and inefficient (Davidson, 2013), not only in terms of technology, but also in practices and processes. That the industry has not experienced appreciable change over recent decades (Egan, 1998) is testament to the industry's conventional stronghold.

3.1.2 Actors

As a socio-technical system, the building industry is also characterized by way of its constituent actors and actor networks. The building industry involves an elaborate variety of actors. Each brings with it a wide range of interests, requirements, and concerns (Ye et al., 2009), which are derived from unique motives and intentions that can be compatible, contradictory, or conflicting with those of other actors. Actors also bring with them a wide range of knowledge, skills, and other resources (Geels, 2002). The availability of these resources is a contributing factor to innovation in socio-technical systems (Loorbach & Rotmans, 2010). In order to provide structure when addressing these actors, this research groups them into three categories: demand-side, supply-side, and external.

Within the building industry, client organizations are a principle demand-side actor. They can vary in size and orientation. In smaller organizations, the building client may be a single person with considerable direct control. This person must therefore fulfill all roles, and often works with the aid of one or more external advisors. In the case of larger organizations, the building client is often characterized by a larger body consisting of various professionals internal to the organization. They also typically have a larger amount of in-house expertise, and roles are allocated based on individual qualifications.

Larger organizations are also more likely to be repeat customers, which provides them with knowledge derived from previous projects.

The supply-side is comprised of all stakeholders with the exception of the building owner. The supply-side represents the collective knowledge of the building industry. In general, this knowledge is technical and practice-oriented in nature. This collective knowledge can be broken down and attributed to the stakeholder groups, which highlights group-specific specializations. Further, in order for a group to be specialized, the individual stakeholders must have certain skills and qualifications. From all of this it becomes possible to more clearly and appropriately allocate roles to individual stakeholders.

Lastly, external stakeholders, such as governmental organizations, meanwhile affect similar power and influence, often through policy enacted at the landscape level. Because of the building industry's significant contribution to the economy, external actors also have a vested interest in its standing. Their interests also include safety, health and welfare, and increasingly environmental performance. This is especially true of governmental organizations, which are working towards compliance with the European sustainable development goals and the Paris Agreement. Another important group of external stakeholders are those affiliated with financial institutions. For the purposes of this research, however, the role of financial institutions is not investigated.

3.1.3 Innovation in the building industry

Before discussing specific developments and innovations or employing the multi-level perspective to evaluate the transition and transformation of the industry, it is crucial to first define innovation as it relates to the building industry. One commonly referenced definition is provided by Slaughter (1998):

"Innovation is the actual use of a nontrivial change and improvement in a process, product or system that is novel to the institution developing the change."

Slaughter (1998) also advances her own definition adding that innovation can result in "substantive changes" to standard practice. Another definition according to Davidson's (2013) "broad-scope view" of innovation states:

"Innovation in construction is viewed specifically in terms of who initiates the processes of innovation and why, emphasizing their impact on other participants in the building process from project initiation to project hand-over."

While Davidson's definition is highly relevant, it is also reflective of the project-focused nature of the building industry wherein little attention is paid to post-construction phases of the building lifecycle. Therefore, the scope of Davidson's definition is altered to include all lifecycle phases for the purposes of this research. Another notable omission from both of these definitions is risk. which is acknowledged as being a highly significant when defining innovation (Murphy et al., 2011).

In their research, Murphy et al. (2011) extract five key elements that they consider sufficient for identifying innovation in the building industry. These elements are:

1) Newness or uniqueness of concept
2) First use within the industry
3) Ability to effect change to standard practice
4) Derived benefits for all stakeholders
5) Associated risk

While sufficient to identify innovation, it could be argued that these elements do not appear capture the breadth of innovation. This is especially true of socio-organization aspects. For instance, no mention is made of the perception of the innovation or (behavioral) intent to use a particular innovation (Orlikowski & Gash, 1994; Sepasgozar & Bernold, 2012).

With respect to the innovation processes, the building industry is inherently different to other industries due to its traditional nature. The findings of Davidson (2013) concisely summarize this concept as follows: "The processes of innovation in construction require that the innovator (possibly starting from a narrow idea or opportunity) broaden his/her view to take into account the impacts of the intended innovation on the priorities of other stakeholders, in an iterative process. In other words, orchestrated organizational changes must accompany – if not precede – technical innovation."

3.2 Developments impacting the building industry

The importance of a solid understanding of the innovation context has already been addressed in previous sections. This section addresses this important research component by highlighting key developments at the landscape, regime, and niche levels that shape the context of this research topic.

3.2.1 Landscape-level developments

At present, the landscape-level changes stem from swift growth and expansion of pervasive developments ranging from globalization and digitization to major technological advances and reactionary stances against climate change. These developments, which are significant enough when considered in isolation, are even more provocative when considered as highly complementary forces of change. Landscape-level developments are resulting in a growing avalanche of change, the cumulative effect of which is now beginning to culminate in significant destabilization of the regime-level from the top down. This research highlights concurrent developments in data and digitization as well as sustainability and environmental welfare.

Data and digitization has been influential in the building industry. Combined with building information modeling, a niche-regime and focal point of this research that will be discussed at length later, the digitization of building information is increasingly changing actor relationships with technology and the expectations they have of it (Whyte & Hartmann, 2017). Consequently, both supply- and demand-side actors are redefining long-established roles and responsibilities and pursuing new avenues of collaboration and integration.

Sustainability and environmental welfare also play an increasingly prominent role, with implications that affect all industries in (nearly) every nation. As a result of the Paris Agreement of 2016, numerous national initiatives have been implemented with the hope of mitigating the impacts of climate change. These efforts are reinforced further by the European Union Sustainable Development Goals (SDGs), which require the policy of all member states to be reflective of these goals by 2030. Furthermore, the overarching conclusion drawn in the 2017 Emissions Gap Report by UN Environment (UNEP, 2017) was that an urgent need exists for accelerated, short-term action and enhanced, long-term ambition in order to fulfill the mission and goals set out by the Paris Agreement and SDGs. These landscape-level changes and resulting demonstrations of national commitment to improve sustainability, environmental and ecological conditions, and the use of natural resources have substantial implications for the building industry. Moreover, given that the construction and use of buildings is a primary target for improvements, these developments mark the arrival of the building industry at a crossroads and raises questions about its future trajectory. Uncertainty and doubt are also being piqued by increasing interest in circularity. Many countries have already taken first steps toward investigating the potential shift towards a (more) circular economy. Thus, it is reasonable to assume that landscape-level change is likely to be imposed in the near future, the implications of which will have massive consequences for the building industry that will undoubtedly contribute to the destabilization of the industry regi

3.2.2 Regime-level developments

The building industry is undergoing a series of procedural, organizational, and technological transformations in an attempt to respond to landscape-level developments. The industry has already made notable shifts towards adapting to and adopting proven trends. With this, however, has come the realization that the exiting, traditional foundation of the industry is incompatible. Clashes between old and new technology can arise, existing processes hinder or even hurt progress, and the people and culture within companies sometimes comes into conflict with what needs to be done to allow the "new" to thrive.

Although transformation within an incumbent regime is negligible compared to that of niche-innovation breakthrough and adoption, the dominant stream in the building industry still experiences ebbs and flows. Because changes within the regime-level are most often the result of minor pressures, tensions, and stress from either the landscape- or niche-level that nudge at the socio-technical regime, their origins tend to be indistinguishable. Notwithstanding, minor changes within the regime-level and a tendency for change to accrue over time can eventually result in a more significant change (Geels, 2002) that would be classified as a transformation pathway according to the typology of de Haan and Rotmans (2011).

A good example of this phenomenon is changing values, which are often reflected in the form of trends. Trends offer valuable insights into what stakeholders perceive as factors, concerns, and ideas for possible change at a given point in time (Ye et al., 2009).

In a study by Ye et al. (2009), interviews with both supply- and demand-side actors in EU countries, namely Spain, Turkey, the Netherlands, Germany, Finland and the UK, revealed important trends within the building industry (Table 3). The findings of this study indicate that key actors are looking beyond the conventional "iron triangle" to explore and seek out other types of added value. The demand-side is leading this trend, focusing on values such as productivity, sustainability, energy and resource efficiency, flexibility, and comfort (Ye et al., 2009).

Table 3. Important building industry trends in six groups (Ye et al., 2009)

Technological/building process	Ecological/environment	Social/cultural/demographical
1. New contract models (PPP)	1. Low-energy buildings	1. Social added value
2. New building processes (procurement)	2. Focus on climate changes	2. Increase smaller / single dwellings
3. Reconstruction, modernisation of old buildings	3. Increasing focus on energy efficiency	3. Improved knowledge infrastructure
Building functionality	Economic/financial	Regulations/political
1. Flexible buildings to adapt to changes of use	1. Focus on life cycle cost	1. Changes in the legislation
2. New solutions to existing building stock	2. Focus on energy management/energy costs	2. Quality standards & certificates
3. Multi-purpose/multi-use	3. Increase flexibility & reduce costs	3. Litigious society - impact on buildings

Despite nearly ten years having elapsed since the study was published, these trends have largely remained subordinate to the dominant stream. This provides further evidence of the staying power of the incumbent building industry regime and the challenges hopeful niche-regime face even when considered as an important industry trends with considerable potential. Despite the slowness of change, these trends indicate that windows of opportunity do exist within the regime-level.

3.2.3 Niche-level developments

In addition to impending destabilitory forces from the landscape-level, the traditional foundations of the longstanding industry regime are also being challenged by an upsurge of disruptive niche-level developments in the form of innovations. Niche-level developments have been growing in number and prominence as a result of new windows of opportunity that have been created in recent decades. Given the increasing level of instability at the regime-level, some newer niche-regimes, such as building information modeling and lifecycle-orientated building approaches, have already succeeded and are currently being embedded into the building industry's common practices. Though each development has a distinct origin, many have merged to form larger and more influential forces of change.

Although there are numerous niche-level developments, four themes of major, increasingly intertwined niche-regime developments are highlighted here: procurement, process, approach, and technology. Additionally, the developments described here can all be characterized as having that moved from lesser niche-level innovations to niche-regimes.

One development impacting the industry reflective change in both procurement and process is the rise of (more) collaborative forms of building procurement, such as integrated building contracts. The American Institute of Architects (AIA, 2007) defines integrated building contracting, otherwise known as integrated project delivery (IPD), as "a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively connects all the players in order to optimize project results, improve project performance, and maximize value and efficiency throughout the entire project life cycle." Increased collaboration on building projects has helped close some gaps and promote collaboration (Kent & Becerik-Gerber, 2010). One notable change is the increased involvement of downstream stakeholders during earlier project phases, especially during the early design phase. Despite this, many supply-side imperfections remain. These new collaborative forms of procurement represent a shift away from the temporary organizational forms typical of the traditional building industry. Despite a growth in popularity, the building industry still shows a preference for conventional procurement approaches due in part to a fear of additional risk and increased potential for liabilities (Chong et al., 2017).

Niche-level developments under the theme "approach" are affiliated with sustainable design and construction principles, such as Lean and integrated product/project development (IPD). Lean is a management-based approach focused on waste minimization and collaborative processed that work together to achieve maximum value. As such, Lean has much in common with IPD and other building processes. While Lean principles do take project lifecycles into consideration, they are typically limited to the traditional sense of a "project" wherein post-construction phases like use, maintenance, and operation tend to be excluded.

Another approach-based development seeking to fill these gaps, and another key feature of this research, is the development of lifecycle-orientated approaches to buildings. This cradle-to-grave mentality promotes consideration of all project phases from project conception to delivery of a completed building in addition to the use, maintenance, operation, any eventual reprogramming, and eventual decommissioning (Eadie et al., 2013). As a result of investigation into lifecycle-oriented building approaches, research has expanded to include other aspects of the building lifecycle, such as the maintenance and operation phases.

The main distinction between traditional building approaches and lifecycle-oriented approaches is the breadth of focus. Traditional projects tend to see a building project just as the phases leading up to the handover of a completed building to a client. While the design and construction are crucial in any building process, traditional approaches relegate the importance of the use, maintenance, and operation of buildings. This is of concern given that the majority of costs associated with buildings are occurred during these phases. In contrast, lifecycle-oriented approaches promote the consideration of all phases of a building's lifecycle from inception through to use and eventual demolition. It also takes the relationship between phases into consideration. Newer, more holistic approaches have become increasingly popular within the industry, especially amongst BCOs and other demand-side actors. As the popularity of lifecycle-oriented building approaches increases, the term has become a sort of catch all for a variety of ongoing procurement, process, and perspective developments. Although lifecycle-oriented approaches to building offer many benefits, they are more complicated to implement than traditional approaches and are still largely unfamiliar within the industry due to infrequent use.

The fourth theme, technology, is an increasingly growing area for the building industry. In this research, special focus is placed on building information modeling (BIM). BIM is arguably the most important innovation in the building industry today. Though it has existed in some form since the 1970s, it was not until the last ten to fifteen years that the awareness of BIM increased. BIM was first conceived as technological innovation. In years thereafter, BIM has evolved into an extremely powerful niche-regime with consequences for the three other niche-level development themes. This niche-regime innovation will be discussed in more depth in Chapter 4.

3.3 Multi-level perspective representation of building industry developments

This chapter has already addressed the major characteristics of the building industry as a socio-technical regime and developments occurring at the landscape, regime, and niche levels. It has also expounded upon innovation as it pertains to the building industry. With this information having been evaluated, it was possible move forward with the characterization of the transition and transformation of the building industry.

The first step in this task was to employ the multi-level perspective introduced by Geels (2002, 2004, 2007) to provide a visual overview of the ongoing transition and transformation of the building industry. In order to capture the aforementioned developments in the landscape, regime, and niche levels, the demarcations associated with the five typologies of change as introduced by Suarez and Oliva (2005) were also employed. Although their typology is with respect to environmental change, this research makes liberal use of the demarcations, applying them to all levels of the multi-level perspective. The resulting figure (Fig. 6) provides a visualization of the dynamic, multi-level perspective of the transition and transformation of the building industry.

The second step, discussed in Section 3.4, was to identify and report on the transition pathways. In addition to the prior exploration, Figure 6 proved a useful tool for the analysis and identification of the historical, current, and potential future transition pathway(s). Based upon the results, a final description characterizing the transition and transformation of the building industry was presented.

For this step, the transition pathway typologies of Geels et al. (2016) and de Haan and Rotmans (2011) were utilized. Because the historical transformation was less nuanced than at present, it was justifiable to use the simpler transition pathway classification proposed by Geels et al. (2016) to characterize the historical transition and transformation of the building, whereas the typologies of de Haan and Rotmans (2011) provided additional nuance necessary to describe the current situation.

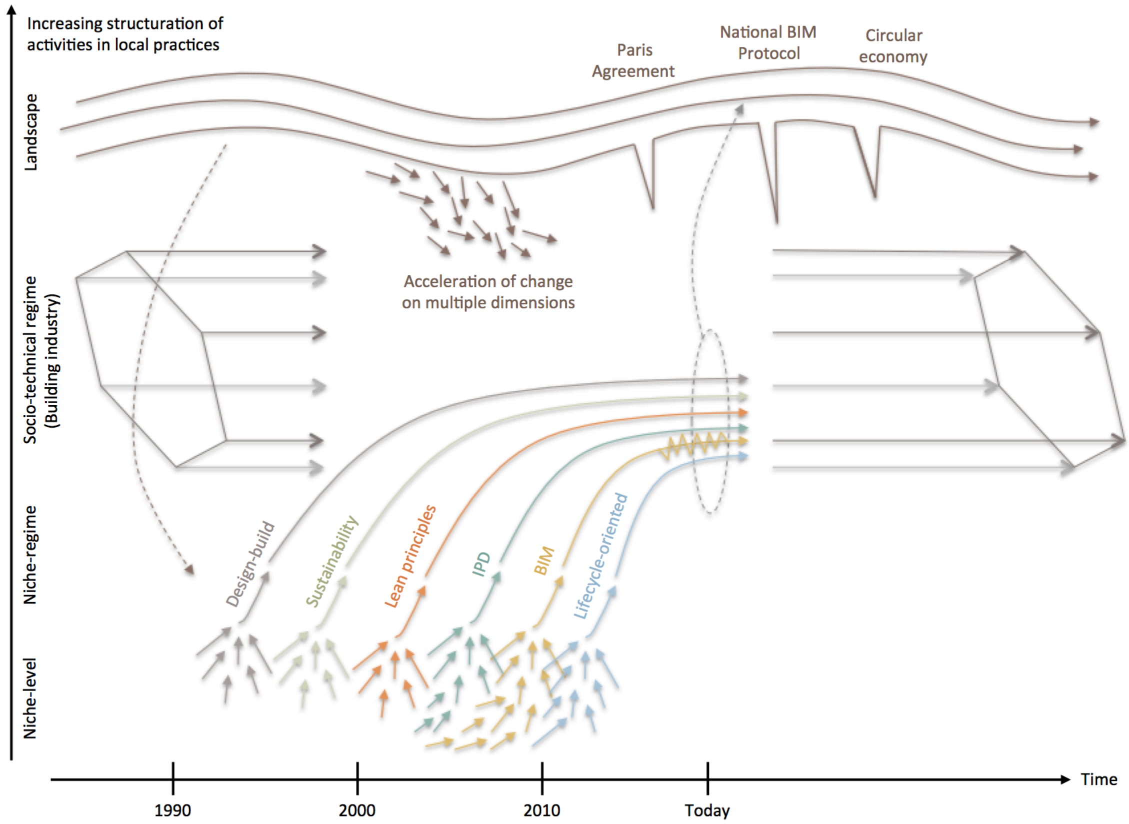


Figure 6: A dynamic, multi-level perspective of transitions and transformation in the building industry (adapted from Geels, 2007 and Suarez & Olivia, 2005)

The following developments are addressed within Figure 6:

- An avalanche of change from the landscape-level due to overarching trends like digitization and sustainability
- Specific shocks resulting from major policy changes from the landscape-level
- Landscape-level influences that stimulate new niche-level developments
- Upsurge of "avalanche" niche-level developments
- Parallel development of niche-regimes
- Niche-regimes just shy of full breakthrough and integration into the socio-technical regime level
- Hyperturbulence of BIM niche-regime due to continuous evolution and added functionality to meet supply- and demand-side needs and requirements
- Uncertainty of future developments and the influence they will have on the landscape-level
- Decrease in time elapsed between creation of a new niche and it becoming a niche-regime poised for breakthrough

3.4 Current transition trajectory

Historically, the building industry regime was highly stable, which has led to deeply embedded values, practices, processes, and approaches that carry on to this day. Since the 1980s, however, this incumbent regime has been increasingly confronted by developments at the landscape, regime, and niche levels. The past two decades have displayed particularly influential developments with considerable increases in the frequency, amplitude, speed, and scope of changes (Suarez & Oliva, 2005) felt by the socio-technical building industry regime. During this period, the state of the building industry went from a well-established and stable dominant regime with a predominantly reproductive transition pathway to a state of increasing tension and pressure that could be categorized as reconfiguration.

Taken together, transition of the building industry in the last half century is characteristic of what Geels et al. (2016) dub "shifts between pathways." A new era of sustainability and long-term thinking is burgeoning, which needs to transcend into the way buildings are conceived, designed, constructed, and used. A new way of thinking and working is emerging to facilitate these needs, but the existing socio-technical system and the regime as it exists cannot effectively support it. Consequently, it has become increasingly apparent that the building industry is undergoing a transition, the rate of which can be expected to quicken and intensify.

Characterizing the future trajectory of transition in the building industry is complex. Up to now neither external conditions nor ebb and flow within the regime-level have created sufficient change to result in destabilization of the incumbent socio-technical regime. Thus, the conditions to stimulate significant evolution or transition are not yet present, though they do appear to be strengthening (Thelen, 2003). The changes that have occurred up to this point have brought with them an increase in complexity, both at the industry regime level and also at the project level. Complexity magnifies the impact of change and the resulting destabilization. As such longstanding issues within the industry derived from its fragmented nature are posing new problems with respect to, among other things, decision-making processes, coordination, and collaboration (Ye et al., 2009).

Referring back to the transition pathways put forward by de Haan and Rotmans (2011) (Figs. 4 & 5), many of the typologies can be eliminated. This research excludes the possibility of a failed transition, and grounds have been set predicting that regime adaptation will occur. What is less clear is the direction from which change will come. Considering that the building industry is currently undergoing significant influence from both the landscape and niche levels, it can be deduced that the influence is not purely top-down or bottom-up. Therefore, neither "radical reform" nor "reconfiguration" is characteristic of the ongoing transition. This leaves two possibilities: the squeezed (top-down and bottom-up) teleological pathway and the adaption dominated transformation pathway.

Recapping these two typologies, teleological transition pathways are "the result of a regime adapting to changed circumstances not by reforming itself but allowing outside influences to reconstellate structures and cultures and simultaneously incorporating novel functioning in these processes" (de Haan & Rotmans, 2011). In transformation transition pathways, transformation occurs within the regime itself via an ongoing evolutionary process of adaption. In this process, the regime responds to tensions and stress by changing itself in a self-steering process so as to meet needs and demands once more. It also frequently involves the absorption of niches or co-evolution with the niche-level (de Haan & Rotmans, 2018).

On the one hand, a teleological pathway appears to be applicable. The incumbent regime is beginning to waver, especially as landscape- and niche-level developments come closer to a destabilizing harmony. Developments in BIM and lifecycle-oriented approaches in particular are nearly in alignment with landscape-level developments. On the other hand, a well-organized driving force external to the regime has yet to materialize. For example, although the aforementioned niche-regimes have experienced individual successes, it has proven difficult for a larger niche featuring two or more merged niche-regime innovation to take form. Consequently, it is most likely that the existing regime will not be replaced. Rather, the building industry seems increasingly willing to undergo adaptation, which is in agreement with the transformation pathway. However, complete transformation from within the regime itself is also doubtful because of the industry's supply-demand relationship, risk-averse nature, and preference for stability. Furthermore, this is in keeping with de Haan and Rotmans' (2011) stance that internally induced change is insufficient to produce a "proper transition". As such, both the teleological and transformation transition pathways have their merits and faults. Thus, the current transition in the building industry can be best characterized simply as dynamic and involving all three levels. With respect to the future, the transition is likely to be complex, non-linear, and distorted by uncertainty. The element of time is also a considerable variable, especially given the dawdling history of transition in this particular dominant regime.

3.5 Insufficient conditions for transition

Following in line with transition theory, the harmonization of these landscape- and niche-level developments has begun to destabilize the incumbent building industry regime. As a result, new windows of opportunity continue to open for niche-regimes to break through and start competing against what was once a stable, long-established regime. Despite this, the conditions to stimulate significant evolution or transition are not yet present, though they do appear to be strengthening (Thelen, 2003).

Although theory suggests that successful niche breakthroughs and amalgamation with the transition pathway stand the chance of giving way to new, stabilizing socio-technical configurations (Fuenfschilling & Truffer, 2014), the reality of the building industry portrays a more complicated set of circumstances. Furthermore, the mounting complexity and instability at the regime level makes the adoption and implementation of new technology markedly more challenging (Sepasgozar & Bernold, 2012). Furthermore, the building industry is not only quite resistant and averse to change but also poorly suited to pursue change even when desired. Further complicating the occurrence of innovation in the building industry is that innovation tends to be driven by demand-side (e.g. client) needs and requirements (Ozorhon et al., 2010; Ye et al., 2009). At first, this seems contradictory given that the industry is largely supply-driven. However, conventions dictated by the well-established mainstream result in a tendency to preclude innovation unless it is in favor of supply-side actors.

This is not to say, however, that innovation does not occur. Although the building industry has earned a reputation for being "low-technology" (Von Tunzelmann & Acha, 2009) and reluctant to innovate (Ozorhon et al., 2010; Sepasgozar & Bernold, 2012), these are characteristics applicable to the industry regime as a whole. Individual projects, however, can be considered as protective spaces in which innovation can occur. In general, it is individual exemplary building projects that exhibit considerable innovation (Barrett, Abbott, Ruddock, & Sexton, 2007). A caveat for innovation in the building industry is, therefore, that innovation occurs on individual projects, which are temporal in nature. Moreover, the knowledge and experiences gained in the execution of such innovation is rarely diffused due to poor knowledge transfer processes, industry fragmentation, and the frequent desire of companies to withhold proprietary information (Artto et al., 2008; Davidson, 2013; Koutamanis, 2017). As such, innovation in the building industry tends to occur in the form of ad-hoc, localized experiments. In failing to create a network and develop structuration, innovations struggle to gain the traction necessary in order to evolve into niche-regimes.

