GRASPING BRUTAL AND INCREMENTAL BIM INNOVATION THROUGH INSTITUTIONAL LOGICS

Eleni Papadonikolaki[1]

The Bartlett School of Construction and Project Management, University College London, 1-19 Torrington Place, London WC1E 6BT, UK

Building Information Modelling (BIM) as an innovation contributes to construction digitalisation. BIM affects various actors of the built environment, e.g. government structures, enterprises, and industry groups. Notably, BIM is not newly-found, yet it radically alters the way construction firms operate. BIM evolved from an industry-sponsored effort to share consistent information among low tiers of the supply chain, towards collaboration across all tiers. As public bodies start to mandate BIM, firms have to radically – or brutally – innovate their businesses. This paper explores BIM innovation via the lens of institutional logics in contexts with low and high BIM diffusion. It compares the United Kingdom – where BIM was mandated in 2016 – and some Nordic countries and the Netherlands – where it is not yet mandated. The study draws upon grey and scientific literature to explain how innovation unfolds macroscopically and concludes that contextual sensitivities are lacking in BIM debate.

Keywords: BIM, innovation diffusion, institutional logic

INTRODUCTION

Innovation entails a new product, service or process (Abernathy and Clark, 1985). Traditionally innovation has been typified into incremental – evolutionary, involving gradual changes – and radical – or brutal – by engaging in completely new approaches (Burns and Stalker, 1961, Abernathy and Clark, 1985). Whereas innovation is mostly observed in projects, it impacts the wider context beyond project-based limitations. Thus, whereas innovations are observed and rely on good projects, context affects them and pushes or suspends change. The construction industry is project-based and considered a laggard in technology take-off and adopting technological innovations (Davies and Harty, 2013). Thus, there is probably a need to look beyond projects, into their context, in order to support innovation adoption and construction management.

This paper explores the interactions of construction management with innovation, drawing upon a recent hot topic in the industry: adoption and diffusion of Building Information Modelling (BIM). Undoubtedly, innovation diffusion relates to a macro-level, whereas adoption relates to a micro-level. Entities adopt innovations at a micro scale, e.g. firms, and ultimately innovation diffuses at a macro-level (Rogers *et al.*, 2005), i.e. the industry. This paper connects these two levels for understanding BIM, especially at macro- level. Various actors of the built environment, e.g. individuals, project teams, firms, supply chains, state, and market affect innovation adoption and

[1] E.Papadonikolaki@ucl.ac.uk

Papadonikolaki, E (2017) Grasping Brutal and Incremental BIM Innovation through Institutional Logics *In:* Chan, P W and Neilson, C J (Eds) *Proceeding of the 33rd Annual ARCOM Conference,* 4-6 September 2017, Cambridge, UK, Association of Researchers in Construction Management, 54-63.

diffusion. Using the concept of *institutional logics,* suggested by Friedland and Alford (1991) as a theoretical lens, the study aims to understand the nuances of innovation. The paper compares countries with high BIM diffusion (some Nordic countries and the Netherlands) with the United Kingdom (UK), which has low BIM diffusion. This theoretical study aims to explore the context that affects BIM diffusion, and is structured as follows. First, the theory and gap on innovation, BIM, and institutional logics are offered. Second, the methodology and methods deployed are presented. In the ensuing sections, the data analysis, discussion against literature, and implications are given. The study concludes with a summary of findings and further research.

THEORETICAL BACKGROUND AND RESEARCH GAP

BIM as Construction Innovation

Diffusion of innovations
The diffusion of innovations model by Rogers (2003) described the process by which innovations spread via communication channels across a social system over time. According to Rogers (2003) some innovations spread relatively rapidly while others spread slowly depending on (a) novelty, (b) compatibility with existing values, beliefs, and experiences, (c) ease to comprehend and adapt, (d) tangibility, and (e) testability. As most real-life systems are not linear, but instead highly complex, likewise during innovation diffusion, multi-scale phenomena add to the complexity. Local networks' interactions trigger the emergence of global structures and behaviours (Rogers *et al.*, 2005). As even the firms that deliver similar services or products are highly heterogeneous, many heterogeneous *micro-scale* behaviours and actions of adoption from those firms contribute to *macro-scale* phenomena, and diffusion (Ibid.). Construction is largely project-based (Morris, 2004) and its projects are unique by displaying high demand and supply variability. Thus, the projects upon which construction industry is organised are also highly heterogeneous and complex. According to Rogers *et al*., (2005) "*acknowledging the centrality of heterogeneity is also consistent with Actor-Network Theory, which, along with diffusion of innovations theory, points to the alignment of social and technical systems in heterogeneous networks*". Acknowledging macro-scale phenomena, context and heterogeneous institutions is necessary for understanding innovation in construction (Larsen, 2005).