Because of these and other difficulties niche-regime breakthrough and adoption can be significantly hampered. These conditions could, for instance, produce a situation in which a window of opportunity exists for breakthrough into the regime-level without a line-up of sufficiently competitive niche-regimes to take advantage of it. In another scenario, an underdeveloped niche-level innovation may emerge only to fail in its competition with the dominant regime due to unpreparedness. This type of failure is unfortunate for otherwise promising innovations as failure causes them to fall victim to negative opinion, thus reducing or eliminating their change at uptake in the regime-level. In short, without viable niche-regimes there is no competition, and therefore no contribution to regime destabilization and diminished conditions for transition. Conversely, windows of opportunity may not appear altogether. The fragmented nature of the building industry in particular makes it difficult for actors to discern benefits of an innovation, which in turn diminishes the motivation of actors to pursue an innovation. Without this motive and intent, actor alliances and their respective resources cannot come together (Davidson, 2013). As such, niche-regimes cannot come into being.

3.6 Chapter summary

Although the building industry needs to transition, it reacts poorly to change and current innovation processes do not support the creation of viable niche-regimes. Conditions for stimulating transition, however, require sufficiently competitive niche-regimes, a lack of which is problematic as it can in turn suppress transition. Furthermore, the current state of the building industry can be best characterized as dynamic and involving all three levels. The trajectory of the transition to a more sustainable building industry is likely to be complex, non-linear, and distorted by uncertainty. The element of time is also a considerable variable, especially given the dawdling history of transition in this particular dominant regime. In short, a ponderous dilemma has arisen that the conditions for change are insufficient to drive effective and efficient transition to a more sustainable building industry.

Due to the critical importance of niche-level developments and their influence on regime transition, it is worthwhile to explore what could be done to improve conditions for the transition to a more sustainable building industry. Given the potential of BIM and the pressing need for viable niche-regimes in order to stimulate transition, it prudent to explore how this particular niche-regime could contribute to the transition to a more sustainable building industry. The proceeding chapters aim to contribute to this body of knowledge and address questions posed by this research.

4. Adoption of BIM by building client organizations

4.1 Combining perspectives

Two transition theory perspectives were addressed in Chapter 2, each with a different emphasis. In the multi-level perspective (MLP), transition is viewed as a dynamic, iterative and interwoven process occurring within and between the landscape, regime, and niche levels that occurs over time. The MLP emphasizes the role of developments and inter-level influence, focusing predominantly on how niche-level innovation experiments arise and bring about changes that stimulate regime-level transition. The extent of these factors is dependent upon the timing and nature of interactions between the three levels. In the second perspective discussed in Section 2.3, transition is viewed as a consequence of actions and interactions taken by actors that assume a transformative role. In this perspective, initiatives, networks, and movements generated by actor alliances shape and direct the transition process in order to bring about systematic change.

Both perspectives have their strengths and flaws. Neither, however, is wrong. As it happens, the two perspectives are complementary. Innovation cannot occur without actor involvement, so combining the two transition perspectives serves as a convenient way of investigating how innovation and actor agency work together to promote regime transition. More specifically, these two perspectives are used in this research to explore the relationship between BIM and building client organizations and their potential joint contribution to the transition to a more sustainable building industry.

Even with two transition theory perspectives from Geels (2002) and de Haan and Rotmans (2018), it can still be challenging to paint a clear picture of how innovation and actor involvement can influence the necessary transition. This is especially true when investigating transition in the building industry since only limited research has been conducted on that topic (Sepasgozar & Bernold, 2012). One way of addressing these problems is by taking a systems innovation approach.

According to Davidson (2013), innovation that affects many stakeholders requires a systems approach. BIM is a perfect example of such an innovation as it affects and is affected by the influence of many actors. Due to the complexity and interconnectedness of socio-technical systems, it is not possible to follow a "normal" innovation pathway. Because the building industry is a socio-technical system, this research therefore adopts a systems perspective, and more specifically one with an innovation focus. The innovation system approach promotes a more holistic perspective of the structures supporting innovation (e.g. actors and institutions) (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007). According to that approach, innovation should be seen as "as an evolutionary, non-linear and interactive process requiring intensive communication and collaboration among different actors, both within firms as well as between firms and other organizations" (Edquist, 1997). Innovation is thus an individual and a collective process. According to Hekkert and Negro (2009), the primary goal of an innovation system is "to contribute to the development and diffusion of innovations."

The technological innovation systems (TIS) perspective augments the innovation system approach through the addition of system dynamics, such as development, diffusion, and implementation. TIS can be defined as "a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology" (Carlsson & Stankiewicz, 1991).

Taken together, the two transition theory perspectives and TIS contribute a structure and holistic approach that enables qualitative analysis of innovation-driven regime transition supported by key actors. For these reasons, this research posits building client organizations and their adoption of BIM on building projects as an innovation system that is capable of invoking change that contributes to industry transition. The remainder of this chapter provides arguments for how the adoption of BIM by building client organizations could contribute to the transition to a more sustainable building industry.

4.2 Literature study methodology

For the literature study, two rounds of searches were conducted. The initial search was based on the following search terms:

- "BIM and building owner"
- "BIM and building client"
- "BIM and maintenance and operation"
- "BIM and facility management"
- "BIM and building lifecycle"

Within these searches, literature was selected based on relevance to the research, focus on process and/or socio-organizational aspects of BIM, and newness of the publication. Following the initial searches, the accumulated literature was inspected. The initial searches and respective inspection raised awareness of gaps in the literature collected in the first search. Although an in depth analysis was not performed at this point to prevent premature focus on any particular aspect, two gaps became evident.

Firstly, some inter-conceptual relationships have been more heavily researched than others. Considerable attention has been placed on the interrelation of BIM and the maintenance, use, and operation aspects of a building's lifecycle. Conversely, very little could be found in academic literature relating BIM and the building owner. It became apparent that academic researchers tend to focus on the interrelation of BIM and the supply-side much more often than BIM and the demand-side.

Secondly, there is only a limited pool of available literature specifically addressing process and socio-organizational aspects of BIM. As a result of this deficit, it became necessary to broaden the search to include technology-focused BIM literature that also made reference to process and socio-organizational factors. It was also determined that non-BIM oriented literature could also be included as long as it had a focus on process and/or socio-organizational aspects of building projects. These transposed factors were later combined with literature that does address building client organizations directly in order to develop a preliminary outline of factors. Because this additional literature contained surplus information, it was important and necessary that the literature study take into consideration only information relevant to this research and its respective boundary. Information gathered from this more general literature was later reinterpreted within the contexts of BIM, integrated building projects, and lifecycle orientation.

The inspection and resulting insights led to subsequent searches in which literature was selected more "organically" in a "snowballing" process. This methodological decision is believed to have had a beneficial impact by creating room for new findings, deductions, and connections rather than relying solely upon previous works, thus increasing the originality of the research. Literature continued to be sourced until a point of saturation was reached. Once a point of saturation was reached, analysis of the collected literature began. Upon completion of the literature analysis the results were synthesized and reported.

4.3 Building information modeling (BIM)

Citing Penttilä (2006), Succar (2009) defines BIM as "a set of interacting policies, processes and technologies generating a 'methodology to manage the essential building design and project data in digital format throughout the building's life-cycle'." Similarly, Hardin and McCool (2015) describe BIM as having three fundamental components: technology, process, and behavior. A third akin perspective is found in the research of Nepal, Jupp, and Aibinu (2014) which identifies technology, organization/people, and process as three main areas of measurement useful for the evaluation of BIM-enabled projects. They also augment it by adding the context of a building project as a fourth element that encompasses the three fundamental components. From this, it is clear that "technology" and "process" are clearly identified facets of BIM. Although a pure consensus is lacking in the third facet, it is possible to make a general deduction for the sake of this research. The three researchers described the third facet as policies, behavior, or organization/people. Though the terminology of the third facet points in different directions, there is an important commonality. All three terms are components of a social system, which includes a wide variety of interrelationships between individuals, groups, and institutions. Because of social system is quite broad, the three BIM facets will be represented in this research as: technology, process, and socio-organizational behavior, and the contextual element is also addressed.

BIM represents both a radical emerging technological and a procedural shift within the building industry (Succar et al., 2007). BIM is a rapidly evolving innovation within the building industry, thus rendering it an unstable and transient technology in a perpetual state of adaptation and change (Poirier et al., 2017; Whyte & Hartmann, 2017). As such, BIM is capable of causing profound disruption in an otherwise slow-to-adapt and rather traditional industry. Today, BIM is synonymous with the new era of construction, and its penetration within the industry goes to show why that is. Based on the current trajectory, the rapid adoption rate of BIM suggests that BIM is expected to reach a market saturation point in near future (Ghaffarianhoseini et al., 2017). The pace continues not only to quicken, but also includes an increasing variety of practitioners that are choosing to adopt BIM. BIM adoption is due largely to the range of benefits associated with using BIM on building projects. Benefits include interoperability capabilities, early building information capture, use throughout the building lifecycle, integrated procurement, improved cost control mechanisms, reduced conflict and project team benefits (Ghaffarianhoseini et al., 2017). Some of these benefits have already been seen in practice while other benefits of BIM are still just theoretical propositions.

Adoption rates within the regime continue to climb and there is near constant development of new functionalities. In practice, BIM can now be found in most reputable firms and has become a frequently used tool in the design and construction phases of a building's lifecycle. If current trends develop further, it can be expected that BIM will permeate into related fields like facility operation and management (Atkin & Bildsten, 2017; Xu et al., 2014). Furthermore, new research has begun exploring the possible uses for BIM in the renovation and demolition phases (Akinade et al., 2017), though this research area is still quite limited.

Supply-side adoption of BIM is quickly approaching a critical mass and the demand is only expected to grow and diversify (Eastman et al., 2011; Hardin & McCool, 2015). As such, BIM can hardly be considered as a new phenomenon anymore, however the saturation is still not great enough to consider it as being fully emerged and embedded within the building industry regime. Regardless, it is not a question of if BIM will take hold, but rather how and to what extent it will be implemented.

The added value of BIM to date has largely been attributed to its use in design and pre-construction phases. According to research by Eadie et al. (2013), results identified that, in the UK, BIM use is concentrated in the design and pre-construction stages at roughly 55 and 52 percent, respectively. Use during the construction stage came in at approximately 35 percent. Although BIM is still mainly a design and construction oriented tool, its benefits do not stop there. Research suggests that implementing BIM across a building's entire life cycle can result in a wealth of potential benefits (Eadie et al., 2013; Hallberg & Tarandi, 2011; Korpela et al., 2015). This is especially true for the maintenance and operation phase, which currently sees only about 9 percent of all BIM use (Eadie et al., 2013).

Recently, awareness of BIM's potential value for facility management (FM), building maintenance and operation (M&O), as well as asset and portfolio management has been steadily increasing (Lu et al., 2017). Currently, practical applications of such BIM use are limited. In the few cases where BIM has been used for FM or M&O, efforts are in their infancy and quite experimental (Wetzel & Thabet, 2015). This piqued interest, however, demonstrates new developments in demands from actors such as building client organizations.

Recalling the multi-level perspective and developments within the building industry, lifecycle-oriented building approaches and BIM have been developing independently for about two decades. Given that lifecycle-oriented building approaches and building information modeling both offer a variety of contributions in response to the landscape-level developments, it reasonable to believe that their uptake in the socio-technical regime would promote improve conditions for transition. It is therefore in the best interest of building industry stakeholders to promote and strengthen further development and merging of these two innovations. Accordingly, this research promotes the formation of a merged niche-regime as a means of promoting the alignment and co-evolution of current, prominent developments. For the purpose of this research, a proxy is given to this merged niche-regime, namely lifecycle-oriented BIM use on building projects.

4.4 Building client organizations (BCOs)

One study indicates that of all the actors involved in a building project, building clients and facility managers are poised to reap the most financial benefits when BIM is implemented (Eadie et al., 2013). A more recent study investigating the benefits of BIM for building owners concluded that although BCOs are already benefiting from design phase BIM implementation, in which they are only indirectly involved, the full value of BIM is yet to be captured across the entire building lifecycle (Cavka et al., 2017).

Building client organizations are increasingly interested in incorporating BIM in their projects. Some examples of BIM benefits specific to building owners are provided in the book by Eastman et al. (2011). Owners can use BIM to:

- Increase building performance
- Reduce the financial risk
- Shorten project schedule
- Obtain reliable and accurate cost estimates
- Assure program compliance

4.4.1 BCO typologies

Client orientations can be generically categorized as falling into the public, semi-public, or private sector. The orientation of a client organization is a determinant factor of the intrinsic motives and interests, which has direct ramifications for its role, power, and influence within the socio-technical system. In general, an organization's mission and values correspond its motives and interests. These factors play an important role as they ultimately shape the strategy of a client organization, which in turn predicates the client organization's strategic goals, targets, and performance measures.

With respect to motives and interests, the main distinction between these categories lies in the private sector's profit driven incentive and the (semi-)public sector's focus on public welfare and the common good. This is not to say that public and private motives and interests are mutually exclusive. Private sectors can also work towards increasing public welfare, for instance. Given the considerable differences in motives and interests between the public and private ends of the spectrum, this research excludes private client organizations. Additionally, client organization size is taken into the scoping consideration. Because smaller client organizations tend to have less experience and are less likely to be repeat customers, this research choses to exclude small and medium size client organizations. Accordingly, the scope of this research includes only large-scale public and semi-public building client organizations, and refers to them jointly as building client organizations (BCOs).

A further distinction can be made by addressing large-scale building client organizations that have a vested interest and responsibility for ownership, maintenance, and operation. This type of BCO is distinct because of its simultaneous supply- and demand-side orientation. This characteristic makes it such that large-scale BCOs are more complex than less diversified demand-side stakeholders. A large-scale BCO typically has multiple vested interests, expectations, and requirements. Also, because of their duality, they tend to have a wider, and often stronger, influence compared to a strictly-demand side stakeholder. This is a considerable difference as a large-scale BCO has power and interest spread throughout the entire building lifecycle. As a result of this broader involvement, they can, in general, be regarded as having a better understanding and regard for the value of inter-phase coordination, and are therefore more likely to see the benefits of implementing BIM across the various lifecycle stages of a building. Thus, just as BIM has greater potential when implemented on integrated building projects, it can be reasoned that the use of BIM is more likely to be maximized when a large-scale BCO is the dominant demand-side stakeholder.

There is reason to question whether or not building client organizations are the single most essential "change-agent" for BIM adoption (Lindblad, 2018). One survey however contradicts Lindblad's claim stating that BCOs are key drivers of innovation and their involvement in the process increases their satisfaction in the results (Ozorhon et al., 2010). Additionally, BCOs are an important actor in the larger industry-wide network and hold a respectable amount of power and influence. Thus, even if BCOs are not the single most essential actor, they do still have the potential to play a significant role in driving BIM adoption.

4.4.2 BCO competencies and maturity

In addition to motives, power, and influence, researchers have identified that building owner competencies and a strategic approach are critical for successful BIM adoption (Love et al., 2013; Succar et al., 2013). Since BIM became accepted as a socio-technical system, researchers have begun exploring BIM maturity from a stakeholder perspective. The most recent BIM maturity model by Siebelink, Voordijk, and Adriaanse (2018) is the result of an assessment of nine existing BIM maturity models. Their research assessed existing models for four main categories of requirements: functional, contextual, user, and structural. Their findings revealed that existing models were insufficient with respect to collaborative aspects, complexity, meaning and definitions of terminology used, organizational processes, and applicability to more than one discipline. Based on their findings, Siebelink et al. (2018) created a new BIM maturity model intended for multi-disciplinary use, including building clients and owners, (Fig. 7) with a balance of technical and organizational aspects. One additional aspect that makes this model particularly well suited to the case study analysis is that it is based upon evaluation of BIM implementation within the Dutch building industry.

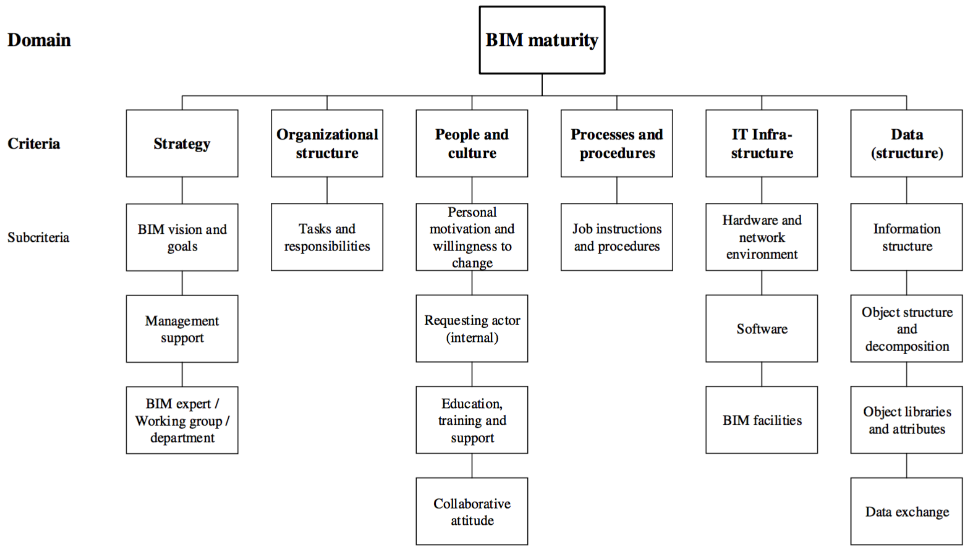


Figure 7. Criteria and sub-criteria of the BIM maturity model (Siebelink et al., 2018)

In their article, Siebelink et al. (2018) also applied the model to assess seven industry subsectors. The assessment included a total of fifty-three interviews, seven of which were conducted for the clients and owners subsector. The results for each of the categories were based upon a scale from 0-5 supported by internal and external process definitions in order to "make supply chain aspects more explicit" (Siebelink et al., 2018). The final results of the study were reported using a color intensity grading (Fig. 8).

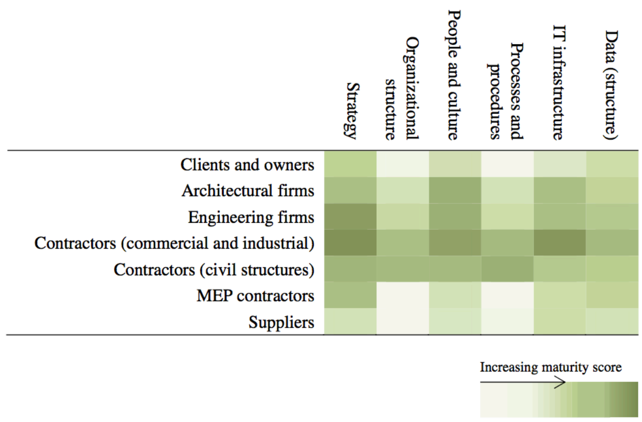


Figure 8. BIM maturity scores of subsectors per BIM maturity criterion (Siebelink et al., 2018)

The main finding of the study was that strong support for BIM exists among the companies that were evaluated, which were deemed "leading companies" within the Netherlands. The results also indicated that there has yet to be a formalization of BIM-related processes, tasks, and responsibilities related to BIM developments. Notably, respondents emphasized that the aspects lagging the furthest behind related to people and culture when it came to implementing BIM. Furthermore, awareness, education, and training were regarded as essential elements in stimulating further development of BIM maturity within companies.

4.5 Current BCO BIM adoption

One of the top responsibilities of the building owner in any project is to clearly identify and lay out the primary mission statement, priorities, and objectives of the project. This responsibility is linked to the definition of the project scope and project documentation specific to the pre-project planning phase. Prior to the rise of BIM, this project documentation focused primarily on all-encompassing project briefing and the main project contract. Now that BIM has become more prevalent and building owners are more aware of the benefits BIM offers in the use and operation phases, some BCOs are choosing to go a step further and address BIM directly (Lindblad & Vass, 2015; Lindblad, 2018). There are a few approaches for this, including the creation of standalone requirements or an execution plan or protocol to demand lifecycle-oriented BIM on building projects. In many cases, these steering devices are being embedded directly into the main project contract.

By addressing lifecycle-oriented BIM directly, the building owner is taking a new step in exercising its influence on other stakeholders. Just as it is important for a building owner to have a clearly documented mission statement and objectives for its project, it is important that the building owner has the same in place for BIM. According to Giel and Issa (2014), the full range of BIM-enabled full life cycle benefits are dependent upon a building owner owners' requirements documentation, assessment of the quality and accuracy of BIM deliverables, and the continued use of BIM into the maintenance and operation phases. Furthermore, by choosing to exercise its influence over BIM, the building owner creates a new responsibility for itself. Just as the building owner is responsible for setting a clear mission statement and objectives, there also becomes a responsibility and supply-side expectation that the BCO can clearly define its needs and expectations for BIM.

In practice, BIM visions and strategies are starting to take shape, especially amongst repeat customers. As part of these strategies and in an attempt to reap the benefits of lifecycle-oriented BIM use on their building projects, some progressive building client organizations have begun implementing steering devices to dictate BIM use on their building projects. Examples of such steering devices can include execution plans, requirements, development roadmaps, or guidelines. In creating these steering devices, BCOs attempt to demonstrate overarching goals, which are important factors for driving BIM use (Nepal et al., 2014).

4.6 Contributions to industry transition conditions

The involvement of BCOs in the adoption and implementation of BIM contributes to the trajectory of BIM as an innovation and, thus, on the trajectory of the building industry. This section highlights some of the key contributions, both positive and negative, as well as challenges that are brought about by BCOs in their pursuit of BIM.

4.6.1 Positive contributions

The range and extent of BIM implications makes it relevant to the entire multi-level perspective. Some researchers even believe that BIM represents a paradigm change with far-reaching benefits and impacts that affect not only the construction industry, but also society at large (Eastman et al., 2011) due to its promises for enhancing sustainability (Bynum et al., 2013) and promoting more holistic, lifecycle-oriented approaches to building projects (Eadie et al., 2013).

BIM is an innovation well suited to enhance sustainability (Bynum et al., 2013) and drive the adoption of more holistic and lifecycle-oriented approaches to building projects (Eadie et al., 2013). Unsurprisingly, therefore, BIM has come to be seen as the common denominator for new and innovative approaches in the design, construction, maintenance, and operation of buildings (Bynum et al., 2013). BIM and its adoption by industry actors represent an important first step towards becoming a more sustainable building industry.

Furthermore, merging the two niche-regime developments to form lifecycle-oriented BIM use on building projects is that it strengthens not only the position of the two innovations, but also other niche-regimes. This is because of the positive and reciprocal relationship between the proxy niche-regime and other developments like sustainability, Lean and green building principles, and also innovation forms of project procurement like IPD (Ahuja et al., 2017; Bynum et al., 2013; Holzer, 2015; Wong & Zhou, 2015). Thus, lifecycle-oriented BIM could potentially stimulate a wide array of alignment and co-evolution of major niche-regimes. In doing so, the amplitude, speed, and scope of associated change is augmented, which increases the likelihood that destabilization will occur. This would provide a window of opportunity not only for lifecycle-oriented BIM to emerge, but also for other niche-regimes as well. Moreover, the need for a unified approach is increasingly being considered as the only way to move forward, which will require the integration of various innovations like BIM and sustainability (Chong et al., 2017).

4.6.2 Challenges

Although research suggests that implementing BIM across a building's entire lifecycle can result in a wealth of potential benefits (Eadie et al., 2013; Hallberg & Tarandi, 2011; Korpela, Miettinen, Salmikivi, & Ihalainen, 2015), lifecycle-oriented BIM use has yet to catch on. This is a result of a combination of factors, one of which being the relative newness of BIM and sustainability concepts within the building industry (Bynum et al., 2013). Another is the considerable uncertainty associated with BIM adoption and how it will continue to develop over time.

The implementation of lifecycle-oriented BIM use on building projects is challenging for all actors in the industry. A literature study by Eadie et al. (2013) on lifecycle-oriented BIM application on building projects in the UK summarizes and ranks key barriers hindering the adoption and use of BIM as follows:

1. Lack of expertise within the project team
2. Lack of expertise within the organizations
3. Lack of client demand
4. Cultural resistance
5. Investment cost
6. Lack of additional project finance to support BIM
7. Resistance at operational level
8. Reluctance of team members to share information
9. Lack of immediate benefits from projects delivered to date
10. Legal issues around ownership, intellectual property, and insurance

It is becoming increasingly apparent that although BIM offers many benefits, it also poses significant challenges. Actors are being confronted not only technologically, but also in terms of their socio-organizational capacity. Some researchers have even argued that for BIM to be successful, a paradigm shift in the building industry is necessary. Furthermore, a recent study investigating a major public building client is Sweden provides new findings that are highly relevant to this research. As a result of this study, Vass and Gustavsson (2017) identify nine interdependent organizational challenges that affect BCOs and their ability to influence transition in the building industry:

1. Changing work practices
2. Providing education and learning
3. Developing a mutual BIM definition
4. Evaluating the business value of BIM
5. Demanding BIM in procurement
6. Creating incentives
7. Including maintenance department
8. Creating new roles
9. Managing interoperability

While these challenges are specific to BCOs, the findings are interesting because they are reflective of organizational challenges faced by the building industry as a whole. It could be said, therefore, that the challenges of adopting and implementing lifecycle-oriented BIM are generally applicable to all actors in the building industry. Thus, rather than the challenges being unique to a particular actor or group of actors, it is more relevant to evaluate actor's response to and attempts to overcome the challenges given their maturity, capabilities, power and influence, resource availability, and other capacities for change. This section therefore elaborates on the current response of BCOs to these challenges as derived from literature and highlights how the response impacts the ability of BCOs to influence transition in the building industry.

4.6.3 Negative contributions

BIM has come to be seen as a sort of holy grail solution. Proponents of BIM have even argued that BIM can alleviate many of the challenges plaguing the building industry (Rezgui et al. 2009, Succar 2009). While this may appear to be the case on the surface, there are several caveats that have been preventing BIM from reaching its full potential. Firstly, just as the majority of research has focused on the technological facet of BIM, industry practitioners often fall into the same trap. Because of the complexity of BIM, many practitioners fail to see BIM for what it is, namely a tool not a solution. For many organizations, this leads to disappointment in the performance of BIM within their organization or even failed adoption.

Although lifecycle-oriented BIM may be able to remedy many of the current challenges in the building industry, an ironic situation arises that new barriers are introduced by the innovation itself. This is because lifecycle-oriented BIM, just like the industry that employs it, is a complex, multi-actor socio-technical system.

Another considerable negative contribution arises from the current pursuits of BCOs to adopt BIM. In their enthusiasm, BCOs are quickly turning to the development of strategies and steering devices to control how BIM will be delivered to and used within the organization. While the creation of steering devices shows interest in adopting lifecycle-oriented BIM within building client organizations, the effort to generate them and the end products themselves have not been particularly successful. This is problematic because such steering devices are key in unlocking the full range of potential lifecycle-oriented BIM benefits (Giel & Issa, 2014) and ultimately driving BIM adoption on a larger scale (Nepal et al., 2014).

These early steering devices have struggled to effectively communicate and align with the wants and needs of the BCO. This is largely a result of the low levels of BIM knowledge, awareness, and maturity of BCOs. Because BIM is not well understood, BCOs are uncertain of their goals, which translates into steering devices that lack clarity. Cavka (2017) addresses four other contributing factors that compromise the ability of BCOs to generate successful steering devices at this point in time. Firstly, owners are often unaware of the information they require for FM/M&O BIM. Secondly, BCOs are not well aware of how to leverage and maximize the use of the information due inexperience in working with BIM. Thirdly, there remains uncertainty in terms of how information should be required and structures. Lastly, the lack of understanding makes it difficult for BCOs to evaluate and implement the information they are provided a project handover. This creates a situation in which BCOs are ill equipped to generate and provide clear formalized steering devices (Cavka et al., 2017).

4.7 Chapter summary

In the beginning of Chapter 4, justifications made for a combined theoretical perspective on innovation in the building industry. More specifically, the strengths of the multi-level perspective from Geels (2002) and the new theoretical framework for actors in transformative change from de Haan and Rotmans (2018) are combined with the technological innovation systems (TIS) perspective. While combining three perspectives adds an added level of complexity to the research, it also contributes structure and a more holistic approach that enables qualitative analysis of innovation-driven regime transition supported by key actors.

Furthermore, on the basis of this combined theoretical perspective, this research posits building client organizations and their adoption of BIM on building projects as an innovation system that is capable of invoking change that contributes to industry transition.

From this position, the third portion of the literature study was conducted to explore currently available information on the current adoption of BIM by building client organizations was investigated. Firstly, a brief overview of the current status of BIM as a radical emerging technological and a procedural shift is given. Thereafter, BCOs, and especially large-scale BCOs, are highlighted. Lastly, the ways in which BCOs contribute to BIM adoption, and thereby to the transition of the building industry, were highlighted.

5. Case study methodology

5.1 Case study evaluation

The case studies conducted for this research are intentionally designed to encourage new insights, as opposed to the evaluation of specific criteria. Explorative research must, however, also be structured. Consequently, the decision was made to create a framework that could be used to systematically evaluate the semi-structured interviews. In this way, it was expected that common themes and results could more easily be identified.

To create the case study evaluation framework, three innovation evaluation frameworks and a multi-disciplinary BIM maturity model were combined. The resources utilized in the framework development are linked to the literature study results discussed in previous chapters. The decision to combine various frameworks was made in order to promote a holistic analysis that would capture a broader spectrum of information.

The following sub-sections highlight the inputs and how elements for the final BCO evaluation framework were selected. The final BCO evaluation framework is presented in Section 5.2.

5.1.1 Functions of innovation systems (FIS)

Technological innovation systems were addressed briefly in Section 4.1. In order to evaluate both structural and dynamic aspects of such innovation systems, Hekkert et al. (2007) propose a framework to study technological change. The framework is comprised of seven functions critical to well-functioning innovation systems:

Function 1: entrepreneurial activities

Function 2: knowledge development

Function 3: knowledge diffusion through networks

Function 4: guidance of the search

Function 5: market formation

Function 6: resources mobilization

Function 7: creation of legitimacy/counteract resistance to change

The seven key functions of innovation systems (FIS) are useful given their suitability for evaluating technological developments and diffusion. FIS is especially useful with respect to the identification of bottlenecks, drivers, and barriers. Furthermore, the seven functions in the FIS framework are well suited for qualitative evaluations, such as the one conducted in this research.

In a study by Hekkert and Negro (2009), empirical research was conducted to test the validity of the FIS framework. Their findings concluded that all seven of the functions are relevant and also highlight that the functions are most appropriate for evaluating "activities endogenous to the system" (Hekkert & Negro, 2009). That said it is not necessarily the case that all seven functions are necessary. Rather, the relevance of functions should be in respect to the system under study. Some functions may not be relevant, or additional functions may be necessary to capture the system correctly.

The indicators used in case study evaluation model borrow directly from FIS functions 1-6. Function 1 was abstracted because entrepreneurial activities cover a wide range. In the case evaluation model, the indicators that capture entrepreneurial activities include: network relations, knowledge and learning, adoption, implementation and use, and nearly all indicators in the "intention" criteria. Functions 2 and 3 were combined with the learning component of SNM to create "knowledge and learning." Function 4, guidance of the search, is covered by the "intention" criteria and also the steering devices indicator. Function 5, market formation, is represented primarily by the indicators network relations, adoption, and implementation and use. Function 6, resource mobilization, was carried over directly. Lastly, Function 7 is captured as more of an undertone throughout the case evaluation as a whole.

5.1.2 Strategic niche management (SNM)

Another framework suitable for analysis of sustainable innovation and transition is Strategic Niche Management (SNM), which is founded on the principles of the multi-level perspective addressed in Section 2.1. Consequently, SNM stresses that the introduction and diffusion of a new innovation cannot be considered separately from its context (e.g. the socio-technical regime and landscape-levels). This emphasis on context helps compensate for one of the main flaws resulting from the endogenous nature of the FIS framework. The SNM approach also highlights the co-evolution of technological and socio-organizational aspects of innovation in the transition towards a more sustainable form of meeting the society needs (Raven et al., 2010). The SNM approach includes an analysis of three sub-processes of niche-level innovation. These sub-processes are: articulation of expectations and visions, building of social networks, and learning at multiple dimensions (Schot & Geels, 2008). Just as the FIS functions are interrelated, so are the sub-processes addressed in SNM. Raven (2005) offers a visualization of the interrelations between the three sub-processes as they relate to innovation experiments (Fig. 10).

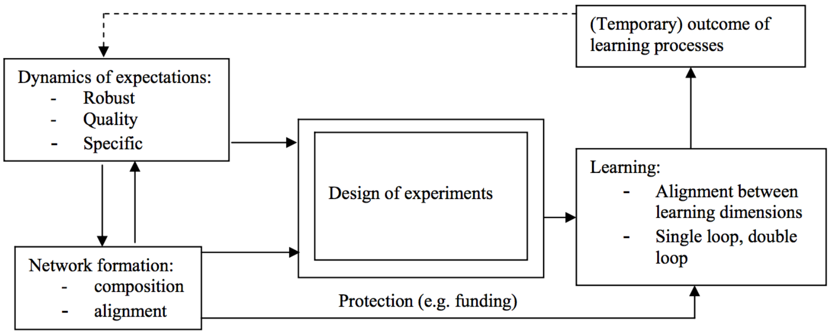


Figure 10. Dynamics in expectations, learning processes and network formation in relation to the design of experiments (Raven, 2005)

When addressing SNM, it is important to note that it is both a means of analysis as well as a set of management principles applicable for the nurturing and development of new innovations. SNM emphasizes the importance of alignment (Kemp, Schot, & Hoogma, 1998), actor diversity and collaboration (R. Raven et al., 2010), and selection of appropriate learning processes (R. Raven et al., 2010). Another key element of SNM is the creation of a protective space. In SNM, a protective space is often a "niche," but can also refer to funding or creation of a protected market space. This idea of protective space likens to FIS Function 5, market formation.

Although SNM and FIS are quite similar, adding the SNM perspective places additional emphasis on the niche-level. The three sub-processes also deepen the conceptualization of some of the seven FIS functions. In the case evaluation therefore, network formation is captured by the indicator "network relations", learning by the "knowledge and learning" indicator, and expectations was carried over directly. Lastly, underlying principles of SNM like contextual dependency, co-evolution, and alignment are taken into consideration and reflected upon later in Chapters 6 and 7.

5.1.3 Technological frames

Even with the two aforementioned frameworks, the human or social aspects are still slightly under addressed. To overcome this gap, a third framework is taken into consideration for the development of the case study evaluation framework, namely technological frames. Technological frames were first popularized by Orlikowski & Gash (1994) as a systematic, socio-cognitive approach for examining people's expectations, knowledge, interpretation, and underlying assumptions of information technology. Orlikowski and Gash (1994) argue that "an understanding of people's interpretations of a technology is critical to understanding their interaction with it."

Three technological frames are addressed: nature of technology, technology strategy and technology in use. A description for each frame is provided in Table 4.

Table 4. Technological frame descriptions (Orlikowski & Gash, 1994)

Nature of technology	Technology strategy	Technology in use
refers to epople's images of the technology and their understanding of its capabilities and functionality	refers to people's views of why their organization acquired and implemented the technology	refers to people's understanding of how the technology will be used on a day-to-day basis and the likely or actual conditions and consequences associated with such use

The technological frames are incorporated into several of the "social" and "advances" criteria indicators as well as the "strategy" indicator. The technological frames were also embedded into the interview questions to help stimulate discussion and to generate a profile of the interview participants. Utilizing the technological frames in the interview process also assisted in differentiating between individual beliefs and perceptions from that of the organization as a whole. This was important given that the object of study in this research was organizations and not individuals working within an organization (Yin & Campbell, 2018).

5.1.4 Multi-disciplinary BIM maturity model

Whereas the three frameworks already addressed in this section focused on innovation in general, the model of Siebelink et al. (2018) is much more specific to the research area. In some ways, the maturity model explores further than the scope of this research. While the IT infrastructure and Data criteria are beyond the scope of this research, it was anticipated that interview participants would undoubtedly bring them up. In keeping with a holistic research approach, it would be misleading to disregard these two criteria of the BIM maturity model altogether. The compromise was to exclude them from the case study evaluation framework, but to provide commentary as necessary. Furthermore, the interview questions were set up to focus on the socio-organizational and process aspects, and the conversation was directed back to that focus area should the interview veer off into "too technical" territory.

Regarding the four remaining BIM maturity model criteria, the associated sub-criteria were incorporated to varying extents. Most notably, the sub-criteria were regrouped to better suit this particular research. For example, the case study evaluation framework takes "strategy" as an indicator representative of a BCO's intentions rather than a standalone criterion. Another example would be that the evaluation framework breaks down "education, training, and support" and embeds them into various indicators within the "positioning" criterion. Modifications such as these were perceived to be acceptable seeing as the goal of the evaluation framework was to assess the potential influence of BCOs on building industry transition as a result of implementing lifecycle-oriented BIM rather than their BIM maturity.

5.2 BCO evaluation framework

From the inputs discussed in the previous section, an evaluation framework was derived. The finalized evaluation framework is presented below in Figure 9.

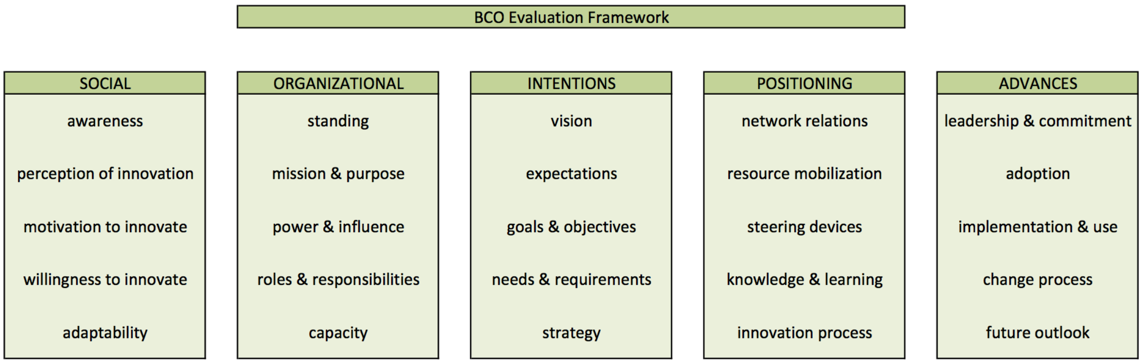


Figure 9. Case study evaluation framework

This framework is geared towards the evaluation interviews conducted with building client organizations selected as part of the case study element of this research. Furthermore, the focus is predominately on the process and socio-organization aspects that current research has yet to explore in much depth. It should also be acknowledged that the framework is a first rendition and, thus, yet to be verified. Although these criteria and indicators were purposefully selected, there are inevitable flaws. Consequently, this framework may not be optimized for use in its current form and there will certainly be room for improvement should a similar framework be necessary in future studies.

5.3 Case study selection and data collection

The case study research focused on the BCO perspective of inter- and intra-organization processes and socio-organizational issues with respect to BIM and its use across the building lifecycle. Just as the theory and literature searches conducted earlier in the research gathered from multiple resources and perspectives, the case studies conducted for this research were intentionally left quite broad so as to collect as much potentially relevant information as possible within the scope of this research.

For this research phase, three large-scale BCOs were selected as case studies. The selection criteria utilized when selecting cases were chosen based on three main criteria:

- The organization is a large-scale owner, operator, and manager of buildings
- The organization (at least a few key individuals within the organization) is aware of BIM, preferably with prior experience
- The organization demonstrates interest in expanding the use of BIM to maintenance and operation activities and other lifecycle-oriented uses
- The organization has expressed an interested in adopting/implementing BIM

Case study selection was also influenced by the availability and willingness of the BCO to participate in the case study. In one case, an organization declined participation in order to focus on developing the organization's BIM strategy. In other cases, even including the cases eventually included in this research, organizations were hesitant to participate because they perceived their BIM maturity as too low to be able to provide helpful practical insights. This posed a considerable limitation to the variety of organizations willing to participate in the case study.

Participants were proposed by the contact person within each of the three organizations and were suggested bases on their role within the organization they represent. Where possible, the interview participants were selected to represent a variety of perspectives. This was possible for Case 1 and 2, however Case 3 included two interviews with comparable functions. The final group of participants represented a variety of roles within the BCOs from strategic and sustainability advisors to technical information management and knowledge coordinators.

Semi-structured interviews were conducted because of the exploratory nature of this research. A list of exemplary questions was derived that was used as a guide during the interviews. These questions were derived in order to capture information relevant to the scope of this study. In addition to the aforementioned perspectives, technological frames were also incorporated.

In total, five interviews were conducted across the three BCOs with a total of seven participants that lasted anywhere from 60 – 80 minutes. The interviews were also recorded for later reference and evaluation. Participants were asked to orient their answers to the particular domain they represent and provide pertinent examples or anecdotes. In general, interviews proceeded in a linear fashion. In some cases, however, participants would incidentally address a later question prior to it being posed. That this became a common occurrence across the interviews is indicative of how convoluted, complex, and pervasive BIM is within BCOs. When this occurred the interview simply followed suit and returned to the predefined list once the trail came to an end or needed redirecting. Additional questions were posed as necessary to clarify specific details and explore unanticipated insights. An outline of exemplary interview questions can be found in Appendix B.

Once all interviews had been conducted, the interviews were analyzed. Using the framework developed in Section 5 exemplary quotes and general commentary were assigned to an appropriate criteria and indicator. This data can be found in Appendix C. Thereafter, the documented data was evaluated individually and a cross-case analysis was performed to identify merits and systemic problems associated with BCO BIM adoption. This analysis is detailed in Chapter 6. Lastly, the main research question regarding improvements that can be made by BCOs to contribute to the transition to a more sustainable building industry is addressed in Chapter 7.

6. Case study analyses

6.1 Case 1

Social

All three participants voiced the opinion that BIM unlocks new potential that is essential to the mission of the organization. Colleagues' perception of the innovation is mixed and polarized. Outside of the individuals in the BIM program, awareness is generally quite low and the perceived usefulness is low as a result. Awareness is being stimulated through BIM-related events and subtle, informal awareness campaigns. Because M&O oriented applications of BIM are not widely available, it is difficult to illustrate the benefits and convince colleagues to embrace BIM in their work. Consequently, the only available examples are design phase BIM models, the level of detail of which is perceived as intimidating by colleagues being introduced to BIM for the first time. Prior experiences contribute to the perception of BIM as being interesting yet far too complicated to explore further, let alone implement.

Organizational

The organization has changed in recent years because of a merger involving four previously separate organizations. The merger has impacted the mission and purpose of the organization as well as its focus and standing. The BCO appears committed to becoming even more procurement based. This would allow the BCO to focus more on real estate and asset management functions as their core business. However, this deepened reliance upon external parties makes the BCO more dependent and potentially vulnerable. Although there is in house knowledge with respect to certain building aspects, very few employees have first hand BIM experience.

The expressed motivation to adopt lifecycle-oriented BIM is to improve information management so that portfolio/asset management becomes more streamlined. The other main source of motivation is to keep up with the market so that communication with the supply-side does not suffer as a result of falling behind. The BCO realizes that it must act as a champion of M&O BIM use. This is crucial since the majority of the organization's work is carried out by external parties. The BCO has considerable influence because of the volume of work it provides to the market and its involvement in all building lifecycle phases. Although they have the ability to influence the industry, they must focus first and foremost on the needs and goals of the BCO. This stance still provides the opportunity to lead by example.

Intentions

The focus of the BCO is on the creation of a digitalized portfolio that uses BIM to more effectively and efficiently share and manage large amounts of information between and within organizations. At present, there are no formal documents declaring an official organization BIM vision or strategy, though one is in development and informal efforts are underway. The primary goal is to move forward incrementally so that informed decisions can be made. The requirements set out in existing steering devices are performance oriented and have been identified by the BCO as having several shortcomings. The BIM information that has been received by the BCO has not been usable despite the existing BIM norm.

Positioning

The BCO works actively with market parties to form new networks and relation to support industry wide BIM-related developments. The BCO has been active in the creation of steering devices. Within the organization, a BIM norm has been developed and is contractually required on some projects. Within the industry, the BCO has been an active participant in high-level policy development and various types of standardization efforts to help streamline BIM within the building industry, often acting as a proponent of M&O aspects. At the project level, relations have improved between primary actors, but the supply chain as a whole remains fragmented. Currently, both supply- and demand-sides, including BCOs, are suffering from integration problems resulting from the industry's traditional approaches and processes.

Resources within the BCO are currently dedicated to day-to-day and post-merger related activities. The focus of these activities is harmonization. Optimization will (presumably) be the next step. BIM is not a priority within the BCO at present, so it has proven difficult to obtain funding and human resources to explore and work on adoption processed. Despite this, one participant commented that the BCO is still in a good position to experiment once the post-merger activities are completed.

Formal BIM knowledge and learning processes are not yet established within the organization. There are few examples of previous M&O BIM applications to learn from and lessons learned from the BCO's earlier BIM initiatives are only started to come into perspective. The general level of knowledge of BIM within the organization, both in terms of perception and use, are low. This is further exaggerated because little to no design work is carried out by the organization itself. Internal opportunities to learn about BIM are limited because the BCO relies heavily on external knowledge, which is does not diffuse/transfer to intra-organizational employees.

Advances

The adoption and implementation of BIM within the BCO is driven by a small group of pro-BIM professionals. The BIM group within the BCO has been proactive with experimenting with BIM via pilot projects and innovative forms of project procurement. A lack of examples nationally and internationally has made this process tedious as these pilot experiments are true tests by trial and error, and several years must pass before results can be evaluated and incorporated into new experiments. The BCO is drawing increasingly closer to a major decision-making moment, so BIM-related progress has reached a plateau and will likely stay there until the vision/strategy is finalized. There is a decision-making predicament that the democratic approach is too slow to effectively stimulate change yet the more aggressive forced approach to BIM implementation has negative impacts on. Consequently, there is no set timeline for implementation of BIM. Additionally, the existing structure of the BCO is not well suited for BIM-related working processes. The structure of the BCO would therefore need to be adjusted if/when BIM becomes integrated into the BCO. Despite these shortcomings and challenges, the participants had a positive outlook for BIM. They expect that progress will be incremental and likely to require a different organizational structure than what exists today.

6.2 Case 2

Social

A wide variety of benefits can be attributed to BIM and the possibilities for its use are endless so long as the information is created, used, and managed appropriately. The BCO is quite open and intent on investigating new innovations. It is already busy with a variety of sustainability initiatives and sees BIM as a potential next step. The market has a slightly different perspective of the organization because of its outward disinterest in receiving BIM or other 3D models at present. BIM awareness within the BCO is low, which the participants believe has a negative influence on their colleagues' willingness and interest to pursue BIM. Intervention to stimulate interest and awareness is necessary, but there is no leadership support for such an initiative at present. Although the BCO is not particularly quick to adapt, but does want to progress to a more holistic approach that fosters integration and lifecycle-oriented approaches. One participant voiced that if an M&O oriented BIM system was already available, they would probably adopt and move forward with it.

Organizational

The BCO is progressive and wants to make considerable progress with respect to sustainability and circularity. Participants were particularly excited by the possibility of helping to bring about market level change and the formation of new alliances. One participant highlighted the importance of being more invested in the activities surrounding their building projects. The BCO has recently undergone reorganization. Employees in the BCO lack BIM competency. Part of the reorganization involves switch to a more team-based approach in part to improve communication. One participant commented that the building and information management department could, in theory, be placed anywhere within the BCO because the information is relevant to all departments.

Intentions

There is no formal vision or strategy for BIM adoption/implementation at this point in time. The informal goal however is to focus more on building lifecycles, especially the M&O phases, and to support these efforts by implementing BIM. The BCO expects that BIM can serve as a potential means for achieving better archive management, building monitoring, and tool for ensuring/reviewing building compliance. The emphasis in on the creation of a single, unified system supported by a BIM protocol that ensures that incoming information can be integrated seamlessly into the system. They are also acutely aware of the dramatic difference in expectations and requirements in place today compared to what it will be in the future. The situation was depicted as being rather binary; the demands for BIM by the BCO will be either minimal or extremely high.

Positioning

Networks and collaboration are crucial for the development of a BIM protocol and eventual implementation. The anticipated change is too great for one organization to move forward without knowing that an alliance is available to support its endeavor. The BCO is currently in a partnership with approx. 12 other similar organizations to generate a standardized, multi-organization BIM protocol.

The innovation process has been challenging because the BCO wants to first come to one coherent solution but does not know what steps to take to get there, which has slowed the investigation and adoption process. Some progress in resource mobilization is being made (e.g. new hires). One participant emphasized that more proactive measures should be taken to prepare. IT aspects and lack of a pre-existing BIM system are barriers to eventual implementation. Further, there are few to no options available directly from the market, so the BCO must generate something itself or in partnerships with other BCOs. Regardless of the path moving forward, the participants emphasized that the information made available to colleagues must be easy and comprehensive enough that people will be willing to read and understand it.

Advances

Participants highlighted that BIM adoption/implementation is not something that can be done in isolation. Despite this, most internal discussion about BIM occurs with a small group of pro-BIM professionals. Both participants responded that the BCO is committed to moving forward with BIM, though a clear leadership initiative is not yet present. The BCO is interested in taking a next step with BIM in the near future.