Building Information Modelling history and precursors
Projects are nexuses of processing information (Winch, 2002). Neo-institutional views on construction project management generate insights on "*how actors construct the reality around them through interaction, thereby performing scripts and routines to generate organisation*" (Winch, 2015). Thus, information flows are key ingredients of management, within and beyond projects. BIM could then be viewed as 'systemic innovation' in the sense that it influences multiple levels of construction (Taylor and Levitt, 2007). BIM is not only a domain of digital artefacts, but has roots in the long process of developing standards for building information, the most long-lived being Industry Foundation Classes (IFC) (Eastman, 1999, Laakso and Kiviniemi, 2012).

BIM is not entirely new for construction as it has evolved from efforts for structuring and consistently representing information and knowledge about building artefacts, which was a predominant line of thought in the 1970s (Eastman, 1999). In the United States of America (USA) initiatives in the mid-1980s for '*building product model'* definitions were developed for exchanging building information amongst computer applications (Ibid.), replacing error-prone human interventions. The advancements in building product modelling followed the long-standing debate on the computerisation and digitalisation of construction (Eastman, 1999). Against widespread belief, BIM is not newly-found, but evolved from efforts by industry consortia to structure building information (East and Smith, 2016), previously known as *building product models*.

BIM affects various actors across construction lifecycle, while policies, processes, and technology interact to generate a digital building (Succar *et al.*, 2012). BIM is a set of loosely-coupled existing and new Information Technology (IT) systems to generate, control, and manage building information. BIM could still be branded as construction innovation, as whereas its content is already known to lower-tiers actors of the supply chain, implementing it in projects from all actors is entirely new and challenging. Its novelty also lies at policies prescribing BIM in contract addendums and workflows for project delivery. Thus, BIM is not anymore privy to a 'cohesive' set of actors, but has passed the 'threshold' of diffusion in construction (Larsen, 2005). Undoubtedly, BIM not only affects the representation of building product information, but also multi-disciplinary teams (Dossick and Neff, 2010, Bryde *et al.*, 2013). Whereas BIM is a technological innovation, it not only influences coordination of IT artefacts, but also complex socio-technical processes to align information and actors (Liu *et al.*, 2016, Papadonikolaki, 2016) across projects, supply chains, and markets.

The Importance of Institutional Logics for Understanding BIM Diffusion

The end of the 20th and the beginning of the 21st century found management scholars problematising on the scope of project management. As projects are embedded into their organisational and institutional contexts (Blomquist and Packendorff, 1998), traditional project management might not be sufficient. Thus, the relational context and the institutional environment of projects should be also managed (Blomquist and Packendorff, 1998). Whereas project management discipline emerged from a Taylorist approach of organising, it now incorporates Social Science. Similarly, construction management developed multi-disciplinary sensitivities and embraced Social Science, and particularly psychology, sociology, philosophy, and organisation theory. Projects shape and are shaped by their environment, that is called embeddedness (Giddens, 1984). Yet, as from the dual structure-agency nature, more emphasis was given on the former than the latter, *institutional logics* were introduced to stress the importance of the relations between agency (behaviour, values, intentions) and context (individuals, organisations, institutions) (Friedland and Alford, 1991). Family, community, religion, state, market, professions, and firms are layers of institutional logics in the West from micro- to macro-scale to understand individuals, organisations, and markets.

In the context of innovation, institutional logics are a useful lens to understand BIM diffusion among firms. Whereas there are many detailed and visionary studies of how innovation unfolds at intra-organisational (Peansupap and Walker, 2006) and project-based settings (micro-scale), there is lack of evidence on how innovation unfolds at a macro-scale. Indeed, there is a lack of contextual awareness in innovation studies (Larsen, 2005). Whyte and Berente (2008) used institutional theory to discuss the influence of BIM on professionalism. Linderoth (2016) used the logics to explore the relation between new technologies and change. Few works studied new technologies across all institutional levels. Those offer a comprehensive view of how innovations unfold, avoiding pitfalls of rhetoric strategies and impression management that unfold by only looking at intra-firm levels (Leiringer and Cardellino, 2008). Comparing BIM diffusion between the UK and Finland (Khosrowshahi and Arayici, 2012), or among UK, Sweden, and France (Davies *et al.*, 2015) some nuances exist. Whereas the North-western European construction and institutional context is treated as one entity (aggregator of institutional logics), it is in fact made up of various national business systems, where state, industry, political, and epistemic networks interact.