BIM models from the design and construction phases have been delivered to the BCO but never used for M&O purposes. The BIM protocol is nearing completion. The BCO expects to begin testing it in the near future. This would mark a great step forward towards adopting more lifecycle-oriented approaches since the BCO has not emphasized M&O aspects in previous projects. Participants have a positive outlook for future developments in BIM and lifecycle-oriented approaches. One participant felt that a revolution in facility management is coming whereas the other perceived the change as surprisingly slow.

6.3 Case 3

Social

BIM is generally perceived as considerable challenge, both in theory and in practice. The level of BIM awareness in the BCO is limited to a small group of individuals. One participant highlighted the necessity of a culture change within the BCO in order for BIM to be successful. Despite being perceived as a challenge, the perceived benefits of BIM convince the BCO to investigate BIM and consider adopting it.

Organizational

The BCO is involved in all building lifecycle phases, though particular emphasis is places on real estate management and M&O. The motivation to adopt BIM is derived from the innovation's potential for information consolidation and improved information access. The BCO is part of a larger multi-organization effort to generate a BIM protocol in part to garner additional power and influence derived from the group/network setting and consequent impact on the market.

Aim & Intent

There is no formal vision or strategy for BIM at this point in time. One participant sees BIM as a single information source that can be used by various departments within the BCO One participant addressed several concerns about the level of detail (LOD) because of its impact on information usability and quality with respect to specific types of use (e.g. day-to-day works vs. building renovation). In the perspective of the participants, BIM needs to be geared to the full lifecycle to prevent data drops. Furthermore, the accruing data should also be reviewed at various points in time to ensure that all parties have contributed information in accordance to the established BIM protocol requirements.

Positioning

The BCO is currently participating in the development of a multi-organization BIM protocol. That network has a common goal of achieving change within the market. Participants emphasized that the BCO wants to evolve and become more invested in the early project phases. Currently the BCO and its processes are poorly suited to BIM adoption and use. Change needs to occur in project procurement and the BCO needs to become more BIM minded.

The participants focus mostly on lacking IT resources, especially computing power and software availability. Some proactive measures have been taken to increase technical knowledge of BIM. The general approach so far is a slow introduction to increase awareness and learning so that colleagues within the BCO remain receptive.

Advances

The BCO has not committed to moving forward with BIM despite its involvement in the development of a multi-organization BIM protocol. One participant mentioned that there is not a clear leadership initiative from the upper management. The BCO is likely to consider the adoption of BIM more seriously once the BIM protocol is completed. In the meantime, some pilot projects have been implemented by the BCO to experiment with BIM. The BIM protocol is expected to help the BCO come to a decision with respect to BIM adoption and implementation. The amount of change required makes taking the step toward adopting M&O BIM a challenge for this traditional BCO. The lack of a M&O-oriented BIM system within the market was emphasized as an adoption barrier. The participants have mixed expectations about the future outlook of BIM. In general, the lack of existing proof and lessons learned within other organizations created hesitation and difficulty in predicting future developments.

6.4 Cross-case analysis

6.4.1 Social

In all three BCOs it appeared that small pro-BIM groups have formed, largely via informal, means. Given their favorable perception of BIM and relatively high level of awareness, especially compared to other colleagues, these groups are particularly motivated and willing to innovate. Outside of these pro-BIM groups, BIM awareness within the BCOs was generally quite low overall. A particular problem appears that awareness is lacking especially in those with the highest levels of decision-making power. This therefore negatively impacts the entire adoption process, as upper management, which steers the organization positioning and intentions, is not particularly motivated or willing to innovate. However, BCOs with more progressive natures were keener to adopt and implement BIM at a quick pace than the more traditional BCO. The level of awareness and benefits perceived by this group is related to the BCO's willingness to innovate.

In some situations, the pro-BIM groups have begun working to increase BIM awareness within the organization. It has proven difficult, however, to raise awareness because of a lack of adequate examples. Few examples of BIM for post-construction, and thus for lifecycle-oriented use, are available. Accordingly, the available examples are often BIM as it is used in the design or construction phase. Such examples are highly technical in nature and have proven to be too intimidating and have negatively impacted the perception of BIM, which has made some in the BCOs less willing to innovate. Others have responded differently, acknowledging that they do see potential benefits, but that the effort and level of adaption necessary to innovate and adopt BIM does not outweigh the benefits.

6.4.2 Organizational

All three organizations have recently undergone reorganization, which has resulted in some instability and need for new processes and harmonization. The BCO in Case 1 indicates a shift towards becoming a "professional client" whereas the two other BCOs indicate interest in increased levels of project involvement, especially in the early phases. All BCOs expressed interest in adopting more lifecycle-oriented approaches in order to keep up with developments in the market. These interests also serve as motivation to pursue innovation and BIM adoption.

The BCOs are active in generating power and influence that can be used to influence market developments. Case 1 already has an inherently high level of power and influence, whereas Cases 2 and 3 rely upon the formation of an alliance with similar BCOs. Although power and influence over the market hold considerable appeal, the BCOs also demonstrate that their priorities must first and foremost be on the core business of their respective BCOs. Although BCO power is strong enough to have market influence in general terms, BCOs are in a less powerful position to influence further lifecycle-oriented BIM developments. This is due largely to the lacking BIM maturity and capacity of the organization. BIM is still a highly technical development requiring advance information management, which goes far beyond the scope of what many BCOs are currently capable of handling.

6.4.3 Intentions

Pro-BIM groups within BCOs have begun shaping early concepts and visions for lifecycle-oriented BIM uses that could benefit their organizations. All organizations emphasized the importance of creating a single information database available to various departments within the larger organization. The importance of data quality and usability was also highlighted. Thus, ensuring that the future BIM requirements produce useful and usable information is a key driver because bad information/requirements would have negative consequences that jeopardize the adoption and implementation of BIM within the BCO.

Regardless of the specifics of the implementation, all BCOs were clear that BIM use within their BCOs must be M&O focused. At present, the visioning progress varies considerably between organizations, especially with respect to the breadth of BIM use. This may be a result of differing levels of awareness, perception, and motivation across the different BCOs. It may also be related to the culture of the BCO and freedom to explore new and innovation technologies. Although BCOs are in a visioning stage, none of the BCOs have yet settled on a formal BIM vision.

It also appears that the definition of goals and objectives associated with their pursuits to adopt BIM are correspondingly weak. For the BCOs, the goal remains overly simplified: adopt BIM. Without a full understanding of potential BIM applications, BCOs are also struggling to develop succinct needs and requirements. Unsurprisingly, none of the BCOs interviewed for the case studies has a formalized BIM strategy at this point in time.

6.4.4 Positioning

Given that BCOs are still only in the earliest steps of BIM adoption, it is peculiar to note that extensive steering devices are being developed in parallel. Despite uncertainty and a lack of commitment to move forward with BIM adoption on a large scale, all organizations are active participants in the development of BIM-related steering devices. Partnerships, collaboration, and alliances are increasingly common means for exploring the possibilities of BIM and navigating the changes necessary to adopt and implement the new innovation. Innovation in the industry is not something that can occur in isolation, and the change cannot occur without co-evolution of the supply and demand sides. Although the innovation and change processes are perceived as evolutionary, there is considerable motivation to ensure that steering devices like BIM protocols are done right since the requirements are futile if they do not support business objective or provide some sort of added value to the BCO.

Only finite resources are currently being made available in the pursuit of BIM. This is likely related to the lack of commitment from upper management within the BCOs. As a result, few resources are being made available for training or acquisition of new skilled hires. Lacking resource availability and quality were also noted as barriers to current attempts of using the sub-optimal BIM models that have been provided on past projects. Two of the BCOs made specific reference to the lack of a currently available M&O BIM system as a barrier for BIM adoption. This may be a result of limited resource availability and/or competency to invent such a system from scratch.

Knowledge and learning processes/measures were largely absent within all three BCOs. All BCOs rely heavily upon external knowledge, which does not diffuse/transfer from the external party to the BCO and limits opportunities for learning. Knowledge and learning can be linked to commitment and willingness to innovate. The current approach within the BCOs is to increase awareness slowly. While this is perceived as a mean to keep employees receptive to the changes, the pace may hinder the level of change needed for adoption and implementation to be swift and successful.

With respect to innovation processes, several issues are present. According to Davidson (2013), innovation that affects many stakeholders requires a systems approach. Due to the complexity and interconnectedness of socio-technical systems, it is not possible to follow a "normal" innovation pathway. In his research into innovation in the building industry, Davidson (2013) provides an overview of the decision-making process for technological and organizational innovation in the construction industry (Fig. 11). The importance of such a process was mentioned briefly in Section 4.1.

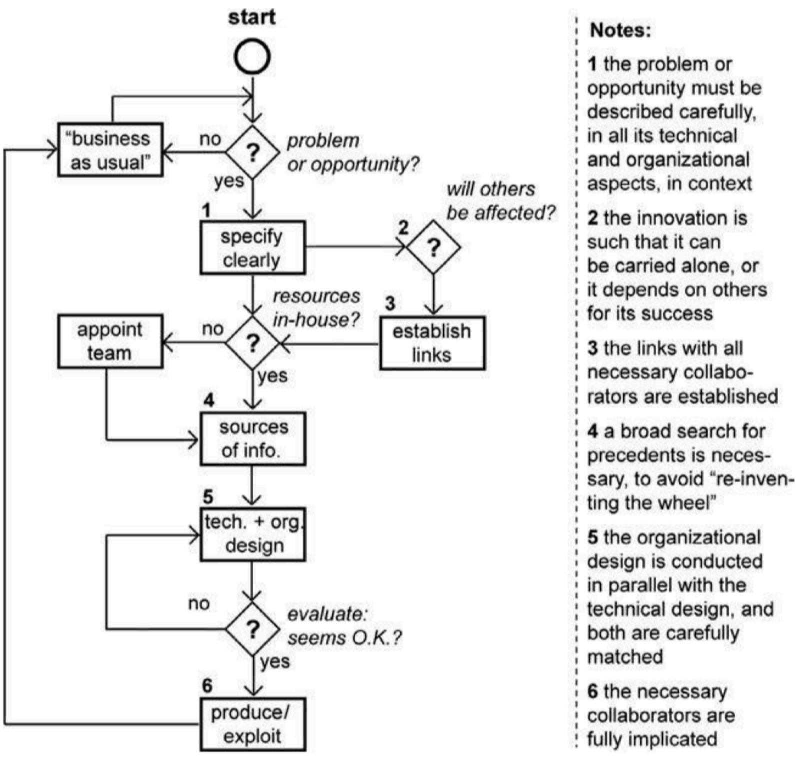


Figure 11. Steps in the decision-making process for technological and organizational innovation (Davidson, 2013)

Superimposing BCO efforts to implement lifecycle-oriented BIM into this decision-making process by Davidson (2013) (Fig. 11) reveals failures at each of the six decision-making moments in the process. As already mentioned, BCOs tend to have a limited awareness and understanding of BIM, which makes it difficult for them to effectively carry out steps 1 -3. Step 4 is complicated by a lack of examples available from which BCOs can learn and take inspiration. Step 5 is currently downplayed, as BCOs are generally reluctant to make significant changes to their structures and procedures. As a result, many BCOs that have begun working towards adopting and implementing lifecycle-oriented BIM focus on exploitation and reverse engineer the other decision-making processes as necessary. This type of decision-making process, or lack thereof, is not sufficient to support implementation of an innovation within an organization (Sargent et al., 2012).

6.4.5 Advances

None of the BCOs In the case study was fully committed to moving forward with BIM. This was mostly attributed to insufficient support from upper management. Democratic approaches attempting to stimulate adoption and implementation of lifecycle-oriented BIM use have proven to be slow with limited result. More aggressive maneuvers are gradually becoming more accepted as they quicken the pace of innovation. Consequently, all BCOs were already experimenting with pilot projects or open to testing via pilot projects in the near future. The number of pilot projects is however still quite small and it takes several years to garner new insights from them. Adoption of lifecycle-oriented BIM on building projects is limited to a few pilot projects. Further, few examples of M&O BIM exist globally, so BCOs are often restricted to learning from their own successes and failures. The various initiatives of the BCOs should become available in the near future. This new batch of steering devices and positioning will likely influence new developments within the industry as the market is forced to adapt to new demand-side requirements. In general, the future outlook is quite positive, though there is a range of expectations. Interview participants view the future transition as anywhere from uncertain or slow to incremental or revolutionary.

The amount of organizational change required is considerable and often off-putting. Existing BCO structures and processes are poorly suited to the adoption and use of BIM at an organizational-level. All interview participants indicated that BIM adoption is an evolutionary process that will require incremental innovation steps. However, the current situation is that the organizations have reached a plateau and are waiting for finalized visions/strategies/protocols to be developed. This is indicative that the next step taken by organizations may likely represent final commitment to adopting BIM and acceptance of the change necessary to make its implementation and use successful both in the short term and the long term. From the case studies, it can also be deduced that both the supply- and demand-side are intimidated, or even unwilling, to address the need for significant restructuring and new business models

Another approach related issue within BCOs, and even in the industry in general, is that when innovation is attempted, it most frequently occurs at the project-level. While this in not inherently problematic, the temporal nature of project organizations often makes it such that the knowledge and lessons learned are not diffused or transferred in an effective way. Project-level innovation is especially problematic when it comes to lifecycle-oriented BIM implementation because BIM is not simply a project-level entity; BIM in its fullest capacity is an organization wide tool. Project-level innovation attempts have a tendency to result in incomplete understanding and implementation of BIM. Consequently, maximized use of lifecycle-oriented BIM cannot occur if implemented on the project level alone.

7. Conclusion and discussion

7.1 Research questions

This research has explored the dynamics of a technological innovation system in which building client organizations influence the transition of the building industry through their implementation of lifecycle-oriented BIM use on their building projects. While many different actors are involved within the system as a whole, this research focused on building client organizations and, more specifically, on those with a public or semi-public orientation. In order to arrive at an answer to the main research question, four sub-questions were also addressed within this report. A synopsis of research sub-questions 1 and 2 are provided below. Sub-question 3 is addressed in the proceeding sub-section together with the main research question.

7.1.1 What is the current trajectory of transition in the building industry?

Characterizing the future trajectory of transition in the building industry is complex. Up to now neither external conditions nor ebb and flow within the regime-level have created sufficient change to result in destabilization of the incumbent socio-technical regime. Given these current conditions, the trajectory of the building industry appears insufficient to bring about transition of sufficient speed and intensity. The conditions, however, do appear to be strengthening at a rapidly increasing rate. Should this development become more refined in the near future, the speed and intensity of transition in the building industry may come closer to matching the demand placed upon it by the landscape-level.

The changes that have occurred up to this point have brought with them an increase in complexity, both at the industry regime level and also at the project level. Complexity magnifies the impact of change and the resulting destabilization. As such longstanding issues within the industry derived from its fragmented nature are posing new problems with respect to, among other things, decision-making processes, coordination, and collaboration (Ye et al., 2009).

Based upon the analysis conducted in Section 3.4, there are two transition pathway typologies that could be used to describe the current trajectory: the squeezed (top-down and bottom-up) teleological pathway and the adaption dominated transformation pathway. Recapping these two typologies, teleological transition pathways are "the result of a regime adapting to changed circumstances not by reforming itself but allowing outside influences to reconstellate structures and cultures and simultaneously incorporating novel functioning in these processes" (de Haan & Rotmans, 2011). In transformation transition pathways, transformation occurs within the regime itself via an ongoing evolutionary process of adaption. In this process, the regime responds to tensions and stress by changing itself in a self-steering process so as to meet needs and demands once more. It also frequently involves the absorption of niches or co-evolution with the niche-level (de Haan & Rotmans, 2018).

Both the teleological and transformation transition pathways have their merits and faults. Thus, the current transition trajectory of the building industry can be best characterized simply as dynamic and involving all three levels. With respect to the future, the transition is likely to be complex, non-linear, and distorted by uncertainty. The conditions, however, are quite hazy, so the accuracy of these characterizations is limited. Moreover, is can be debated that the existing conditions are insufficient to initiate or support transition, or at least not transition to the speed and extent demanded by landscape-level developments and demands.

7.1.2 How could the adoption of BIM by building client organizations contribute to the transition to a more sustainable building industry?

Despite such great promise and an industry-wide commitment to moving forward with BIM at the helm, several hurdles and barriers must first be overcome. The supply- and demand-side barriers suggest that one of the greatest hurdles facing BIM is that implementing BIM requires a compound paradigm change within organizations (Ahuja et al., 2017) and the building industry as a whole (Eastman et al., 2011). Achieving a paradigm shift is challenging in any industry, and an even greater challenge to overcome in the building industry given its traditional and slow to innovate nature. Additionally, the risk adversity of the building industry and adoption lag makes overcoming hurdles considerably more laborious (Sepasgozar & Bernold, 2012). These and other industry-related barriers stem from the distinction of the building industry as a complex, multi-actor socio-technical system.

BIM has already reached a certain level of saturation within the industry/market, which almost certainly guarantees that it will continue to persist. Relating technology adoption to institutional theory, BIM as a tool has become a norm (the extent to which it is a norm can be argued, as can the way that the tool is used). Institutional theory can also explain and support why process and behavioral aspects are now evolving in order to support this development.

Although BIM is increasingly proving its worth, it cannot be implemented successfully without a supportive process and alliance of actors capable of reducing fragmentation and better insights into the entire building process. Moreover, involvement and proactive decision-making are lacking in early phases, which hinders the ability for arrangements to be made for FM and M&O during the design phase (Ye et al., 2009). It suffices to say that the lack of a lifecycle-oriented approach to BIM implementation on building projects perpetuates and sometimes exaggerates fragmentation issues and emphasizes the disconnect of the highly touted design and construction phases from the downplayed use and operation phases of a building's lifecycle (Wetzel & Thabet, 2015). It seems only natural therefore that coupling BIM with a lifecycle-oriented building approach could reduce some of the existing challenges and promote the use of BIM in all lifecycle phases. Research also supports this proposition because of indications that BIM provides a beneficial tool for realizing lifecycle management in building projects (Xu et al., 2014). The two innovations are therefore inherently mutually enhancing.

Referring back to the transformative actor roles discussed in Section 2.3, BCOs could potentially come to assume one or more of the following roles. Progressive BCOs seeking to lead the way in lifecycle-oriented BIM use could take on the "toppler" role by embracing the innovation and bringing it into the regime-level. Should BCOs follow a more conservative approach and opt for later adoption of lifecycle-oriented BIM, the "supporter" role may be more appropriate. Regardless of the risk inclination, BCOs are also likely to play a "boundary spanning" role given the need to create alignment and a unified vision and set of values between the supply- and demand-sides of the building industry in order to transition to occur. Lastly, BCOs will likely need to accept the need to adopt a "boundary shaking" role in order to stimulate the internal process, structure, and socio-organizational changes necessary for lifecycle-oriented BIM use on building projects to be a success.

If positioned correctly, BCOs could drive both the merging of the two niches and its imminent breakthrough into the socio-technical regime. An added benefit of successfully linking BIM and BCOs is reduced risk of innovation abandonment, which in turn increases innovation uptake within the construction industry.

7.2 Systemic problems and recommendations

Building client organizations are currently in the early steps of adopting BIM. They see the potential benefits for their organizations, but also perceive a high level of risk and uncertainty. As a result, action to adopt and experiment with BIM on building projects has been slow. This is due in no small part to the lack of BIM awareness within BCOs outside of the small pro-BIM working groups. One of the main limitations in practice is that BIM-enabled projects are still a relatively new concept. Best practices are in their infancy, and stakeholders from the building owner to organizations throughout the entire supply chain are still in the early learning and adaption phase. As such, BIM is still not fully understood. Organizations such as BCOs are at a particular disadvantage due to low levels of BIM maturity. The situation on the whole leads to jeopardized adoption of the innovation and suboptimal implementation. Generally, BCOs therefore do not know the specifics of what to do with BIM. Without this insight, visions for the adoption and eventual implementation are often vague.

Increase awareness, competencies, and opportunities for learning

- Increasing BIM awareness can positively impact various aspects of BCO BIM adoption. Aware
- When information is made available to BCO employees, the information must be suitable for the audience (e.g. comprehensive but not too long or overly technical).

BCO competencies and BIM maturity, or a lack thereof, in combination with other aforementioned factors have also made it difficult for BCOs to begin developing robust and specific goals and objectives. Comparing the case study results to the BIM maturity scores for clients and owners by Siebelink et al. (2018) (Figs. 7 & 8), there are discrepancies. Although the BIM maturity model was not applied directly within this research, it is still possible to provide some necessary commentary about these potential. The two most notable are the mid-range scores Siebelink et al. attribute to the "strategy" and "people and culture" for clients and owners. Referring to the BIM maturity model, "strategy" includes the following sub-criteria: BIM vision and goals, management support, BIM expert/working group/department. While the cases did indicate that pro-BIM groups are present, the case studies do not provide sufficient support of maturity in the two other sub-criteria. With respect to the other criteria, "people and culture", four sub-criteria were identified: personal motivation and willingness to change, requesting actor, education, training and support, and collaborative attitude. The case studies support all but the "requesting actor" category since official requests for BIM have not yet become a formalized issue by way of strategy, requirements, or steering devices. Rather, the discrepancy lies in the closed off nature of what was observed in the case studies. There are indeed people who are exemplary with respect to maturity in the aforementioned sub-criteria. However, and as low levels of organization-wide BIM awareness in the case studies show, people and culture of BCOs on the whole is unexceptional. The lack of BIM-related knowledge development and resource allocation observed in the case studies is a prime example. Despite these discrepancies, the case study findings do support the general placement of clients and owners as having a lower level of BIM maturity than other key actors in the building industry.

Delve deeper in order to identify needs and develop a vision and subsequent BIM strategy

- Having a clear and well-developed vision in place can help streamline the development of process and strategy, decision-making, and relationships that are necessary to ensure consistency between projects and shape the socio-organizational structures needed to support effective BIM adoption.
- Strategy is beneficial for three primary reasons. Firstly, strategy is important in projects with low autonomy and highly complex stakeholder networks. Secondly,

the negotiating position of the building owner, and its ultimate level of power and influence in the project, is jeopardized if it does not start off with a clearly defined strategy. Thirdly, it is somewhat premature to look beyond strategy at this point in time because the present process and socio-organization knowledge of BIM is still lacking.

Although lifecycle-oriented BIM shows considerable potential, its success is dependent on stakeholder collaboration, the creation of new affiliations, and socio-organizational changes (Murphy, 2014). The upsurge and proliferation of BIM across the building industry has forced many actors to form new networks quickly in order to deliver new functions and to meet required performance levels. In this rush, BCOs have been pursuing innovation and decision-making processes rather erroneously. This lack of holistic innovation shows that, in many organizations, the adoption process of BIM is broken.

Adopt a more systematic innovation process

- Innovation for the sake of innovation alone will only continue the current situation of stagnant BIM adoption and fragmented, incomplete implementation across the building lifecycle.

Innovations have two sides, developments of the technology and developments of the processes. For an innovation to be successful, both must develop simultaneously. This is important since new innovations, like BIM, cannot be expected to fit into traditional processes or socio-organizational structures. In the case of BIM, this requirement creates a vicious circle in which the supply-side, demand-side, the industry context, and BIM itself all play a part. Clashes between old and new can arise, existing processes can hinder or even hurt progress, and the people and culture within companies can sometimes come into conflict with what needs to be done to allow the "new" to thrive. If this complexity is not effectively managed, there is an increased risk of project failure (Winch, 2012) and failure of BIM itself, which jeopardizes its future potential.

Make necessary changes and coevolve

- While technology-driven innovations like BIM have the potential to resolve longstanding problems, the use of technology alone is insufficient to enhance performance (Sargent et al., 2012).
- To derive the maximum possible benefits from BIM implementation, BIM must develop at the inter- and intra-organization-level (Vass & Gustavsson, 2017) and be innovation driven rather than project driven (Murphy, 2014). This is a challenge in and of itself given that actors in the building industry struggle to organize themselves in non-conventional ways.
- Furthermore, BIM is a particularly demanding tool to implement; there is no predefined or one-size-fits-all approach. BIM needs to be oriented to a specific use so that data can be generated, attributed, and managed accordingly (Whyte & Hartmann, 2017).

7.3 Discussion

Research into the building industry and BIM in particular are fraught with challenges. Citing Miettinen and Paavola (2014), Vass and Gustavsson (2017) emphasize that BIM needs to be studied as a multidimensional, historically evolving, complex phenomenon. Consequently, to research BIM is to attempt to zoom in on a constantly evolving and multifaceted tool that is still not fully understood. Moreover, research also needs to take into consideration that BIM is embedded into an inherently complex and dynamic macro-, meso-, and micro-level contexts. This nature imposes various challenges and complexity, which this research has attempted to embrace rather than oversimplify. This research approach has been chosen because it promotes active discovery and is appropriate for research areas with considerable knowledge gaps.

Despite the progress that has been made, the nature of magnitude of these BIM-related obstacles are not fully understood. As a result, BIM use across the full lifecycle of a building remains fragmented both in theory and in practice. Furthermore, the imminence of major landscape-level changes and call for a paradigm shift in the building industry have made it increasingly relevant, if not necessary, to develop new approaches to manage the transition and further development of the innovations.

Although innovation within the building industry is slowly becoming better understood, it should also be noted that the factors influencing adoption processes and transformation in this industry are still not clearly understood (Sepasgozar & Bernold, 2012). Moreover, the greatest barrier affecting both the supply- and demand-side is that implementing any type of BIM properly requires a compound paradigm change within individual organizations (Ahuja et al., 2017) and the building industry as a whole (Eastman et al., 2011). The aforementioned dualities and convoluted set of problems make it appreciable as to why further research into BIM, and especially its process and socio-organizational aspects, is necessary.

That said, a variety of avenues exist for potential future research. There is considerable room to continue investigating the building industry from a transition theory perspective. This could provide valuable insights into how key industry stakeholders can contribute, both individually and collectively, to the transition towards a more sustainable building industry. Similarly, new frameworks could be developed to provide more well-informed decision-making and innovation processed geared towards application in the building industry. With respect to future research regarding BCOs, one avenue could be to explore the types of BIM applications most valuable to a particular type of organization. For example large-scale organizations were shown in the case studies to have a tendency to outsource much of their M&O work. It may be the case then that large-scale BCOs may be able to benefit more from asset management oriented BIM functionalities than for M&O. Findings related to that line of research would be valuable to demand-side stakeholders investigating how BIM can be used to improve their business operations.

7.4 Limitations

Various limitations arose in this research that should be mentioned. Firstly, the research topic itself is representative of a highly complex, multi-actor socio-technical system. As such, it lies in the hands of the researcher to provide reasonable boundaries, thereby delineating the scope of the research.

In the case of this research, it was decided that the focus should be placed on establishing the general context of the building industry as it presents in developed nations. Once established, this context was evaluated according to transition theories to further deepen the contextual understanding and foundation of further parts of the research. The transition theories, in this case, pose inherent limitations as they are still under development. Furthermore, this research focuses on building client organizations, and even more specifically on large-scale building client organizations. Consequently, other stakeholders associated with the supply- and demand-sides are not addressed. Though this is a limitation of scope, the focus on BCOs is a strength of this research as it enables the contribution of new knowledge to an otherwise under addressed stakeholder.

Another limitation of this research was the lack of existing literature directly related to the research theme. Although BIM is a popular research topic, there was little information about the relationship between BIM and BCOs. Of the literature that was available, the majority was focused for the most part on technical aspects of adoption and implementation, whereas this research aimed to investigate more deeply into socio-organizational aspects.

Other limitations were also posed by the use and execution of case studies. Given the time and resources available to the researcher, only three BCOs were interviewed as part of the research. This is quite a small sample, so the results and subsequent conclusions are only able to capture a small glimpse into the bigger picture of BCO BIM-related developments. Another limitation associated with the case study methodology was that interviews could not always be conducted on a one-on-one basis. It is therefore possible that the response of one interview participant may have influenced that of other participant(s).

7.5 Reflection

In closing, a few words should be said regarding the scientific and social relevance of this research.

One of the main contributions of this research was evaluation of the building industry using principles attributed to transition theory. This combination is quite unique. Moreover, it illustrates the adaptability of the transition theory principles themselves, which until now have been used to evaluate industries considerably more adaptable and innovation-rich than the building industry. Additionally, given the newness of the theoretical framework proposed by de Haan and Rotmans (2018), this research represents an early application of the framework.

Although this research made heavy use of theory, it is also socially relevant. The growing interest of building industry stakeholders in applying BIM is evidence that this innovation is only becoming more relevant within the building industry as a whole. Because this progress is driving the development of new BIM-related applications, the future of BIM is highly relevant. This research contributes to this discussion by highlighting systematic problems currently experienced by BCOs, a key demand-side stakeholder, which represent a step towards new understanding as to how further pursuits of BIM should be directed.

References

Ahbabi, M., & Alshawi, M. (2015). BIM for client organisations: A continuous improvement approach. *Construction Innovation*, *15*(4), 402–408. https://doi.org/10.1108/CI-04-2015-0023

Ahuja, R., Sawhney, A., & Arif, M. (2017). Driving lean and green project outcomes using BIM: A qualitative comparative analysis. *International Journal of Sustainable Built Environment*, *6*(1), 69–80. https://doi.org/10.1016/j.ijsbe.2016.10.006

AIA. (2007). Integrated Project Delivery: A Guide. *American Institute of Architects*, 1–62. https://doi.org/10.1016/j.autcon.2010.09.002

Akinade, O. O., Oyedele, L. O., Omoteso, K., Ajayi, S. O., Bilal, M., Owolabi, H. A., … Henry Looney, J. (2017). BIM-based deconstruction tool: Towards essential functionalities. *International Journal of Sustainable Built Environment*, *6*(1), 260–271. https://doi.org/10.1016/j.ijsbe.2017.01.002

Artto, K., Martinsuo, M., Dietrich, P., & Kujala, J. (2008). Project strategy: strategy types and their contents in innovation projects. *International Journal of Managing Projects in Business*, *1*(1), 49–70. https://doi.org/10.1108/17538370810846414

Atkin, B., & Bildsten, L. (2017). A future for facility management. *Construction Innovation*, *17*(2), 116–124. https://doi.org/10.1108/CI-11-2016-0059

Bakker, R. M. (2010). Taking Stock of Temporary Organizational Forms: A Systematic Review and Research Agenda. *International Journal of Management Reviews*, *12*(4), 466–486. https://doi.org/10.1111/j.1468-2370.2010.00281.x

Barrett, P., Abbott, C., Ruddock, L., & Sexton, M. (2007). Hidden innovation in the construction and property sectors. *RICS Research Paper Series*, *7*(20), 1–21. Retrieved from http://usir.salford.ac.uk/id/eprint/18373%5Cnhttp://amr.aom.org/content/14/4/562.short

Becerik-Gerber, B., & Kensek, K. (2009). Building information modeling in architecture, engineering, and construction: Emerging research directions and trends. *Journal of Professional Issues in Engineering Education and Practice*, *136*(3), 139–147. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000023

Bynum, P., Issa, R. R. A., & Olbina, S. (2013). Building information modeling in support of sustainable design and construction. *American Society of Civil Engineers*, *139*(1), 24–34. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000560.

Carlsson, B., & Stankiewicz, R. (1991). On the nature, function and composition of technological systems. *Journal of Evolutionary Economics*. https://doi.org/10.1007/BF01224915

Cavka, H. B., Staub-French, S., & Poirier, E. A. (2017). Developing owner information requirements for BIM-enabled project delivery and asset management. *Automation in Construction*, *83*(November), 169–183. https://doi.org/10.1016/j.autcon.2017.08.006

Chong, H. Y., Lee, C. Y., & Wang, X. (2017). A mixed review of the adoption of Building Information Modelling (BIM) for sustainability. *Journal of Cleaner Production*, *142*, 4114–4126. https://doi.org/10.1016/j.jclepro.2016.09.222

Davidson, C. (2013). Innovation in construction – before the curtain goes up. *Construction Innovation*, *13*(4), 344–351. https://doi.org/10.1108/CI-02-2013-0007

Davis, K. (2017). An empirical investigation into different stakeholder groups perception of project success. *International Journal of Project Management*, *35*(4), 604–617. https://doi.org/10.1016/j.ijproman.2017.02.004

de Haan, F. J., & Rotmans, J. (2018). A proposed theoretical framework for actors in transformative change. *Technological Forecasting and Social Change*, *128*(December 2017), 275–286. https://doi.org/10.1016/j.techfore.2017.12.017

de Haan, & Rotmans, J. (2011). Patterns in transitions: Understanding complex chains of change. *Technological Forecasting and Social Change*, *78*(1), 90–102. https://doi.org/10.1016/j.techfore.2010.10.008

Dutta, S. (2015). *The Global Innovation Index 2015*. *Stronger Innovation Linkages for*. https://doi.org/978-2-9522210-8-5

Eadie, R., Browne, M., Odeyinka, H., McKeown, C., & McNiff, S. (2013). BIM implementation throughout the UK construction project lifecycle: An analysis. *Automation in Construction*, *36*, 145–151. https://doi.org/10.1016/j.autcon.2013.09.001

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM Handbook: A Guide to Building Information Modelling For Owners, Managers, Designers, Engineers and Contractors Second Edition*. *John Willey & Son Inc*. https://doi.org/10.1002/9780470261309

Edquist, C. (1997). *Systems of innovation: Technologies, institutions and organizations*. (C. Edquist, Ed.), *Long Range Planning*. Abingdon: Routledge. https://doi.org/10.1016/S0024-6301(98)90244-8

Egan, J. (1998). *Rethinking Construction : The Report of the Construction Task Force*. *HMSO*. https://doi.org/Construction Task Force. Uk Government

Frambach, R. T., & Schillewaert, N. (2002). Organizational innovation adoption: A multi-level framework of determinants and opportunities for future research. *Journal of Business Research*, *55*(2), 163–176. https://doi.org/10.1016/S0148-2963(00)00152-1

Fuenfschilling, L., & Truffer, B. (2014). The structuration of socio-technical regimes—Conceptual foundations from institutional theory. *Research Policy*, *43*(4), 772–791. https://doi.org/10.1016/j.respol.2013.10.010

Gaziulusoy, A. I., & Brezet, H. (2015). Design for system innovations and transitions: A conceptual framework integrating insights from sustainablity science and theories of system innovations and transitions. *Journal of Cleaner Production*, *108*, 1–11. https://doi.org/10.1016/j.jclepro.2015.06.066

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, *33*(6–7), 897–920. https://doi.org/10.1016/j.respol.2004.01.015

Geels, F. W., Kern, F., Fuchs, G., Hinderer, N., Kungl, G., Mylan, J., … Wassermann, S. (2016). The enactment of socio-technical transition pathways: A reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990-2014). *Research Policy*, *45*(4), 896–913. https://doi.org/10.1016/j.respol.2016.01.015

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research*

Policy, *36*(3), 399–417. https://doi.org/10.1016/j.respol.2007.01.003

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., & Raahemifar, K. (2017). Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges. *Renewable and Sustainable Energy Reviews*, *75*(October 2015), 1046–1053. https://doi.org/10.1016/j.rser.2016.11.083

Giel, B., & Issa, R. R. A. (2014). Framework for Evaluating the BIM Competencies of Building Owners. In *Computing in Civil and Building Engineering (2014)* (Vol. 32, pp. 552–559). https://doi.org/10.1061/9780784413616.069

Hallberg, D., & Tarandi, V. (2011). On the Use of Open BIM and 4D Visualisation in a Predictive Life Cycle Management System for Construction Works. *Journal of Information Technology in Construction (ITCON)*, *16*, 445–466. Retrieved from http://www.itcon.org/2011/26

Hardin, B., & McCool, D. (2015). *BIM and construction management: proven tools, methods, and workflows*. Indianapolis: John Wiley & Sons. Retrieved from https://ebookcentral-proquest-com.tudelft.idm.oclc.org/lib/delft/detail.action?docID=2060411#

Hekkert, M. P., & Negro, S. O. (2009). Functions of innovation systems as a framework to understand sustainable technological change: Empirical evidence for earlier claims. *Technological Forecasting and Social Change*, *76*(4), 584–594. https://doi.org/10.1016/j.techfore.2008.04.013

Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S., & Smits, R. E. H. M. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change*, *74*(4), 413–432. https://doi.org/10.1016/j.techfore.2006.03.002

Holzer, D. (2015). BIM for procurement - procuring for BIM. In R. H. Crawford & A. Stephan (Eds.), *Living and Learning: Research for a Better Built Environment: 49th International Conference of the Architectural Science Association 2015* (pp. 237–246). Melbourne.

Kemp, R., Schot, J., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis & Strategic Management*, *10*(2), 175–198. https://doi.org/10.1080/09537329808524310

Korpela, J., Miettinen, R., Salmikivi, T., & Ihalainen, J. (2015). The challenges and potentials of utilizing building information modelling in facility management: the case of the Center for Properties and Facilities of the University of Helsinki. *Construction Management and Economics*, *33*(1), 3–17. https://doi.org/10.1080/01446193.2015.1016540

Koutamanis, A. (2017). Briefing and Building Information Modelling: Potential for integration. *International Journal of Architectural Computing*, *15*(2), 119–133. https://doi.org/10.1177/1478077117714914

Lindblad, H. (2018). Black boxing BIM: the public client's strategy in BIM implementation. *Construction Management and Economics*, *6193*, 1–12. https://doi.org/10.1080/01446193.2018.1472385

Lindblad, H., & Vass, S. (2015). BIM Implementation and Organisational Change: A Case Study of a Large Swedish Public Client. *Procedia Economics and Finance*, *21*(15), 178–

184. https://doi.org/10.1016/S2212-5671(15)00165-3

Loorbach, D. (2010). Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework. *Governance*, *23*(1), 161–183. https://doi.org/10.1111/j.1468-0491.2009.01471.x

Loorbach, D., & Rotmans, J. (2010). The practice of transition management: Examples and lessons from four distinct cases. *Futures*, *42*(3), 237–246. https://doi.org/10.1016/j.futures.2009.11.009

Lu, Y., Wu, Z., Chang, R., & Li, Y. (2017). Building Information Modeling (BIM) for green buildings: A critical review and future directions. *Automation in Construction*, *83*(November), 134–148. https://doi.org/10.1016/j.autcon.2017.08.024

Markard, J., Hekkert, M., & Jacobsson, S. (2015). The technological innovation systems framework: Response to six criticisms. *Environmental Innovation and Societal Transitions*, *16*, 76–86. https://doi.org/10.1016/j.eist.2015.07.006

Miettinen, R., & Paavola, S. (2014). Beyond the BIM utopia: Approaches to the development and implementation of building information modeling. *Automation in Construction*, *43*, 84–91. https://doi.org/10.1016/j.autcon.2014.03.009

Murphy, M. E. (2014). Implementing innovation: A stakeholder competency-based approach for BIM. *Construction Innovation*, *14*(4), 433–452. https://doi.org/10.1108/CI-01-2014-0011

Murphy, M., Heaney, G., & Perera, S. (2011). A methodology for evaluating construction innovation constraints through project stakeholder competencies and FMEA. *Construction Innovation*, *11*(4), 416–440. https://doi.org/10.1108/14714171111175891

Nepal, M. P., Jupp, J. R., & Aibinu, A. A. (2014). Evaluations of BIM: Frameworks and Perspectives. In *2014 International Conference on Computing in Civil and Building Engineering* (pp. 769–776).

Orlikowski, W. J., & Gash, D. C. (1994). Technological frames: making sense of information technology in organizations. *ACM Transactions on Information Systems*, *12*(2), 174–207. https://doi.org/10.1145/196734.196745

Ozorhon, B., Abbott, C., & Aouad, G. (2010). Innovation in Construction: A Project Lifecycle. *SCRI Research Report 4*, (August 2016), 903–912. https://doi.org/10.13140/RG.2.1.1235.1203

Penttilä, H. (2006). Describing the changes in architectural information technology to understand design complexity and free-form architectural expression. *Electronic Journal of Information Technology in Construction*, *11*, 395–408.

Peppard, J., & Breu, K. (2003). Beyond Alignment: A Coevolutionary View of the Information Systems Strategy Process. *International Conference on Information Systems*. https://doi.org/10.1080/0268396032000122141

Poirier, E. A., Forgues, D., & Staub-French, S. (2017). Understanding the impact of BIM on collaboration: a Canadian case study. *Building Research and Information*, *45*(6), 681–695. https://doi.org/10.1080/09613218.2017.1324724

Raven, R., Bosch, S. Van den, & Weterings, R. (2010). Transitions and strategic niche management: towards a competence kit for practitioners. *International Journal of Technology Management*, *51*(1), 57. https://doi.org/10.1504/IJTM.2010.033128

Raven, R. P. J. M. (2005). *Strategic niche management for biomass*. Eindhoven University of

Technology.

Rezgui, Y., Zarli, A., Technologies, I., Hopfe, C. J., Directions, F., Issue, S., … Applications, M. (2009). Editorial - Building Information Modeling Applications , Challenges , and Future Directions, *14*(October), 613–616.

Sargent, K., Hyland, P., & Sawang, S. (2012). Factors influencing the adoption of information technology in a construction business. *Australasian Journal of Construction Economics and Building*, *12*(2), 72–86. https://doi.org/10.5130/ajceb.v12i2.2448

Schot, J., & Geels, F. W. (2008). Technology Analysis & Strategic Strategic niche management and sustainable innovation journeys : theory , findings , research agenda , and policy Strategic niche management and sustainable innovation journeys : theory , findings , research agenda , and po, *20*(October 2011), 37–41. https://doi.org/10.1080/09537320802292651

Sepasgozar, S. M. E., & Bernold, L. E. (2012). Factors Influencing Construction Technology Adoption. In *International Conference on Sustainable Design, Engineering, and Construction 2012*. Retrieved from https://doi.org/10.1061/9780784412688.078

Siebelink, S., Voordijk, J. T., & Adriaanse, A. (2018). Developing and Testing a Tool to Evaluate BIM Maturity: Sectoral Analysis in the Dutch Construction Industry. *Journal of Construction Engineering and Management*, *144*(8), 05018007. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001527

Slaughter, E. S. (1998). Models of Construction Innovation. *… of Construction Engineering and Management*.

Smink, M., Negro, S. O., Niesten, E., & Hekkert, M. P. (2015). How mismatching institutional logics hinder niche-regime interaction and how boundary spanners intervene. *Technological Forecasting and Social Change*, *100*, 225–237. https://doi.org/10.1016/j.techfore.2015.07.004

Suarez, F. F., & Oliva, R. (2005). Environmental change and organizational transformation. *Industrial and Corporate Change*, *14*(6), 1017–1041. https://doi.org/10.1093/icc/dth078

Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automation in Construction*, *18*(3), 357–375. https://doi.org/10.1016/j.autcon.2008.10.003

Succar, B., Sher, W., Aranda-Mena, G., Williams, T., & Eastman, C. (2007). A proposed framework to investigate Building Information Modelling through knowledge elicitation and visual models. *Australasian Universityies Building Education (AUBEA2007)*, (May 2014).

Takim, R., Harris, M., & Nawawi, A. H. (2013). Building Information Modeling (BIM): A New Paradigm for Quality of Life Within Architectural, Engineering and Construction (AEC) Industry. *Procedia - Social and Behavioral Sciences*, *101*, 23–32. https://doi.org/10.1016/j.sbspro.2013.07.175

Thelen, K. (2003). How Institutions Evolve: Insights from Comparative Historical Analysis. In *Comparative Historical Analysis in the Social Sciences*. https://doi.org/10.1111/j.1469-0691.2011.03558.x/pdf

United Nations Environment Programme (UNEP). (2017). *The Emissions Gap Report 2017 - A UN Environment Synthesis Report. United Nations Environment Programme (UNEP)*. https://doi.org/ISBN 978-92-9253-062-4

Vass, S., & Gustavsson, T. K. (2017). Challenges when implementing BIM for industry change. *Construction Management and Economics*, *35*(10), 597–610. https://doi.org/10.1080/01446193.2017.1314519

Von Tunzelmann, N., & Acha, V. (2009). Innovation In "Low-Tech" Industries. In *The Oxford Handbook of Innovation*. https://doi.org/10.1093/oxfordhb/9780199286805.003.0015

Wetzel, E. M., & Thabet, W. Y. (2015). The use of a BIM-based framework to support safe facility management processes. *Automation in Construction*, *60*, 12–24. https://doi.org/10.1016/j.autcon.2015.09.004

Whyte, J. K., & Hartmann, T. (2017). How digitizing building information transforms the built environment. *Building Research and Information*, *45*(6), 591–595. https://doi.org/10.1080/09613218.2017.1324726

Whyte, J., & Sexton, M. (2011). Motivations for innovation in the built environment: New directions for research. *Building Research and Information*, *39*(5), 473–482. https://doi.org/10.1080/09613218.2011.592268

Wielinga, E., & Geerling-Eiff, F. A. (2009). *Networks with Free Actors: An Organic Approach to Innovation and Transition*. (K. J. Poppe, K. Termeer, & M. Slingeland, Eds.), *Transitions towards Sustainable Agricultural and Food Chains in Peril-urban Areas*. Wageningen: Wageningen Academic Publishers.

Witkamp, M. J., Raven, R. P. J. M., & Royakkers, L. M. M. (2011). Strategic niche management of social innovations: the case of social entrepreneurship. *Technology Analysis & Strategic Management*, *23*(6), 667–681. https://doi.org/10.1080/09537325.2011.585035

Wittmayer, J. M., Avelino, F., van Steenbergen, F., & Loorbach, D. (2017). Actor roles in transition: Insights from sociological perspectives. *Environmental Innovation and Societal Transitions*, *24*, 45–56. https://doi.org/10.1016/j.eist.2016.10.003

Wong, J. K. W., & Zhou, J. (2015). Enhancing environmental sustainability over building life cycles through green BIM: A review. *Automation in Construction*. Elsevier B.V. https://doi.org/10.1016/j.autcon.2015.06.003

Xu, X., Ma, L., & Ding, L. (2014). A framework for BIM-enabled life-cycle information management of construction project. *International Journal of Advanced Robotic Systems*, *11*(1), 1–13. https://doi.org/10.5772/58445

Ye, J., Hassan, T. M., Carter, C. D., & Kemp, L. (2009). Stakeholders' requirements analysis for a demand-driven construction industry. *Journal of Information Technology in Construction*, *14*(October), 629–641. Retrieved from http://www.itcon.org/2009/41

Yin, R., & Campbell, D. (2018). *Case study research and applications: Design and methods* (6th ed.). Thousand Oaks, California: SAGE Publications.

Zietsma, C., & Lawrence, T. B. (2010). Institutional Work in the Transformation of an Organizational Field : The Work and Practice Work, *55*, 189–221.

Appendix A: Scientific article

Transitioning to a more sustainable building industry: an evaluation of the current trajectory

Sydney Folsom

Delft University of Technology, Faculty of Technology, Policy and Management

Abstract

The building industry is faced by a variety of developments that challenge its long established traditional socio-technical regime. It has become increasingly apparent that the industry as it exists today is out of alignment with and cannot fulfill the demands and requirements placed on it. Consequently, a need exists for the industry to transition. In this article, the multi-level perspective of transition theory is applied to investigate the current trajectory of the building industry transition. Thereupon, commentary is provided on why the transition is likely to be occurring so slowly.

Keywords

Building industry, transition, multi-level perspective

1. Introduction

1.1 Demand for a more sustainable building industry

The building industry is a notorious energy and resource consumer. According to United Nations statistics, the manufacturing of building materials accounts for approximately 10% of all global energy end-use (UNEP, 2011) and energy consumption during the use and operation phase of buildings produces 30–40% of total global green house gas emissions (UNEP, 2007). Furthermore, evidence increasingly suggests that emissions resulting from activities during the building phase are as significant as during the use and operation phase (Wong & Zhou, 2015). In addition to intensive energy consumption, the creation and demolition of constructions contributes upwards of 40% of all waste in developed countries (UNEP, 2011). Although the construction industry has many negative impacts in terms of energy and resource consumption, it also plays a central role in national economies (Ozorhon, Abbott, & Aouad, 2010) and increasing quality of life through the generation and sustainment of the built environment (Whyte & Sexton, 2011; Ye, Hassan, Carter, & Kemp, 2009).

Sustainability and environmental welfare have risen to prominence in political agendas worldwide. Nearly all countries are working actively toward the development and implementation of new policy, which holds considerable implications that affect all industries. As a result of the Paris Agreement of 2016, numerous national initiatives have been implemented with the hope of mitigating the impacts of climate change. These efforts are reinforced further by the European Union Sustainable Development Goals, which require the policy of all member states to be reflective of these goals by 2030. There is also an increasing awareness that "system innovations for sustainability" or "transitions" of socio-technical systems are necessary in order to become more sustainable (Gaziulusoy & Brezet, 2015). Given the building industry's status as a notorious energy and resource consumer, it is therefore unsurprising that it has become a primary target for improvements. In short, the building industry is being pressured to dispense of its traditional practices in favor of more sustainable and long-term approaches for the design, construction, management, and eventual deconstruction of buildings.