This paper studies content- and context-related dimensions of BIM innovation. First, the study does not generalise on the diffusion of any construction innovation, but only focuses on technological, IT-driven innovation that falls under the umbrella of BIM. As BIM is not yet another innovation *hype* (Dainty *et al.*, 2015), but has emerged from a complex history of standardisation and 'pull' efforts in the realm of construction IT from lower tiers of the supply chain (Eastman, 1999), acknowledging these efforts might support the understanding of BIM innovation diffusion. Second, there are currently many voices supporting the transferability of best-practices from BIM innovation across countries (Wong *et al.*, 2010, Khosrowshahi and Arayici, 2012, Davies *et al.*, 2015). However, it is important to understand the extent to which such BIM best-practices are compatible and transferable across contexts. Only then, any mimetic mechanisms for diffusing BIM innovation in countries and across projects could be justifiable and sustainable. Thus, there is room for additional understanding of innovation diffusion through the contextual lens of institutional logics.

METHODOLOGY AND METHODS

The study follows an exploratory systematic review (Greenhalgh *et al.*, 2004) to seek the relation between context and BIM innovation, through an institutional logics lens. By reviewing various contexts in North-western Europe, the study examines the possibility to transfer conditions for BIM innovation diffusion across countries. The main research question is formulated as follows: "*How does the diffusion of BIM innovation unfold across countries and what are the implications for policy and management?*". In construction, we distinguish three typologies of national business systems (Winch, 2002) across developed countries (excluding developing countries):

- *Anglo-Saxon* systems, such as those of the UK and the USA, which rely on liberal market values, stock market, and have low state regulation,
- *corporatist* systems, such as Germany and the Netherlands, which primarily rely on banks, and are driven by coordination efforts between state and market. The market is considered a 'social partner' of the state. In the Netherlands, this corporatist culture is referred to as '*poldermodel*' culture (Winch, 2002),
- *state-led* systems, such as France and Japan, which display higher coordination between state and market than the corporatist type system.

Denmark, Sweden, and Finland probably also are of *corporatist* culture. Danish firms are keen to negotiate and reach consensus, as industry is regulated as to innovation and loosely regulated as to market rules (Gottlieb and Jensen, 2016). Sweden has both centralised state control and dispute resolution culture (Bröchner *et al.*, 2002), like the Netherlands. Finland has relational stability of actors, fluid boundaries, and network-level change agents, which implies a *corporatist* culture (Taylor and Levitt, 2007). Unwritten rules governed by culture, ethics, and idiosyncrasies shape the context. As technology is also a cultural phenomenon, adopting technological innovations is influenced by culture and idiosyncrasies. The paper is a systematic review of scientific and grey literature, expert advice, and publicly-issued reports on BIM, following the method of Greenhalgh *et al.,* (2004). The data is from Anglo-Saxon and corporatist countries: the UK, Netherlands, and some Nordic countries. The data was thematically analysed around weight of policy and logics involved. Table 1 shows the data sources:

Table 1: Data sources on BIM innovation in countries (numbers indicate sources studied).

Data sources	National contexts across North-western European countries United Kingdom	Netherlands	Scandinavia	Finland
Scientific literature	>41	>27	>15	>11
Publicly-issued mandate	1	N/A	3	2
Government reports	9	1	2	1
Industry report	8	3	5	4
Online sources	2	3	–	–
Anecdotal data by industry experts	>20	>30	2	5

DATA AND FINDINGS

Levels for Analysing BIM Innovation

As BIM increasingly attracts interest from various industry players, it inevitably becomes the focus of high quality research. Greenhalgh *et al.,* (2004) distinguish four categories of innovation in service firms: diffusion, dissemination (also referred to as adoption), implementation and sustainability (until the innovation becomes mainstream). Drawing upon that, research on BIM unfolds in three wide categories:

- *Adoption* of isolated firms –based on individual perceptions of employees;
- *Implementation* in projects – from case study analyses of projects and
- *Diffusion* at a macro-level – by targeting specific professions or countries.

BIM adoption studies provide rich insights into intra-firm barriers and enablers. Son *et al.,* (2015) analysed BIM adoption in architects in China using TAM, and individual perceptions and mistrust were key barriers. Both relational and technical aspects shape the transformation of contractors in the USA for BIM adoption (Ahn *et al.*, 2015). As adoption unfolds at micro- and diffusion to macro-scale, implementation relates to an intermediate or meso-level, which greatly affects the former. Likewise, technical and organisational BIM implementation studies offer a firm grasp of BIM advantages and shortcomings. Some identified benefits lie in design management (Elmualim and Gilder, 2014), project management, communication, coordination (Dossick and Neff, 2010) and performance (Bryde *et al.*, 2013). Yet, BIM adoption and implementation studies often do not detail context, as this is rarely included into their research scope.

BIM Innovation Diffusion across North-Western Europe

BIM diffusion studies facilitate better understanding of how BIM innovation unfolds across contexts, and whether this is evolutionary or revolutionary (Burns and Stalker, 1961). In projects with various BIM-using firms, implementation varies, as firms carry various BIM capabilities, due to heterogeneity in service and size (Succar *et al.*, 2012, Succar and Kassem, 2015). Succar and Kassem (2015) categorised BIM diffusion dynamics into *top-down*, *middle*-out, and *bottom-up*, depending on pressure, i.e. downwards, horizontal, or upwards, by government, large or small firms, respectively. In Europe, to control various nuances and instrumentalities of BIM, and prescribe BIM implementation to reap its acclaimed benefits, various national initiatives from the government and professional industry associations suggest quasi-contractual means of BIM-related agreements among actors, e.g. pre-contract BIM Execution Plan' (CPIc, 2013) under the efforts of the UK BIM Level 2 mandate, and 'BIM Protocol' Norm issued – but not mandated – by the Dutch Government Building Agency (GBA) (Rijksgebouwendienst, 2012). Both mandates are inspired from the – recently mandated – Norwegian 'BIM Manual' (Statsbygg, 2011). Also in the UK, many mandates in the form of Publicly Available Specification (PAS) have been issued to prescribe BIM use in project delivery, such as the family of PAS 1192.

However, the UK and Nordic countries' mandates have different scope. The Finnish and Norwegian mandates place emphasis on interoperability and using IFC-compliant software. In essence, they mandate 'OpenBIM' initiative for neutral BIM standards. In Sweden, only the transport authority mandates BIM. BIM is not mandated for buildings (Hooper, 2015), same as in the Netherlands. Other European countries plan BIM mandates, e.g. France will issue regulations to mandate BIM for public buildings in 2017 (Davies *et al.*, 2015) and Germany will issue BIM mandates by 2020. A cross-country study of six BIM initiatives stated that for "*effective implementation of BIM in a country, both the public and private sector should work collaboratively to set up a suitable environment*" (Wong *et al.*, 2010). But not all countries inspire close collaboration of public and private. Whereas "*policy makers can also adopt or adapt compatible BIM content types from other countries and thus reduce duplication of efforts*" (Kassem *et al.*, 2015), context is very crucial. Thus, by examining all pertinent social layers, conditions for partial transferability of BIM diffusion mechanisms could be identified. Table 2 shows social layers active in BIM diffusion across countries.

Table 2: Cross-country comparison of social layers active (shown in bullets) in BIM diffusion.

Institutional logics	National contexts across North-western European countries			
Social layers	UK	Netherlands	Scandinavia	Finland
Contracting & consulting firm(s)	•	•	•	•
Public clients	•	•	•	•
Private clients	–	•	•	•
Suppliers	–	•	•	•
Software vendors	–	•	–	•
Long-term partners	–	•	•	•
Professional bodies	•	–	–	–
Personal & a-spatial networks	•	•	•	•
State regulation	•	–	•	•

DISCUSSION AND IMPLICATIONS

Understanding BIM Diffusion through Institutional Logics

Mapping and understanding institutional logics of BIM innovation across countries, helps to the understand BIM diffusion. Innovation always applies to both micro- and macro-levels. BIM innovation is adopted incrementally in firms and radically in projects that influence and are influenced by their context (macro-level) varyingly, according to institutional logics. Likewise, personal networks and lateral institutions enable the solidification of knowledge, learning, and innovation (micro-level). Widén *et al.,* (2013) explored the importance of engaging key agents, e.g. innovation brokers, role models and risk-takers, early in innovation diffusion. In BIM diffusion, various layers from Table 2 could play such role, e.g. suppliers, software vendors and professional bodies. Mapping them could help engage them. Similarly, different compositions of institutional logics have different equilibria. Policy-makers and other actors interested in pushing BIM in national markets could leverage from these logics, since BIM emerged from a pull strategy (Eastman, 1999) decades ago. Any European-wide BIM guidelines need contextual sensitivities to avert generalised decisions. Acknowledging diverse logics and contexts is crucial for successfully managing innovation as projects are not alone sufficient for inducing and managing innovation.