1.2 Transition occurring too slowly

Despite good intentions and actions on behalf of the building industry to respond to these demands, transition does not appear to be occurring rapidly enough. In point of fact, the overarching conclusion drawn in the 2017 Emissions Gap Report by UN Environment (UNEP, 2017) was that an urgent need exists for accelerated, short-term action and enhanced, long-term ambition in order to fulfill the mission and goals set out by the Paris Agreement and Sustainable Development Goals.

Given the pressing need for more rapid transition, this research sets out to address two related questions.

1. *What is the current trajectory of transition in the building industry?*
2. *Why is transition occurring at such a slow rate?*

1.3 Methodology

Because research into innovation and transition in the building industry is limited, this research first establishes a foundational background based upon established and state-of-the-art theory. In researching socio-technical systems, and even more so when conducting transition research, the context is crucial to understanding. Therefore, the next step was to capture the context of the building industry as it exists within developed countries, and in the Netherlands in particular.

For this next step, the transition pathway typologies of Geels et al. (2016) and de Haan and Rotmans (2011) were utilized. Because the historical transformation was less nuanced than at present, it was justifiable to use the simpler transition pathway classification proposed by Geels et al. (2016) to characterize the historical transition and transformation of the building, whereas the typologies of de Haan and Rotmans (2011) provided additional nuance necessary to describe the current situation. Based upon the results, the last step was to identify root causes of the transition's slowness are described.

2. Transition and innovation

2.1 Multi-level perspective (MLP)

The multilevel perspective (MLP) is a model that was developed in order to garner a better understanding of regime shifts, specifically the shift from one stable regime to another, in socio-technical systems. The multi-level perspective is composed of three nested, hierarchical levels — namely the landscape, patchwork of regimes, and niches (Geels, 2002) (Fig. 1). Although it is referred to as a nested hierarchy, it is important to keep in mind that socio-technological transition is not the result of a single, linear or vertically integrated process. Rather, the process is iterative and interwoven. Thus, the outcome of socio-technological change is the result of a dynamic relationship between all three levels over a period of time (Raven, 2005).

Following along with the hierarchy, the stability of the levels varies, with high stability at the landscape-level, relative yet variable stability as the regime-level, and low stability at the niche-level. Additionally, the greater the stability, the greater the structuration (Geels, 2002). Furthermore, the resulting interplay between the three levels determines the overall stability and structuration of the niche itself (Witkamp, Raven, & Royakkers, 2011).

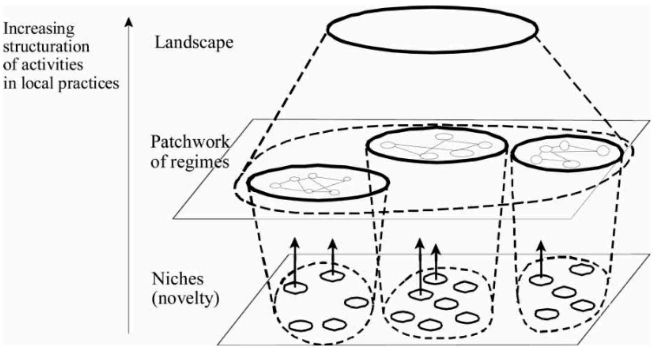


Figure 1. Multiple levels as a nested hierarchy (Geels, 2002)

Figure 2 offers a standardized visualization of the multi-level perspective. The visualization of the multi-level perspective seeks to show that socio-technical regimes (patchwork of regimes) and innovations (niches) both occur within a larger context, the landscape, which consists of deeply embedded trends (Raven, 2005). This visual representation also depicts the nature of the systems as various streams and flows. The regime-level in particular can be likened to an ebbing and flowing stream, the turbulence of which varies according to landscape and niche level pressures.

The MLP as a methodology and visualization tool are still evolving. Earlier interpretations, for example, included different regime specifications within the socio-technical regime-level (Geels, 2002). Newer versions, like the one in Figure 2 have added additional arrows to signify new findings on the interaction between the three levels. In this case, the arrows are representative of the influence of broader landscape- and regime-level developments on the perceptions of niche actors and the size of support networks (Geels & Schot, 2007).

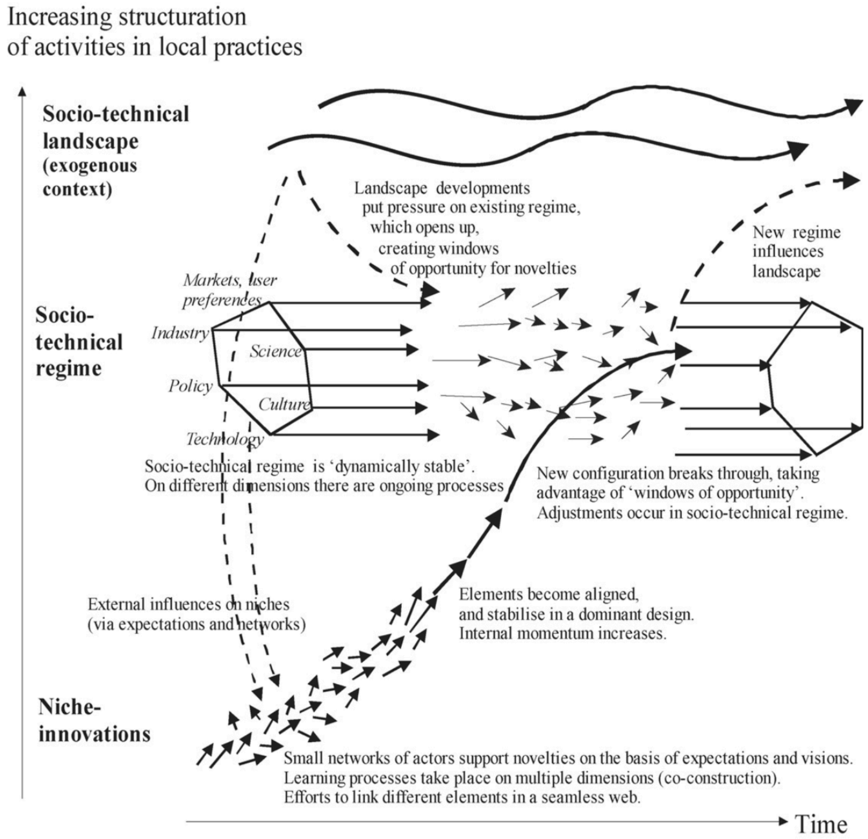


Figure 2. Standardized multi-level perspective of transition (Geels & Schot, 2007)

At the top of the nested hierarchy in the multi-level perspective is the landscape, which consists of societal, institutional, and other background factors that enable and constrain regime and niche developments (Raven, 2005). Of the three levels, the landscape is the most structure. Thus, by definition, the landscape lies beyond the influence of individual actors yet has a major influence upon them (Geels, 2004;Raven et al., 2010).

Embedded into the landscape is the regime-level. Simply stated, the regime is the incumbent, mainstream way that things are done in a socio-technical system. The regime-level is reflective of a socio-technical system and is comprised of a "patchwork of regimes". Within the multi-level perspective on transitions, six key regimes are identified: market/user preferences, industry, policy, technology, culture, and science (Geels & Schot, 2007) (Fig. 2). Although other regimes exist, these six provide a sufficient overview and address key aspects of institutional theory.

The third level is niche-innovations. This level is comprised of "embryonic nuclei for future" that are still is the developmental stage and have yet to achieve strong enough institutionalization to emerge into the regime-level (Fuenfschilling & Truffer, 2014). Niche-level developments can vary in size and degree of potential change. Of the three levels, the niche-level has the least structuration.

If broken down further, the MLP could actually be said to contain a fourth "level", that of experiments. Early efforts in generating the MLP distinguish between experiments and niches. This distinction helps to describe the process by which local experiments connect and develop over time leading to the development of a regime (Fig. 3). It also demonstrates the importance of the creation and transfer of knowledge and experiences gained from innovation experiments in the creation of structuration that supports further niche development and regime emergence.

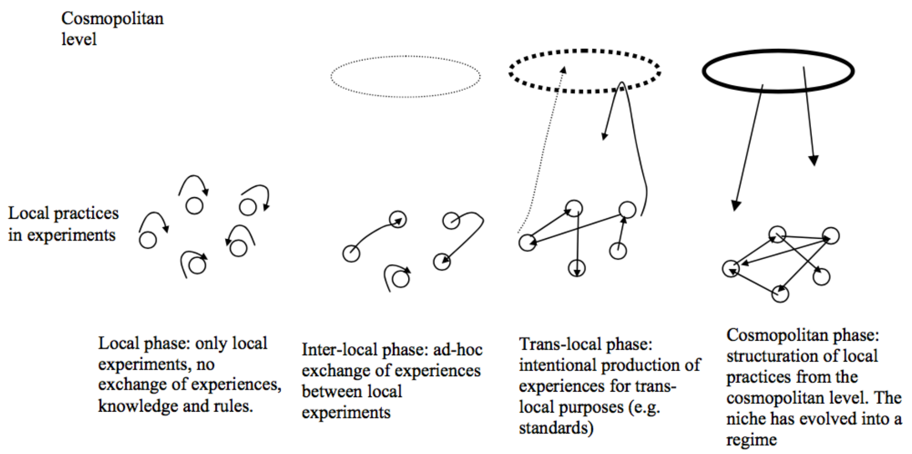


Figure 3. Emerging level of niches in relation to local practices in experiments (Raven, 2005)

An additional feature added later by de Haan and Rotmans (2011) is the "niche-regime". As the name suggests, the characteristics lie somewhere between that of niches and the regime. For a niche-level innovation to be promoted to a "niche-regime", it must provide a viable or competitive advantage compared to the incumbent regime(s) of the greater socio-technical-regime. Niche-regimes are therefore poised for breakthrough into the regime-level should the correct conditions transpire to form a window of opportunity. Should breakthrough occur, the niche-regime then proceeds to compete actively within the incumbent regime. The niche-regime therefore compares roughly to the trans-local phase in Figure 3.

2.2 Transition patterns and pathways

Transition can occur in a variety of ways. Based on prior transition research, Geels et al. (2016) classify four types of transition pathways: "substitution", "transformation", "reconfiguration", and "de-alignment and re-alignment." While these classifications are useful for analyzing transformation, reality does not adhere to clear-cut classification. Based upon the nature of transitions as continuous and contested change processes between a variety of actors, the conceptualization of transition pathways has expanded to include "shifts between pathways" (Geels et al., 2016). Geels et al. (2016) also identify that shifts between transition pathways are influenced by a wide range of developments including: changes in actor coalition composition and strength, learning processes and experiences, and landscape developments (Geels et al., 2016). While these pathways help to support the new theoretical framework discussed in Section 2.3, they are too simplistic to support a qualitative narrative of a transition for analysis.

De Haan and Rotmans (2011) offer another perspective on transition pathway typology. Interestingly, this publication predates that of Geels by five years yet explores transition typologies in greater depth. Just as Geels (2016) refers to shifts between pathways, de Haan and Rotmans (2011) describe transitional change as a "chain of patterns" driven by conditions for change, such as tensions, stress, and pressure. Three types of transition patterns are defined as follows by de Haan and Rotmans (2011):

- Reconstellation (top-down) – "A new constellation emerges, or an existing one gains power by influences from outside the societal system., reconstellation and adaptation."
- Empowerment (bottom-up) – "A new constellation emerges, or an existing one gains power, either by itself or through interacting or merging with other constellations within the societal system."
- Adaptation – "A constellation alters its functioning either through interacting or merging with other constellations within or from outside the societal system."

The next step undertaken in their research was to create transition pathway typologies for these typologies. For this, the reconstellation and empowerment patterns were carried over directly. Adaptation, however, proved more complicated. Whereas the two other patterns have clear top-down or bottom-up characteristics, adaptation appears to be more internally induced. Instead of creating one category for adaptation, the researchers opted instead to create two separate categories. Transformation pathways are characterized as adaption dominated. Although they introduce transformation pathways into their research, de Haan and Rotmans (2011) challenge the notion that change can occur within a vacuum by disputing whether this type of internally induced change qualifies as a "proper transition". This is a highly relevant point for this research as it emphasizes the complexity and interconnectedness of socio-technical systems. The second category is the squeezed transition pathway, which is effectively simultaneous reconstellation and empowerment. The squeezed pathway is in keeping with previously established transition research, such as the multi-level perspective.

Also taken into consideration in the creation of the transition pathway typologies were the influence of the incumbent regime or the ultimate success or failure of the transition effort with respect to change in the existing, dominant regime. In total, eleven transition pathways are included in the typology (Table 1). The researchers acknowledge that a myriad of transition pathways are possible, they believed that the typology sufficiently addresses the distinguishable criteria.

Table 1. Transition pathway typologies (de Haan & Rotmans, 2011)

Transition pathway typology				**Type of regime change**
Top-down	*Bottom-up*	*Squeezed*	*Transformation*	
Radical reform	Reconfiguration	Teleological	Transformation	*(with regime adaptation)*
Revolution	Substitution	Emergent	-	*(without regime adaptation)*
Collapse	Backlash	Lock-in	System breakdown	*(failed transition)*

Combining the multi-pattern approach and transition pathway typologies together with descriptions of the transition conditions, it becomes possible to develop a narrative of the transition at hand that can then be qualitatively analyzed.

2.3 Conditions for transition

As mentioned previously, the regime-level is an ebbing and flowing steam in a constant state of flux. It is, therefore, the circumstances or the nature of the change or both that distinguish normal change from the transformative (de Haan & Rotmans, 2011). The basic condition capable of initiating transition is destabilization of the regime level (Fuenfschilling & Truffer, 2014). Destabilization of the regime level creates windows of opportunity for niche-level and niche-regime developments to challenge the existing, dominant regime. According to the multi-level perspective, destabilization occurs as a result of interactions between processes occurring within each of the three levels. The processes can be attributed as follows (Geels & Schot, 2007):

- Landscape: changes that lead to creation of pressure on the regime
- Socio-technical regime: destabilization that results in windows of opportunity for niche emergence
- Niche: buildup of momentum and support of an innovation by powerful alliances

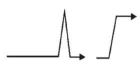
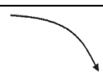
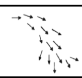
Similarly, De Haan and Rotmans (2011) assert that conditions for transitional change arise when the societal system is compromised in some way, making the status quo unsustainable. As socio-technical systems are composite, open, and contextually influenced, they can be compromised by factors internal or external to the system. Three general conditions for transitional change according to de Haan and Rotmans (2018) are tensions, stress, and pressure. Tensions refer to flux between the system and its environment that are dependent upon complementary structural and cultural aspects and symmetry. Stress and pressure are both considered as internal factors that compromise the system therefore creations conditions for transition. Stress occurs when the dominant regime is inconsistent or inadequate in its performance. This often transpires as a result of mismatch between needs, structure, and culture. Lastly, pressure is system compromise resulting from direct competition between the dominant regime and niche or niche-regime developments. From the MLP perspective, it could be argued that pressure is internal to the regime-level and also originates from the landscape and niche levels.

Further, transition is a process of change from one state to another. Change can come in a variety of forms, four dimensions of which are highlighted by Suarez and Oliva (2005):

1. Frequency: number of environmental disturbances per unit of time
2. Amplitude: magnitude of deviation from initial conditions caused by a disturbance
3. Speed: rate of change of disturbance
4. Scope: number of environmental dimensions that are affected by simultaneous disturbances.

Based upon these dimensions, Suarez and Oliva (2005) derive five types of environmental change (Table 2) with respect to management and organizational adaptation.

Table 2. Dimensions and typologies of environmental change (Suarez & Oliva, 2005)

Frequency	Amplitude	Speed	Scope	Type of environmental change	Demarcation
low	low	low	low	Regular	
high	low	high	low	Hyperturbulence	
low	high	high	low	Specific shock	
low	high	low	low	Disruptive	
low	high	high	high	Avalanche	

A one-to-one relationship does not exist between the type of change and amount of regime-level destabilization that occurs. However, it could be generally stated that the higher the frequency, amplitude, speed, and/or scope of the change, the greater the regime-level destabilization is likely to be. Consequently, the type of change experienced by a socio-technical system affects the conditions for transition.

For as much as destabilization of the regime is necessary for niche breakthrough to occur, (re)stabilization plays an equally important part (Loorbach, 2010). As de Haan and Rotmans (2018) put it, "Transformation is as much about breaking down as it is about building up." Re-stabilization of the regime level can come in a variety of forms, as indicated by the transition patterns and pathways discussed in Section 3.4 in which the regime does or does not adapt. In the case of a failed transition, instability continues and, in theory, new windows of opportunity are created for niche-level developments to emerge, thus initiating a new potential stabilization process.

Relating change to re-stabilization is a trickier matter given that the system response to change is unpredictable. For example, a specific shock may lead to quick reactionary measures and swift re-stabilization whereas hyperturbulance may create uncertainty and an unwillingness to (re)act, therefore prolonging re-stabilization. Considering the aforementioned system dynamics, it can therefore be deduced that regime-level destabilization is intensified when multiple regimes undergo transition simultaneously.

Furthermore, the destabilization, change, and re-stabilization of a regime are not the result of one single experiment. The importance of creation and transfer of knowledge and experiences with respect to the development and emergence of niche-regimes was highlighted earlier in Section 2.1. One additional condition captured by both transition theory perspectives is aptly summed up by Raven (2005) who describes regime change as requiring "a long trajectory of many experiments and the emergence and stabilization of a niche level." Another important condition for transition is, thus, time.

3. Building industry as a socio-technical regime

The building industry is a mature industry that holds strongly to its conventions (Takim et al., 2013; Ye et al., 2009). As it currently exists, the building industry is largely supply-driven despite having little control over demand-side factors placed upon it (Davidson, 2013). Furthermore, the building industry is a highly stable, which implies that technologies and market conditions are tend to change slowly (Von Tunzelmann & Acha, 2009). Moreover, it is representative of a socio-technical system. This system can be characterized as a project-based "multi-industry" (Davidson, 2013) that relies upon temporary, project-based supply-side organizations (Bakker, 2010) to execute building projects that fulfill the requirements and expectations of demand-side actors. This heterogeneous nature results in considerable fragmentation within the industry, a consequence of which is the industry's notoriety for being generally inefficient (Ahbabi & Alshawi, 2015; Becerik-Gerber & Kensek, 2009; Ozorhon et al., 2010). The building industry is also distinguished by its generally risk-averse stance, strong values represented by the "iron triangle" of time, cost, and quality (Davis, 2017; Ye et al., 2009), and a tendency to stick to the status quo.

Taken as a whole, the characteristics of the building can be further associated with and reflected by a strong preference and tendency toward maintaining the status quo. Unsurprisingly therefore, the building industry is frequently characterized as being "low-technology" (Von Tunzelmann & Acha, 2009) and reluctant to innovate (Ozorhon et al., 2010; Sepasgozar & Bernold, 2012). In general, the building industry does not regard innovation as a productive activity because it requires the development and new knowledge and skills as well as new processes and systems (Davidson, 2013). Combined, these characteristics have led the building industry to lag significantly behind other industries (Dutta, 2015) When innovation does occur in the building industry, the process is generally slow and inefficient (Davidson, 2013), not only in terms of technology, but also in practices and processes. That the industry has not experienced appreciable change over recent decades (Egan, 1998) is testament to the industry's conventional stronghold.

As a socio-technical system, the building industry is also characterized by way of its constituent actors and actor networks. The building industry involves an elaborate variety of actors. Each brings with it a wide range of interests, requirements, and concerns (Ye et al., 2009), which are derived from unique motives and intentions that can be compatible, contradictory, or conflicting with those of other actors. Actors also bring with them a wide range of knowledge, skills, and other resources (Geels, 2002). The availability of these resources is a contributing factor to innovation in socio-technical systems (Loorbach & Rotmans, 2010). In order to provide structure when addressing these actors, this research groups them into three categories: demand-side, supply-side, and external.

Within the building industry, client organizations are a principle demand-side actor. They can vary in size and orientation. In smaller organizations, the building client may be a single person with considerable direct control. This person must therefore fulfill all roles, and often works with the aid of one or more external advisors. In the case of larger organizations, the building client is more often characterized by a larger body consisting of various professionals internal to the organization. They also typically have a larger amount of in-house expertise, and roles are allocated based on individual qualifications. Larger organizations are also more likely to be repeat customers, which provides them with knowledge derived from previous projects.

The supply-side is comprised of all stakeholders with the exception of the building owner. The supply-side represents the collective knowledge of the building industry. In general, this knowledge is technical and practice-oriented in nature. This collective knowledge can be broken down and attributed to the stakeholder groups, which highlights group-specific specializations. Further, in order for a group to be specialized, the individual stakeholders must have certain skills and qualifications. From all of this it becomes possible to more clearly and appropriately allocate roles to individual stakeholders.

Lastly, external stakeholders, such as governmental organizations, meanwhile affect similar power and influence, often through policy enacted at the landscape level. Because of the building industry's significant contribution to the economy, external actors also have a vested interest in its standing. Their interests also include safety, health and welfare, and increasingly environmental performance. This is especially true of governmental organizations, which are working towards compliance with the European sustainable development goals and the Paris Agreement.

4. Developments impacting the building industry

The importance of a solid understanding of the innovation context has already been addressed in previous sections. This section addresses this important research component by highlighting key developments at the landscape, regime, and niche levels that shape the context of this research topic.

4.1 Landscape-level developments

At present, the landscape-level changes stem from swift growth and expansion of pervasive developments ranging from globalization and digitization to major technological advances and reactionary stances against climate change. These developments, which are significant enough when considered in isolation, are even more provocative when considered as highly complementary forces of change. Landscape-level developments are resulting in a growing avalanche of change, the cumulative effect of which is now beginning to culminate in significant destabilization of the regime-level from the top down. This research highlights concurrent developments in data and digitization as well as sustainability and environmental welfare.

Data and digitization has been influential in the building industry. Combined with building information modeling, a niche-regime and focal point of this research that will be discussed at length later, the digitization of building information is increasingly changing actor relationships with technology and the expectations they have of it (Whyte & Hartmann, 2017). Consequently, both supply- and demand-side actors are redefining long-established roles and responsibilities and pursuing new avenues of collaboration and integration.

Sustainability and environmental welfare also play an increasingly prominent role, with implications that affect all industries in (nearly) every nation. As a result of the Paris Agreement of 2016, numerous national initiatives have been implemented with the hope of mitigating the impacts of climate change. These efforts are reinforced further by the European Union Sustainable Development Goals (SDGs), which require the policy of all member states to be reflective of these goals by 2030. Furthermore, the overarching conclusion drawn in the 2017 Emissions Gap Report by UN Environment (UNEP, 2017) was that an urgent need exists for accelerated, short-term action and enhanced, long-term ambition in order to fulfill the mission and goals set out by the Paris Agreement and SDGs. These landscape-level changes and resulting demonstrations of national commitment to improve sustainability, environmental and ecological conditions, and the use of natural resources have substantial implications for the building industry. Moreover, given that the construction and use of buildings is a primary target for improvements, these developments mark the arrival of the building industry at a crossroads and raises questions about its future trajectory. Uncertainty and doubt are also being piqued by increasing interest in circularity. Many countries have already taken first steps toward investigating the potential shift towards a (more) circular economy. Thus, it is reasonable to assume that landscape-level change is likely to imposed in the near future, the implications of which will have massive consequences for the building industry that will undoubtedly contribute to the destabilization of the industry regime.

The importance of these landscape-level developments has not gone unnoticed. In the Netherlands, progress is being made towards achieving sustainability and climate oriented goals by leveraging the power of data and digitalization. The most imminent development relevant to the building industry is the upcoming "Digitalization and Computerization of the Building Agenda", which is also referred to as the "Digideal [for the] Built Environment" (in Dutch, the *"Digitalisering en Informatisering uit de Bouwagenda"* and *"Digideal Gebouwde Omgeving"*).

4.2 Regime-level developments

The building industry is undergoing a series of procedural, organizational, and technological transformations in an attempt to respond to landscape-level developments. The industry has already made notable shifts towards adapting to and adopting proven trends. With this, however, has come the realization that the exiting, traditional foundation of the industry is incompatible. Clashes between old and new technology can arise, existing processes hinder or even hurt progress, and the people and culture within companies sometimes comes into conflict with what needs to be done to allow the "new" to thrive.