Typologies of BIM Innovation Diffusion

Whereas this study analysed institutional logics of BIM innovation per country, the analysis is clustered around business systems. The Anglo-Saxon and corporatist systems are respectively of radical and incremental BIM diffusion. Notably, Sweden and the Netherlands, with high state regulation, follow bottom-up strategy and have not mandated

BIM, whereas the UK with low regulation mandated BIM (Table 2). First, whereas the UK displays less state involvement and *laissez-faire* mentality, had numerous politicised decisions for pushing BIM, similarly to BIM mandate in 2007 in the USA. Yet, the USA seem to have lost momentum in BIM innovation, as not a lot of traction has been gained since (McGraw-Hill, 2014a). In the decade that followed their mandate, most USA construction firms still do not use BIM (McGraw-Hill, 2014b). However, mandating BIM in public projects has different implications for the USA and UK, as these countries have varyingly intertwined institutions and policies, i.e. social infrastructure. In the UK, the government is the biggest construction client. Given that public and social procurement (e.g. hospitals and schools) in the UK is high, correspondingly more construction firms are affected from the mandates. Also, placing the UK PAS 1192-2 under public revision, to involve more institutional logics in BIM diffusion, might indicate a new 'cultural shift', featuring bottom-up strategies.

Second, whereas BIM is not globally mandated in the Netherlands and most Nordic countries (Table 2), firms are keen to use it (Davies *et al.*, 2015). The Netherlands published their public but not mandatory BIM guide in 2012 but have high BIM diffusion, same as Norway that only recently (2016) mandated it. These countries are not in BIM industry reports, such as of McGraw-Hill (2014b). Personal, informal, and long-term inter-firm relations (Bröchner *et al.*, 2002, Gottlieb and Jensen, 2016), support BIM diffusion from a middle-out perspective. Surprisingly, professional bodies there are not yet very active in policy-making, whereas the UK Royal Institute of British Architects (RIBA) is. *Corporatist* countries have mandated interoperability, which are supported by bottom-up initiatives by construction alliances and software vendors (Hooper, 2015, Papadonikolaki, 2016). The actors receive pressure to be IFC-compliant, as opposed to the top-down BIM diffusion in *Anglo-Saxon* countries. Any generalisation and transferability of BIM policies are valid when firms compete within a truly global plateau, e.g. international architectural competitions, where BIM was required as early as 2008. When discussing BIM as a global market phenomenon, contextual awareness is needed. Generalisations based on solely economic growth are misguided when social context (logics) and infrastructure are not also acknowledged.

Supporting BIM Innovation Policy

BIM innovation is seen as incremental or radical – brutal – in the UK, from a macro-level view. As innovations are strategically deployed in projects, they depend on micro-, meso-, and macro-level institutional layers, e.g. individuals, firms, clients, suppliers, networks, and state. Innovation management requires synergy among these layers. Aligning the logics helps smooth acceptance of technology (Linderoth, 2016). Rethinking the composition of institutional logics could be used to mobilise key actors, e.g. professional associations, software vendors, suppliers, corporate groups, to induce incremental innovation, mainly in countries with 'top-down' BIM diffusion. Dainty *et al.,* (2015) challenged the effectiveness of mandates and policies for BIM diffusion because such policies are usually discontinued for lack of political influence, as in the reform agendas from 1934, 1944 to Latham and Egan reports. However, it seems that the UK political influence grows strong. Fernie *et al.,* (2006: 98) noted the '*need for contextual thinking and sensitivity within organisational studies and in the discourse mobilised by the contemporary reform movement'*. Undoubtedly, both the context and content of innovation are needed to understand its diffusion. After all, Kale and Arditi (2006) had previously acknowledged that while innovation is diffused across the industry, the particulars of innovation also evolve over time. This fact also aligns with BIM, considering how it evolved over the decades from a pull strategy under a different name, i.e. *building product models*. Thus, adjustments in BIM innovation diffusion and hybrid top-down and bottom-up mechanisms emerge, e.g. in the UK's recent decision to place the BIM mandate under public revision (early 2017).