Although transformation within an incumbent regime is negligible compared to that of niche-innovation breakthrough and adoption, the dominant stream in the building industry still experiences ebbs and flows. Because changes within the regime-level are most often the result of minor pressures, tensions, and stress from either the landscape- or niche-level that nudge at the socio-technical regime, their origins tend to be indistinguishable. Notwithstanding, minor changes within the regime-level and a tendency to accrue over time can eventually result in a more significant change (Geels, 2002) that would be classified as a transformation pathway according to the typology of de Haan and Rotmans (2011). A good example of this phenomenon is changing values, which are often reflected in the form of trends. In a study by Ye et al. (2009), interviews with both supply- and demand-side actors in EU countries revealed important trends within the building industry (Table 3). The findings of this study indicate that key actors are looking beyond the conventional "iron triangle" to explore and seek out other types of added value. The demand-side is leading this trend, focusing on values such as productivity, sustainability, energy and resource efficiency, flexibility, and comfort (Ye et al., 2009).

Table 3. Top three important building industry trends in six groups (Ye et al., 2009)

Technological/building process	Ecological/environment	Social/cultural/demographical
1. New contract models (PPP)	1. Low-energy buildings	1. Social added value
2. New building processes (procurement)	2. Focus on climate changes	2. Increase smaller / single dwellings
3. Reconstruction, modernisation of old buildings	3. Increasing focus on energy efficiency	3. Improved knowledge infrastructure
Building functionality	Economic/financial	Regulations/political
1. Flexible buildings to adapt to changes of use	1. Focus on life cycle cost	1. Changes in the legislation
2. New solutions to existing building stock	2. Focus on energy management/energy costs	2. Quality standards & certificates
3. Multi-purpose/multi-use	3. Increase flexibility & reduce costs	3. Litigious society - impact on buildings

Despite nearly ten years having elapsed since the study was published, these trends have largely remained subordinate to the dominant stream. This provides further evidence of the staying power of the incumbent building industry regime and the challenges hopeful niche-regime face even when considered as an important industry trends with considerable potential. Despite the slowness of change, these trends indicate that windows of opportunity do exist within the regime-level.

4.3 Niche-level developments

In addition to impending destabilitory forces from the landscape-level, the traditional foundations of the longstanding industry regime are also being challenged by an upsurge of disruptive niche-level developments in the form of innovations. Niche-level developments have been growing in number and prominence as a result of new windows of opportunity that have been created in recent decades. Given the increasing level of instability at the regime-level, some newer niche-regimes, such as building information modeling and lifecycle-orientated building approaches, have already succeeded and are currently being embedded into the building industry's common practices. Though each development has a distinct origin, many have merged to form larger and more influential forces of change.

Although there are numerous niche-level developments, four themes of major, increasingly intertwined niche-regime developments are highlighted here: procurement, process, approach, and technology. Additionally, the developments described here can all be characterized as having that moved from lesser niche-level innovations to niche-regimes.

One development impacting the industry reflective change in both procurement and process is the rise of (more) collaborative forms of building procurement, such as integrated building contracts. The American Institute of Architects (AIA, 2007) defines integrated building contracting, otherwise known as integrated project delivery (IPD), as "a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively connects all the players in order to optimize project results, improve project performance, and maximize value and efficiency throughout the entire project life cycle." Increased collaboration on building projects has helped close some gaps and promote collaboration (Kent & Becerik-Gerber, 2010). One notable change is the increased involvement of downstream stakeholders during earlier project phases, especially during the early design phase. Despite this, many supply-side imperfections remain. These new collaborative forms of procurement represent a shift away from the temporary organizational forms typical of the traditional building industry. Despite a growth in popularity, the building industry still shows a preference for conventional procurement approaches due in part to a fear of additional risk and increased potential for liabilities (Chong et al., 2017).

Niche-level developments under the theme "approach" are affiliated with sustainable building practices. One set of approach related developments is "Lean" design and construction principles. Lean is a management-based approach focused on waste minimization and collaborative processed that work together to achieve maximum value. As such, Lean has much in common with IPD and other building processes. While Lean principles do take project lifecycles into consideration, they are typically limited to the traditional sense of a "project" wherein post-construction phases like use, maintenance, and operation tend to be excluded.

Another approach-based development seeking to fill these gaps, and another key feature of this research, is the development of lifecycle-orientated approaches to buildings. This cradle-to-grave mentality promotes consideration of all project phases from project conception to delivery of a completed building in addition to the use, maintenance, operation, any eventual reprogramming, and eventual decommissioning (Eadie, Browne, Odeyinka, McKeown, & McNiff, 2013). As a result of investigation into lifecycle-oriented building approaches, research has expanded to include other aspects of the building lifecycle, such as the maintenance and operation phases. Although lifecycle-oriented approaches to building offer many benefits, they are more complicated to implement than traditional approaches and are still largely unfamiliar within the industry due to infrequent use.

Building information modeling, more commonly referred to as BIM, represents the fourth theme, technology. BIM is arguably the most important innovation in the building industry today. Though it has existed in some form since the 1970s, it was not until the last ten to fifteen years that the awareness of BIM increased. BIM was first conceived as technological innovation. In years thereafter, BIM has evolved into an extremely powerful niche-regime with consequences for process, perspective, and even procurement. In fact, the range and extent of BIM implications makes it relevant to the entire multi-level perspective. Some researchers even believe the BIM represents a paradigm change with far-reaching benefits and impacts that affect not only the construction industry, but also society at large (Eastman et al., 2011) due to its promises for enhancing sustainability (Bynum et al., 2013) and promoting more holistic, lifecycle-oriented approaches to building projects (Eadie et al., 2013).

5. Current state of building industry transition

5.1 Current and future trajectory

Historically, the building industry regime was highly stable, which has led to deeply embedded values, practices, processes, and approaches that carry on to this day. Since the 1980s, however, this incumbent regime has been increasingly confronted by developments at the landscape, regime, and niche levels. The past two decades have displayed particularly influential developments with considerable increases in the frequency, amplitude, speed, and scope of changes (Suarez & Oliva, 2005) felt by the socio-technical building industry regime. During this period, the state of the building industry went from a well-established and stable dominant regime with a predominantly reproductive transition pathway to a state of increasing tension and pressure that could be categorized as reconfiguration.

Taken together, transition of the building industry in the last half century is characteristic of what Geels et al. (2016) dub "shifts between pathways." A new era of sustainability and long-term thinking is burgeoning, which needs to transcend into the way buildings are conceived, designed, constructed, and used. A new way of thinking and working is emerging to facilitate these needs, but the existing socio-technical system and the regime as it exists cannot effectively support it. Consequently, it has become increasingly apparent that the building industry is undergoing a transition, the rate of which can be expected to quicken and intensify.

Characterizing the future trajectory of transition in the building industry is complex. Up to now neither external conditions nor ebb and flow within the regime-level have created sufficient change to result in destabilization of the incumbent socio-technical regime. Thus, the conditions to stimulate significant evolution or transition are not yet present, though they do appear to be strengthening (Thelen, 2003). The changes that have occurred up to this point have brought with them an increase in complexity, both at the industry regime level and also at the project level. Complexity magnifies the impact of change and the resulting destabilization. As such longstanding issues within the industry derived from its fragmented nature are posing new problems with respect to, among other things, decision-making processes, coordination, and collaboration (Ye et al., 2009).

Referring back to the transition pathways put forward by de Haan and Rotmans (2011), many of the typologies can be eliminated. This research excludes the possibility of a failed transition, and grounds have been set predicting that regime adaptation will occur. What is less clear is the direction from which change will come. Considering that the building industry is currently undergoing significant influence from both the landscape and niche levels, it can be deduced that the influence is not purely top-down or bottom-up. Therefore, neither "radical reform" nor "reconfiguration" is characteristic of the ongoing transition. This leaves two possibilities: the squeezed (top-down and bottom-up) teleological pathway and the adaption dominated transformation pathway.

Recapping these two typologies, teleological transition pathways are "the result of a regime adapting to changed circumstances not by reforming itself but allowing outside influences to reconstellate structures and cultures and simultaneously incorporating novel functioning in these processes" (de Haan & Rotmans, 2011). In transformation transition pathways, transformation occurs within the regime itself via an ongoing evolutionary process of adaption. In this process, the regime responds to tensions and stress by changing itself in a self-steering process so as to meet needs and demands once more. It also frequently involves the absorption of niches or co-evolution with the niche-level (de Haan & Rotmans, 2018).

On the one hand, a teleological pathway appears to be applicable. The incumbent regime is beginning to waver, especially as landscape- and niche-level developments come closer to a destabilizing harmony. Developments in BIM and lifecycle-oriented approaches in particular are nearly in alignment with landscape-level developments. On the other hand, a well-organized driving force external to the regime has yet to materialize. For example, although the aforementioned niche-regimes have experienced individual successes, it has proven difficult for a larger niche featuring two or more merged niche-regime innovation to take form. Consequently, it is most likely that the existing regime will not be replaced. Rather, the building industry seems increasingly willing to undergo adaptation, which is in agreement with the transformation pathway. However, complete transformation from within the regime itself is also doubtful because of the industry's supply-demand relationship, risk-averse nature, and preference for stability. Furthermore, this is in keeping with de Haan and Rotmans' (2011) stance that internally induced change is insufficient to produce a "proper transition". As such, both the teleological and transformation transition pathways have their merits and faults. Thus, the current transition in the building industry can be best characterized simply as dynamic and involving all three levels. With respect to the future, the transition is likely to be complex, non-linear, and distorted by uncertainty. The element of time is also a considerable variable, especially given the dawdling history of transition in this particular dominant regime.

5.2 Insufficient conditions for transition

Following in line with transition theory, the harmonization of these landscape- and niche-level developments has begun to destabilize the incumbent building industry regime. As a result, new windows of opportunity continue to open for niche-regimes to break through and start competing against what was once a stable, long-established regime. The level of destabilization, however, appears to be insufficient to bring about transition of sufficient speed and intensity.

Although theory suggests that successful niche breakthroughs and amalgamation with the transition pathway stand the chance of giving way to new, stabilizing socio-technical configurations (Fuenfschilling & Truffer, 2014), the reality of the building industry portrays a more complicated set of circumstances. Furthermore, the mounting complexity and instability at the regime level makes the adoption and implementation of new technology markedly more challenging (Sepasgozar & Bernold, 2012). Furthermore, the building industry is not only quite resistant and averse to change but also poorly suited to pursue change even when desired. Further complicating the occurrence of innovation in the building industry is that innovation tends to be driven by demand-side (e.g. client) needs and requirements (Ozorhon et al., 2010; Ye et al., 2009). At first, this seems contradictory given that the industry is largely supply-driven. However, conventions dictated by the well-established mainstream result in a tendency to preclude innovation unless it is in favor of supply-side actors.

This is not to say, however, that innovation does not occur. Although the building industry has earned a reputation for being "low-technology" (Von Tunzelmann & Acha, 2009) and reluctant to innovate (Ozorhon et al., 2010; Sepasgozar & Bernold, 2012), these are characteristics applicable to the industry regime as a whole. Individual projects, however, can be considered as protective spaces in which innovation can occur. In general, it is individual exemplary building projects that exhibit considerable innovation (Barrett et al., 2007). A caveat for innovation in the building industry is, therefore, that innovation occurs on individual projects, which are temporal in nature. Moreover, the knowledge and experiences gained in the execution of such innovation is rarely diffused due to poor knowledge transfer processes, industry fragmentation, and the frequent desire of companies to withhold proprietary information (Artto et al., 2008; Davidson, 2013; Koutamanis, 2017). As such, innovation in the building industry tends to occur in the form of ad-hoc, localized experiments. In failing to create a network and develop structuration, innovations struggle to gain the traction necessary in order to evolve into niche-regimes.

Because of these and other difficulties niche-regime breakthrough and adoption can be significantly hampered. These conditions could, for instance, produce a situation in which a window of opportunity exists for breakthrough into the regime-level without a line-up of sufficiently competitive niche-regimes to take advantage of it. In another scenario, an underdeveloped niche-level innovation may emerge only to fail in its competition with the dominant regime due to unpreparedness. This type of failure is unfortunate for otherwise promising innovations as failure causes them to fall victim to negative opinion, thus reducing or eliminating their change at uptake in the regime-level. In short, without viable niche-regimes there is no competition, and therefore no contribution to regime destabilization and diminished conditions for transition. Conversely, windows of opportunity may not appear altogether. The fragmented nature of the building industry in particular makes it difficult for actors to discern benefits of an innovation, which in turn diminishes the motivation of actors to pursue an innovation. Without this motive and intent, actor alliances and their respective resources cannot come together (Davidson, 2013). As such, niche-regimes cannot come into being.

6. Conclusion

In the multi-level perspective (MLP), transition is viewed as a dynamic, iterative and interwoven process occurring within and between the landscape, regime, and niche levels that occurs over time. The MLP emphasizes the role of developments and inter-level influence, focusing predominantly on how niche-level innovation experiments arise and bring about changes that stimulate regime-level transition. The extent of these factors is dependent upon the timing and nature of interactions between the three levels.

In short, transition occurs as the result of change that destabilizes the dominant regime and subsequent re-stabilization. The extent of destabilization relates to the frequency, amplitude, speed, and scope of changes that occur at any of the three levels, though internal regime-level change is usually negligible. The pressure, tension, and stress at the regime-level caused by such changes results in destabilization, which creates windows of opportunity for viable niche-regimes to break through into and compete with the regime. Various outcomes dependent on the presence or absence of regime adaptation are possible, which in turn dictate the re-stabilization of the regime level and transition pathway.

Such an urgent need, however, comes into direct conflict with the conventional stronghold and slow-to-change nature of the building industry. Although the building industry’s attitude towards challenge and change is often despondent, such developments also pose new opportunities.

Although outright transition is unattainable in socio-technical regimes, adaptation and transformation are possible. However, neither can efficiently nor effectively occur in the absence of sufficient stability. Thus, for a regime to progress further along its transition pathway, the stability of the regime must first return to a certain acceptable level. Because of the nature of socio-technical regimes and regardless of the source and extent of change, it is the actors and actor alliances that ultimately shape and direct the transition path.

Due to the critical importance of niche-level developments and their influence on regime transition, it is worthwhile to explore what could be done to improve conditions for the transition to a more sustainable building industry. Given the potential of BIM and the pressing need for viable niche-regimes in order to stimulate transition, it prudent to explore how this particular niche-regime could contribute to the transition to a more sustainable building industry. The proceeding chapters aim to contribute to this body of knowledge and address questions posed by this research.

Because innovation is both an individual and collective process, a systems approach is necessary to cope with the complexity and interconnectedness of innovation of socio-technical systems. Furthermore, a technological innovation systems perspective emphasizes the role of contextually dependent systems dynamics in shaping the functions critical to the workings of a socio-technical system.

References

Ahbabi, M. Al, & Alshawi, M. (2015). BIM for client organisations: A continuous improvement approach. *Construction Innovation*, *15*(4), 402–408. https://doi.org/10.1108/CI-04-2015-0023

AIA. (2007). Integrated Project Delivery: A Guide. *American Institute of Architects*, 1–62. https://doi.org/10.1016/j.autcon.2010.09.002

Artto, K., Martinsuo, M., Dietrich, P., & Kujala, J. (2008). Project strategy: strategy types and their contents in innovation projects. *International Journal of Managing Projects in Business*, *1*(1), 49–70. https://doi.org/10.1108/17538370810846414

Bakker, R. M. (2010). Taking Stock of Temporary Organizational Forms: A Systematic Review and Research Agenda. *International Journal of Management Reviews*, *12*(4), 466–486. https://doi.org/10.1111/j.1468-2370.2010.00281.x

Barrett, P., Abbott, C., Ruddock, L., & Sexton, M. (2007). Hidden innovation in the construction and property sectors. *RICS Research Paper Series*, *7*(20), 1–21. Retrieved from http://usir.salford.ac.uk/id/eprint/18373%5Cnhttp://amr.aom.org/content/14/4/562.short

Becerik-Gerber, B., & Kensek, K. (2009). Building information modeling in architecture, engineering, and construction: Emerging research directions and trends. *Journal of Professional Issues in Engineering Education and Practice*, *136*(3), 139–147. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000023

Chong, H. Y., Lee, C. Y., & Wang, X. (2017). A mixed review of the adoption of Building Information Modelling (BIM) for sustainability. *Journal of Cleaner Production*, *142*, 4114–4126. https://doi.org/10.1016/j.jclepro.2016.09.222

Davidson, C. (2013). Innovation in construction – before the curtain goes up. *Construction Innovation*, *13*(4), 344–351. https://doi.org/10.1108/CI-02-2013-0007

Davis, K. (2017). An empirical investigation into different stakeholder groups perception of project success. *International Journal of Project Management*, *35*(4), 604–617. https://doi.org/10.1016/j.ijproman.2017.02.004

de Haan, F. J., & Rotmans, J. (2018). A proposed theoretical framework for actors in transformative change. *Technological Forecasting and Social Change*, *128*(December 2017), 275–286. https://doi.org/10.1016/j.techfore.2017.12.017

de Haan, & Rotmans, J. (2011). Patterns in transitions: Understanding complex chains of change. *Technological Forecasting and Social Change*, *78*(1), 90–102. https://doi.org/10.1016/j.techfore.2010.10.008

Dutta, S. (2015). *The Global Innovation Index 2015. Stronger Innovation Linkages for*. https://doi.org/978-2-9522210-8-5

Eadie, R., Browne, M., Odeyinka, H., McKeown, C., & McNiff, S. (2013). BIM implementation throughout the UK construction project lifecycle: An analysis. *Automation in Construction*, *36*, 145–151. https://doi.org/10.1016/j.autcon.2013.09.001

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM Handbook: A Guide to Building*

Information Modelling For Owners, Managers, Designers, Engineers and Contractors Second Edition. *John Willey & Son Inc*. https://doi.org/10.1002/9780470261309

Egan, J. (1998). *Rethinking Construction : The Report of the Construction Task Force*. *HMSO*. https://doi.org/Construction Task Force. Uk Government

Fuenfschilling, L., & Truffer, B. (2014). The structuration of socio-technical regimes—Conceptual foundations from institutional theory. *Research Policy*, *43*(4), 772–791. https://doi.org/10.1016/j.respol.2013.10.010

Gaziulusoy, A. I., & Brezet, H. (2015). Design for system innovations and transitions: A conceptual framework integrating insights from sustainablity science and theories of system innovations and transitions. *Journal of Cleaner Production*, *108*, 1–11. https://doi.org/10.1016/j.jclepro.2015.06.066

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, *33*(6–7), 897–920. https://doi.org/10.1016/j.respol.2004.01.015

Geels, F. W., Kern, F., Fuchs, G., Hinderer, N., Kungl, G., Mylan, J., … Wassermann, S. (2016). The enactment of socio-technical transition pathways: A reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990-2014). *Research Policy*, *45*(4), 896–913. https://doi.org/10.1016/j.respol.2016.01.015

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy*, *36*(3), 399–417. https://doi.org/10.1016/j.respol.2007.01.003

Koutamanis, A. (2017). Briefing and Building Information Modelling: Potential for integration. *International Journal of Architectural Computing*, *15*(2), 119–133. https://doi.org/10.1177/1478077117714914

Loorbach, D. (2010). Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework. *Governance*, *23*(1), 161–183. https://doi.org/10.1111/j.1468-0491.2009.01471.x

Loorbach, D., & Rotmans, J. (2010). The practice of transition management: Examples and lessons from four distinct cases. *Futures*, *42*(3), 237–246. https://doi.org/10.1016/j.futures.2009.11.009

Ozorhon, B., Abbott, C., & Aouad, G. (2010). Innovation in Construction: A Project Lifecycle. *SCRI Research Report 4*, (August 2016), 903–912. https://doi.org/10.13140/RG.2.1.1235.1203

Raven, R., Bosch, S. Van den, & Weterings, R. (2010). Transitions and strategic niche management: towards a competence kit for practitioners. *International Journal of Technology Management*, *51*(1), 57. https://doi.org/10.1504/IJTM.2010.033128

Raven, R. P. J. M. (2005). *Strategic niche management for biomass*. Eindhoven University of Technology.

Sepasgozar, S. M. E., & Bernold, L. E. (2012). Factors Influencing Construction Technology Adoption. In *International Conference on Sustainable Design, Engineering, and Construction 2012*. Retrieved from https://doi.org/10.1061/9780784412688.078

Suarez, F. F., & Oliva, R. (2005). Environmental change and organizational transformation.

Industrial and Corporate Change, *14*(6), 1017–1041. https://doi.org/10.1093/icc/dth078

Takim, R., Harris, M., & Nawawi, A. H. (2013). Building Information Modeling (BIM): A New Paradigm for Quality of Life Within Architectural, Engineering and Construction (AEC) Industry. *Procedia - Social and Behavioral Sciences*, *101*, 23–32. https://doi.org/10.1016/j.sbspro.2013.07.175

Thelen, K. (2003). How Institutions Evolve: Insights from Comparative Historical Analysis. In *Comparative Historical Analysis in the Social Sciences*. https://doi.org/10.1111/j.1469-0691.2011.03558.x/pdf

United Nations Environment Programme (UNEP). (2017). *The Emissions Gap Report 2017 - A UN Environment Synthesis Report. United Nations Environment Programme (UNEP)*. https://doi.org/ISBN 978-92-9253-062-4

Von Tunzelmann, N., & Acha, V. (2009). Innovation In "Low-Tech" Industries. In *The Oxford Handbook of Innovation*. https://doi.org/10.1093/oxfordhb/9780199286805.003.0015

Whyte, J. K., & Hartmann, T. (2017). How digitizing building information transforms the built environment. *Building Research and Information*, *45*(6), 591–595. https://doi.org/10.1080/09613218.2017.1324726

Whyte, J., & Sexton, M. (2011). Motivations for innovation in the built environment: New directions for research. *Building Research and Information*, *39*(5), 473–482. https://doi.org/10.1080/09613218.2011.592268

Witkamp, M. J., Raven, R. P. J. M., & Royakkers, L. M. M. (2011). Strategic niche management of social innovations: the case of social entrepreneurship. *Technology Analysis & Strategic Management*, *23*(6), 667–681. https://doi.org/10.1080/09537325.2011.585035

Wong, J. K. W., & Zhou, J. (2015). Enhancing environmental sustainability over building life cycles through green BIM: A review. *Automation in Construction*. Elsevier B.V. https://doi.org/10.1016/j.autcon.2015.06.003

Ye, J., Hassan, T. M., Carter, C. D., & Kemp, L. (2009). Stakeholders' requirements analysis for a demand-driven construction industry. *Journal of Information Technology in Construction*, *14*(October), 629–641. Retrieved from http://www.itcon.org/2009/41

Appendix B: Exemplary interview questions

Q1: Can you introduce yourself and tell a bit about your role within the organization?

Q2: What kind of building client organization is the organization?

(e.g. public, private, semi-public)

Q3: Can you explain to me in your own words what BIM is?

Q4: Why does the organization want to use BIM?

Q5: What are the advantages of BIM adoption for the organization?

Was it these advantages that convinced the organization to adopt BIM?

Are there other factors that influenced the organization's decision to adopt BIM?

Q6: Would you say that the organization is committed to moving forward with BIM?

When did this commitment occur?

Q7: In your opinion, what have been the biggest barriers to adopting BIM?

Would you say that the barriers are primarily internal, external, or comparable?

Q8: What role do you think the organization plays in the industry's adoption of BIM?

As a public organization, is the organization also externally motivated to adopt BIM?

What are these external factors?

Q9: Why does the organization want to use BIM?

Q10: How does the organization currently use/implement BIM on its building projects?

What are the expectations for future use?

Q11: What kind of steering devices or techniques does the organization use to implement BIM on its building projects?

(e.g. procurement method, contractual/written devices, standards)

Would you describe these devices/techniques as effective? Why or why not?

Q12: In addition to formal steering devices and techniques, what has the organization done to communicate its BIM strategy and promote BIM use to the industry?

(e.g. educational workshops, collaborative think tanks)

Do you believe that this communication and promotion have been successful? Why or why not?

Q13: What role do you think the organization plays in stimulating the lifecycle-oriented use of BIM on its building projects?

Q14: What barriers does the organization see in implementing BIM across the entire lifecycle of a building?

What has been done to reduce these barriers already?

What will or could be done in the future to further reduce these barriers?

Q15: Does the organization have an organization-level strategy for the adoption and implementation of BIM?

Does the organization have clearly defined mission, vision, and goals for BIM?

Would you say that there are clear links between the organization's organization-level BIM strategy and the project-level BIM strategy?

Q16: How would you describe the process of adopting BIM within the organization up to this point?

(adoption within the organization itself, not on individual projects)

(e.g. level of effort required, duration, level of cooperation/participation)

Who has been involved in this process?

Do you feel that BIM is compatible with the organization and its way of working?

Has there been any resistance to the proposed changes?

Q17: Does the organization see BIM as something they have to get right the first time, or as an evolutionary process?

Q18: What is the organization's outlook on BIM for the future?

(e.g. positive, negative, mixed)

Q19: What is your outlook on BIM for the future?

Appendix C: Interview responses

Case 1 interview responses

	CASE 1		
	Interview A	Interview B	Interview C
Profile	Background in architecture; Currently works in building knowledge management within the organization, focus on BIM, sustainability, safety, etc.	Building informatics background Advisory and improvements of real estate information for the org. Approx. 25 years in the org. Explore the possibilities of (new) technology for portfolio information mgmt and other real estate related applications Senior building information advisor	Strategy and vision development within the org. Background in urban planning Approx. 3 years within the org.
Familiarity with BIM	Familiar with 3D modeling, has used it in his work	Considerable knowledge on the topic complimented by a high awareness of developments over time	Became familiar with BIM about two years ago when tasked with strategy development
What is BIM?	"BIM = building information model information connected to all its parts various levels of detail"	"I can only give you my opinion because there are a lot of discussion about how to interpret that term." "Whenever people start to work together on the basis of geometrically integrated information, I start to call that BIM." emphasis on the geometry aspect of BIM not a term specific to a specific building lifecycle phase "The essential thing is not the geometry itself but the fact that all kind of valuable bits and pieces of information are connected to the geometry in a clever way."	"a digital building with all of the information that can be viewed in 3D layers" "it's about working together ... with building related data"
SOCIAL			
awareness	not clear to everyone what the added value of BIM is or can be	almost no one within the org. has experience working with BIM few people realize that a type of BIM that lies between the two extremes (e.g. do nothing and solve everything) is possible or wise	"BIM is in the shadow" within the org.
perception of innovation	BIM unlocks new ways to "get in touch with our core business" still need to determine how useful BIM is/can be for the org.	When introducing BIM to those who are unaware of the technology, two types of reactions were highlighted: "This is marvelous, it's going to solve everything" "This is far too complicated, let's not do it" those introduced to BIM see it as an interesting innovation, but also as something impossible to achieve in practice and are therefore less willing to innovate	"it's a must for us"
motivation to innovate	follow in line with market developments be part of the modern movement not fall behind want to fulfil their clients needs (e.g. suitable accommodations)	benefits of a better organized information database that can increase the effecacy of portfolio mgmt; a control point of view	BIM is a necessary communication tool
willingness to innovate	status quo is fine a lot of the people in the org. are more into asset mgmt, M&O; they do not see enough added value to sway them into wanting to incorporate the innovation speed and enthusiasm varies	positive reactions tend to be quite naïve negative reactions lead to immediate disapproval those who work in operations are particularly sceptical because of their prior experiences, having seen already how difficult it is to do information management with other systems that were considerably simpler many perceive that the task at hand (e.g. mgmt of large amount of information in traditional databases) is already challenging enough	"enthusiasm, this human component, is very important" "I want to make them enthusiastic about using BIM"
adaptability	people in the org. are not designing buildings themselves, so their functions/tasks would stay the same convenient technology in theory	largely a passive attitude; won't move forward with BIM unless forced a lack of initiative	"There's always resistance to change" the four organizations that have merged have their own sets of values which are still influential even four years after the merger occurred; some of the former organizations are more adaptable and interested in innovation than others
ORGANIZATIONAL			
standing	public organization hire a lot of people large volume of work recent merger	a procurement organization, thus relies heavily upon external knowledge and services the client role is the primary focus most of the work is externalized, which puts the org. into a vulnerable position	the current org. is the result of a merger of four organizations that occurred four years ago future direction of the org. is still hazy still working on becoming one unified org. a major player in the industry
mission & purpose	majority of the work is maintenance oriented "we are a maintenance organization" maintenance, operation, and asset management activities		continued shift to a more procurement driven/focused org. provide suitable and well maintained accommodations to governmental agencies focus on creating a sustainable real estate portfolio
power & influence	big player in the market "we have been leading" with respect to standardization and information requirements (e.g. BIM norm) industry has actively been adopting this norm	publication of BIM norm had an influence when first published (approx. 8 years ago) has a unique position to stimulate market adoption and implementation of BIM given its standing "The best we can do in stimulating the outside world is by showing that we take this information aspect really seriously." has the ability to influence and inspire both supply-side and also other demand-side organizations, especially when leading by example	because of the org.'s involvement in all lifecycle phases, it is in a unique position to stimulate the market "as a big organization, we can force [the market] to comply" "We feel stronger in projects than we do in standardization."
roles & responsibilities	external parties expect an org. with considerable expertise; well developed requirements; role model	hold the end responsibility for their buildings, also for safety, welfare, etc. primary responsibility is internal to the org. despite the impact it can have on the market	the organization is involved in and responsible for every building lifecycle aspect
capacity	many employees have only basic technology skills; would not know how to make use of BIM a variety of specialist knowledge is available in house few modellers in the organization		
INTENTIONS			
vision	complete digitalized portfolio / BIM database for internal use as a main driver clearer, less abstract, better information oversight	have reliable and ready to use information, not for the pure purpose of building maintenance work (which is done by an external party), but rather for portfolio management and compliance oriented issues	want to have entire buildings available in BIM streamline communication between auxilary organizations under the larger umbrella org. (includes real estate mgmt, IT, operations) by all using the same BIM models/information database work towards enabling BIM use throughout all building lifecycle phases
expectations	"cliché advantages" like less failure costs	org. expects that the contracted party can demonstrate what they are working on, but do not specifically require that they must use BIM in its work (though the contracted party often uses BIM for its own advantage anyway)	
goals & objectives	focus on asset mgmt better information mgmt move in a 3D direction creation of an information exchange system	pilot projects will use BIM as a collaboration tool take a M&O focus on new protocols and standardization with the hope of increasing applicability and usefulness of the information that is delivered upon project completion make sure the the M&O information required has a business case; info without a true use will be neglected and ultimately bogg down the system	some goals based on incremental BIM advancements in the coming years no specific qualitative goals "My goal is to have people come to me and say 'Hey, I want to use BIM' and then connect them to the right person."
needs & requirements	important to figure out so that org. does not swamp itself with unnecessary information	for the larger part, BIM information for the create a better internal understanding of what the org. actually needs in order to carry out M&O on their buildings working towards developing a specific set of information requirements relating to the maintenance phase	
strategy		no formal strategy at this point in time; a few guidelines do exist decision was made to stop trying to dictate the way BIM is used for design and construction, focus instead on how the information needs to be delivered for M&O use	no clear strategy at this point in time

	CASE 1		
	Interview A	Interview B	Interview C
POSITIONING			
network relations	work with contractors to develop BIM Basis ILS (BIM basic information delivery specifications / BIM basis Informatieleveringspecificatie) / BIM Loket with other major public organizations pursuing BIM	networks established via contract (difficult to comment on the informal aspects of the relationship) network formation between primary actors is improving, but further supplychain integration is still fragmented, which creates additional though less obvious barriers the conglomerate struggles to function as a whole, which results in considerable information loss and rework heavy reliance upon contractors, all of which have their own way and preferences for information mgmt too many actors is the network make the false assumption that the way BIM information is structured and organized for design and construction is well-suited for M&O use, though that is not the case	the org.'s internal BIM program (network of employees) is comprised only of people who are completely pro-BIM; sceptics are not partiuclarly interested nor welcome difficult to communicate with the contractors because the org. does not work with BIM BIM is quickly becoming an essential tool for the promotion and support of network relations "If we were not at the table, maintenance and operation would not have been included [in the Digideal]" supply-side does not welcome the M&O focus because it makes their work more challenging as they need to cater to a demand that does not directly benefit them
resource mobilization		difficult to convince mgmt that investing in skill development for unproven innovations is worthwile understaffed, which makes it difficult to train current employees to work with new innovations external parties have successfully delivered BIM information prior to the delivery of a new building or after a renovation process was completed, but updated information thereafter has never been provided this occurred despite explicit performance requirements for updated information to be provided in the M&O phase as stated in the contract	resources heavily invested in post-merger and normal day-to-day activities few resources avaialble to focus on new developments after the merger is complete, resources will free up that could be refocussed/allocated to BIM-related efforts funding and HR is limited, which is slowing the greater adoption effort
steering devices	Governance (e.g. Digideal) creation of a national-level BIM norm project procurement and contracts required use of BIM on new projects as specificied by the BIM norm	pilots will be built off of an existing maintenance oriented contract form that the org. has considerable experience with BIM norm invoked the specification/expectation that the org. would receive BIM information in adherence to a specific structure from the external parties the BIM norm was connected specifically to DBFMO style contracts DBFMO contracts promoted the delivery of an integrated product, including an integrated information product based on the BIM norm DBFMO contracts were long term, which promoted the M&O aspects of the building lifecycle performance oriented contracts	BIM norm predates the org. merger, but is not being addressed within the harmonization effort BIM standarization efforts Digideal contracts and standardization are the most powerful tool to enforce requirements and ensure that the supply-side/market conforms to the established requirements the org. is moving away from using DBFMO contracts now that some of the downsides are being experiences; investigating other options
knowledge & learning	few examples of the innovation having been used for those sorts of functions BIM/GIS group	lack of concise understanding of what information is actually needed for M&O; current approach is too ad hoc when introduced to the technology, the often extremely high LOD (likely attributed to them BIM model having been used for the design phase) is too intimidating, especially compared to what most have previously experiences should start training people to work with BIM, but that requires mgmt approval attempts at knowledge diffusion through model demonstrations are often daunting and create a sense of alarm at the thought of the org. needing to execute such a change need to reflect on what information has been needed and useful in the past and to bring that into the required information use practical insights to determine information requirements	taking subtle steps to raise awareness, which is helping to stimulate some discussion organization of BIM awareness events "we have to do more" wants to stimulate the human component of innovation adoption try to present BIM as a tool to make progress in and to fulfill the org.'s mission and purpose the duration of these projects makes it such that lessons learned are not quickly available
innovation process	not leading in day-to-day use	previous examples of standardization, especially those for CAD, were "quite superficial" and left too much freedom to the external parties; the resulting data was not uniformly structured struggle to ensure that the information generated by the contractors is also able to be used within the org. current information structuring is not usuable in the long-term, it is very much geared to the specifics of one particular building lifecycle phase and/or one specific actor within the network purely discussion based decision-making is too slow	focus is on the merger rather than on new innovation adoption although resouces can be hard to come by, the org. is better positioned to experiment with new innovations compared to major semi-public organizations "We can develop BIM in a lifecycle-oriented way if we do it on our own." the org. has placed itself as a champion of sorts to ensure that M&O aspects are incorporated into national-level BIM efforts involving both supply- and demand-side actors innovation is inherently annualized because funding is allocated on a per-year basis continue to move forward; make side-steps if something does not work out rather than retreating back to the status quo
ADVANCES			
leadership & commitment	top-down upper mgmt and more grassroots supporters small group very committed, the rest is neutral	leading by example may be much more powerful than leading on a managerial level; a much more "real effect" Some in the org. are committed, especially with respect to how the org. will operate in the future The majority does not know what BIM means, have never seen anything like it, and show no interest in bothering with BIM	bottom-up motivated approach committed, but mostly because it is not an option anymore full team support would be very helpful, especially since "BIM is going to happen" and there is "no way back"
adoption	focus on pilots start off simple and evolve/move on to more complicated uses later lack of available BIM functionality for M&O or asset mgmt remains quite low overall	decision to adopt BIM and implement the innovation on experimental projects has been made utilize a pilot scale and testing to see if improvement is possible; a step by step process	has the impression that the adoption would be much further along today if the merger had not occurred efforts have reached a plateau
implementation & use	implement BIM themselves on a few smaller projects in the operation phase in general, most BIM use related to the org. is carried out by contractors and other third parties we get models, but they are not useful for use as-is data mgmt is much more difficult than most people thought at the outset	preparing for new pilots scheduled to start next year pilot sets up a collaborative effort between the public org. and private/public parties for building maintenance and facility management (a total of three parties; the public org. is the end responsbile party) to be implemented on existing buildings	currently, BIM has only been implemented on DBFMO contracts new pilot projects where BIM is used in a targeted way, no for the entire building there are ultimately just two ways to implement BIM, the "Dutch way" or the "American way" (e.g. a more democratic and discussion oriented approach or a direct and forced approach) development of new norms and standards are done the "Dutch way" experimentation and pilots are done as a hybrid/more "American way"
change process	evolutionary process slow	the necessary changes are not all related to BIM itself some of the problems impeding change have existed for a long time already (e.g. CAD drawings, technical asset information) very difficult to create a uniform structure to organize and manage the information collected from the various parties downstream actors in the supplychain struggle from similar problem as those experienced by the org. the few people who are working of promoting BIM adoption within the org. see the process is evolutionary	still working and highly focused on post-merger activities harmonization program, less emphasis on optimization BIM is not being addressed as part of the harmonization effort implementing BIM requires changes in the way the org. is organized, perhaps even evolve into a different type of organization although a forced approach is possible, an awareness based and friendlier approach is preferred to stimulate intra-organizational BIM adoption and eventual implementation trying to stimulate change within the org. and within the market simultaneously evolutionary process
future outlook	optimistic	idea of creating new department for information mgmt as a future need positive outlook "It will be a slow moving, step by step process" looking back on the developments ten years from now, an appreciable change should be obvious no expectation of a "spectacular technological advancement" that will solve the existing problems	there is no set timescale dictating how the org. will move forward with BIM adoption, implementation, or (re)evaluation at this point in time the org. structure needs to evolve in order to better support BIM, especially with respect to internal collaboration and involvement "I hope BIM is going to make us a better partner for everyone to work with."

Case 2 interview responses

	CASE 2	
	Interview A	Interview B
Profile	sustainability advisor focus on creating a more sustainable real estate portfolio BREEAM, healthy buildings, circularity advise and inform colleagues; assist with strategy development approx. 1 year within the org.	head of building information mgmt daily operations, document mgmt working on developing a plan for the future of the department approx. 2 years within the org.
Familiarity with BIM	familiar with BIM as an innovation and its potential uses for real estate mgmt no direct work with BIM	very familiar, especially wrt. technical aspects of BIM
What is BIM?	digital version of a buildings proposed/envisioned version during design and construction phases; living version during use/operations phase an up to date version of the existing building tool for building end of life, especially with respect to material reuse and recycling suprised that BIM adoption in the industry is still quite behind where he expected it would be by now (10 year time period)	"a more intelligent way of dealing with information" tool for connecting various types of information tool that can "help people make their own connections in the future"
SOCIAL		
awareness	interest in BIM has grown via internal communication and network building BIM is discussed within a small group aware that there are benefits, but not the full range of possibilities	need to raise awareness of the complexity of BIM
perception of innovation	sees a variety of benefits in the beginning, it was not clear to many in the org. (real estate side) what BIM was or its benefits	"it would be a great help" endless possibilities, just have to set the information up in the right way to enable it "really different from how we do things right now" BIM is more than just a model or a specific software, it is about intelligence that the implementation is not going fast enough
motivation to innovate	sustainability targets (e.g. saving energy, reducing emissions) wants and needs of society circularity use the protocol as a "quick win" to catch back up with the market	"we can help invent the wheel" "connect to what is happening in the market"
willingness to innovate	"I believe we are open for innovation" open to innovation so long as it proves its worth "we're investigating our options" "need to see how we can incorporate it as soon as possible" "as an organization, we are willing to embrace BIM" external parties do not see the org. as willing to innovate because the org. does not want to receive the BIM models	already seeking out sustainability certifications (e.g. BREEAM) "everybody wants to go for [BIM]" "there's almost no resistence" "If there was a system available, we would have a consultation right here, right now and probably choose it."
adaptability	decisions take time, no quick decision-making heavy reliance on research and proof/evidence	
ORGANIZATIONAL		
standing	semi-public organization running behind the market org. undergoing reorganization "the whole building industry is quite traditional"	semi-public organization
mission & purpose	real estate maintenance & operation	
power & influence	actively form alliances, team up to help stimulate the market "we try to push for a shift where we work on more integrated contracting"	
roles & responsibilities	would like to see the org. take on a stronger role in influencing sustainability related change if they can have a say in making forward progress, accept it as a responsibility "we also need to provide more input in the design phase"	
capacity	specialist knowledge in house "we need to start training people"	modeling is a weakness some in-house M&O technicians specialized maintenance is hired in
INTENTIONS		
vision	"I hope there is [a vision], but it hasn't been shared with me"	want to integrate the work of the various departments (e.g. real estate and M&O) a system supported by a protocol
expectations	"It's about the total lifecycle. I wouldn't choose one [phase] over another"	wants a more lifecycle-oriented approach IFC model (Industry Foundation Classes)
goals & objectives		use BIM for better archive mgmt code compliance building energy demands; linking that information to "the system" "our emphasis should be more on exploitation"
needs & requirements		"we go from almost no [BIM] demands to extremely high demands; there is no inbetween"
strategy	at present, "the protocol is the strategy"	

	CASE 2	
	Interview A	Interview B
POSITIONING		
network relations	"BIM is starting to connect the various parties in the design phase" changes impending on how teams interact, when they are incorporated in projects switch to project teams the market is further along than the org.	working on developing multi-organization BIM protocol network includes all parties within the category (approx. 12 organizations in total) recent reorganization building and information mgmt group was formerly grouped together with real estate department, now part of facilities/M&O department building and information mgmt could belong anywhere because it is relevant to "everybody" operations and maintenance is a separate department within the org.; real estate and asset mgmt is another department also has relations with national government initiatives and other large players (also happen to be public/semi-public orgs.) more bonds being created as a result of more integrated approach, pursuit of lifecycle-orientation
resource mobilization	potential barriers on the HR level in the future "do we have the right person in place" need a plan for the future wrt. staffing to make sure BIM can be used effectively "we don't even have the software to be able to open these BIM models"	there is no platform/system upcoming BIM protocol includes (some) staffing aspects IT (e.g. compatible computers) new hire(s) to boost weaknesses in near future handheld, portable tools that M&O technicians use in day-to-day work are already being used
steering devices	future projects will contractually require that the BIM protocol is followed (following testing)	working on developing multi-organization BIM protocol (2 years in development) a 2D protocol for deliverables has been used for many years already; general 2D models/drawings and a more M&O oriented 2D deliverable "you do it like this or we don't contract you" contract as a critical tool in getting what is wanted/needed
knowledge & learning	identified a lack of knowledge as a possible reason for why some colleagues are not interested in BIM sees increasing awareness as potentially very powerful tool; however there is no one currently leading such an initiative working/collaboration between departments open channels	few examples of the innovation having been used for those sorts of functions "I believe the people can be trained" not a lot of knowledge at present within the org. as a whole; knowledge is posessed by only a select few trying to make the BIM protocol as readable as possible so that it can also inform colleagues within the org. communication between departments is increasing as a result of a more lifecycle-oriented focus "I believe the people can be trained"
innovation process	in the past the focus was more traditional, focusing on the design and construction phases take on a more holistic approach; look at multiple areas where change is possible to see how they help individually and together within a larger strategy "a strict protocol can definitely help provide guidance to our partners in the early phase of a building project" could have started sooner with the adoption process	"this question is so big that you can't do it on your own" some things take much longer than others better to launch something soon and improve from there rather than continuing to work in the background get the protocol to the best possible state within a given timeframe and move quickly to testing
ADVANCES		
leadership & commitmet	"We've been interested but taking the next step" "Someone needs to move forward with this topic, and that will take some time." initiative is mostly bottom-up the org. is committed to moving forward with BIM	top-down support of BIM for M&O; encouragement to move forward directors want to move forward with BIM, and quite rapidly "absolutely", the org. is committed
adoption	BIM is being used in the design phase of new building projects "since we're not ready, we don't do much with the BIM models we already have" wait until the protocol is ready, then move forward with BIM	"we are pretty far along [with the BIM protocol]" one year brainstorming and one year working on a concrete protocol next step it to implement and test the BIM protocol because the models are not M&O friendly, the models are still being converted to 2D upon construction completion M&O still is not being taken into consideration during the initiation of new projects "until we can define it clearly, we cannot use the BIM model in the M&O phase"
implementation & use		org. received BIM models and then asks the question "what can we do with it?" not much use of BIM currently "when we get [the BIM models] we're happy, but we can't use them in the operation phase"
change process	"I think there is a shift" form more integrated project teams evolutionary process form teams to reduce communication gaps within the org. "it's important to come to one solution"	what is being asked of the market requires a totally different approach before the market will accept the protocol, the platform needs to be sufficient "The change is so radical that the market must first be prepared for this, and for that we need a big platform to launch this." evolutionary process "don't know which steps to take"
further outlook	"moving forward, we need to incorporate BIM" heading in a good direction, just surprisingly slowly should be looking more at what we can already be doing	"it's a very interesting time" a revolution in archiving is coming believes that BIM can play a big part in the org.'s pursuit of a more lifecycle-oriented approach expects significant change in the coming years figure out how to incorporate BIM into existing buildings as well predicts a hybrid situation for the future (e.g. level of detail based on cost-benefit analysis) "I think it will be a revolution"

Case 3 interview responses

	CASE 3	
	Interview A	Interview B
Profile	Technical information manager	Technical information manager
Familiarity with BIM	quite aware, especially with respect to the technical aspects	recently took a course in BIM quite aware, especially with respect to the technical aspects
What is BIM?	many aspects that can be used for a variety of applications information database	building information management a broad thing the can be used to merge information and form a chain of practitioners
SOCIAL		
awareness	colleagues have limited awareness of BIM on the whole	participant had recently completed a one year course in BIM creating awareness is a big challenge
perception of innovation	using BIM in M&O is still a big challenge	potential for "big advantages"
motivation to innovate	information consolidation make the information more useful and usable	"we are dealing with a lot of information, so [BIM] is really important" improve information access
willingness to innovate	"we want to go there"	
adaptability		a culture change is necessary for BIM to be successful in the future
ORGANIZATIONAL		
standing	semi-public	traditional organization
mission & purpose	real estate mgmt new buildings renovation M&O technical aspects	
power & influence	working together will lead to a bigger impact	
roles & responsibilities		involved in everything from project conceptualization through to building decommissioning
capacity		"right now we have a very low BIM level"
INTENTIONS		
vision	one database of building information that can be provided to other departments create a single information source	needs to focus on full lifecycle
expectations		the org. should be given a chance to review the data at various points along the way during design and construction phases as a check to see if the end model will fulfill the org.'s needs and requirements
goals & objectives		strike a balance in LOD so that the model is appropriate for day-to-day use, intermittent larger M&O work, and long-term use (e.g. major renovation, decommissioning)
needs & requirements		keep the amount of information reasonable and manageable avoid overwhelming those who (will) work with BIM a model with an appropriate LOD, without losing critical information
strategy		
POSITIONING		
network relations	working on developing a multi-organization BIM protocol group working on BIM protocol wants to "achieve something in the market" "we also need to participate in the design phase" regardless of there being a protocol or not lack of early involvement/intervention wrt. BIM	"the organization is developing" many employees have been part of the org. for >5 years
resource mobilization	computers that can manage the software and amount of information lack of a system for M&O oriented use	have BIM models of new building(s), but they are too data heavy to work with
steering devices	missing specifications for how BIM needs to be set up	a standardized BIM protocol is being developed to specify the specifications of the post-construction, M&O oriented BIM model protocol to promote M&O BIM from project outset as part of the contract protocol focuses primarally on the information handed over upon construction completion it is hard to say if the protocol is nearly ready or "right"
knowledge & learning		highlights a current lack of BIM knowledge in org. as a whole "we are still learning" the end protocol must be readable, not too long or too short
innovation process	"have to do a lot of things right to get BIM ready for the operations phase" the protocol is not ready, so little is being done in the leadup to its publication	"you can ask a lot in the protocol, but you've also got to do something with all the information" "we want to do it right, which is why it is taking a long time"
ADVANCES		
leadership & commitment		no formal decision has been made to move forward with BIM a small part of the organization is committed to moving forward with BIM participant highlights a lack of commitment at present "From the top there no interest at this point"
adoption	approach is to slowly introduce BIM so that the entire org. gradually becomes aware and remains receptive	"We are busy setting up a procedure to streamline [adoption of BIM in the organization]."
implementation & use		"We also started a number of pilot projects."
change process	"BIM is not compatible with the current way of working within [the organization] because the contracts are still traditional." "The entire chain of the organization must be BIM minded and that is not the case yet." evolutionary process because BIM itself is still developing "You [need to] have the right people to change the organization"	"the step to [M&O] is really big" "it's pretty hard" evolutionary process small improvements every day to have a positive impact; both top-down and bottom-up small steps and proper management will lead to a workable result
further outlook	"We are still at the beginning. Much effort is still needed to prepare the organization for this." BIM will be used a lot in day-to-day work there is still a long way to go	mixed expectations difficult to predict