CONCLUSIONS

The paper explored two realities of BIM innovation diffusion. First, BIM diffusion policy tends to neglect the historical antecedents of BIM, which emerged through a pull strategy. Whereas policy and research bodies see BIM as a *brutal* innovation, its underlying principles were introduced in construction years ago. BIM is seen as brutal in the UK, due to the mandates, and incremental in some Nordic countries and the Netherlands, where it is differently mandated. Second, context and culture influence BIM, as incongruent social layers are activated for its diffusion (Table 2). Mapping and comparing these logics across countries revealed two mechanisms of top-down and bottom-up BIM diffusion. The cross-country comparison of logics, suggests that efforts to diffuse BIM across countries in 'one-size-fits-all' fashion are probably misguided, and could hinder productivity, satisfaction, and performance. Developing both BIM-specific and contextual awareness facilitates BIM innovation management. Future study will address the sampling limitations via snowballing technique.

REFERENCES

Abernathy, W J and Clark, K B (1985) Innovation: Mapping the winds of creative destruction. *Research policy,* **14**(1)**,** 3-22.

Ahn, Y H, Kwak, Y H and Suk, S J (2015) Contractors' transformation Strategies for adopting Building Information Modeling. *Journal of Management in Engineering,* **32**(1)**,** 05015005, 1-13.

Blomquist, T and Packendorff, J (1998) Learning from renewal projects: content, context and embeddedness. *Projects as arenas for renewal and learning process.* Springer, 37-46.

Bröchner, J, Josephson, P and Kadefors, A (2002) Swedish construction culture management and collaborative quality practice. *Building Research & Information,* **30**(6)**,** 392-400.

Bryde, D, Broquetas, M and Volm, J M (2013) The project benefits of Building Information Modelling (BIM). *International Journal of Project Management,* **31**(7)**,** 971-980.

Burns, T E and Stalker, G M (1961) *The Management Of Innovation*. London: Tavistock.

Cpic, (2013) *CPIx Pre-Contract Building Information Modelling (BIM) Execution Plan (BEP).* Avaiable from https://goo.gl/PnCPFe [Accessed 22nd July 2017].

Dainty, A, Leiringer, R, Fernie, S and Harty, C (2015) Don't Believe the (BIM) Hype: The Unexpected Corollaries of the UK 'BIM Revolution. *Proceedings of the Engineering Project Organization Conference, The University of Edinburgh, Scotland, UK.*

Davies, R, Crespin-Mazet, F, Linne, A, Pardo, C, Havenvid, M I, Harty, C, Ivory, C and Salle, R (2015) BIM in Europe: Innovation networks in the construction sectors of Sweden, France and the UK. *In*: Raiden, A and Aboagye-Nimo, E (Eds.), *Proceedings of the 31st Annual ARCOM Conference*, 7-9 September 2015, Lincoln, UK. Association of Researchers in Construction Management, 1135-1144.

Davies, R and Harty, C (2013) Measurement and exploration of individual beliefs about the consequences of building information modelling use. *Construction Management and Economics,* **31**(11)**,** 1110-1127.

Dossick, C S and Neff, G (2010) Organizational divisions in BIM-enabled commercial construction. *Journal Of Construction Engineering And Management,* **136**(4)**,** 459-467.

East, B and Smith, D, (2016) The United States National Building Information Modeling Standard: The First Decade. In: *33rd CIB W78 Information Technology for Construction Conference (CIB W78 2016)*, Brisbane, Australia.

Eastman, C (1999) *Building Product Models: Computer Environments, Supporting Design and Construction*. Boca Raton, Florida, USA: CRC Press.

Elmualim, A and Gilder, J (2014) BIM: innovation in design management, influence and challenges of implementation. *Architectural Engineering and Design Management,* **10**(3-4)**,** 183-199.

Fernie, S, Leiringer, R and Thorpe, T (2006) Change in construction: A critical perspective. *Building Research and Information,* **34**(2), 91-103.

Friedland, R and Alford, R R (1991) Bringing society back in: Symbols, practices and institutional contradictions. *In*: *The New Institutionalism in Organizational Analysis*, 232-263

Giddens, A (1984) *The Constitution Of Society: An Outline Of The Theory Of Structuration*. Cambridge, USA: Polity Press.

Gottlieb, S C and Jensen, J S, Year. Governmentalities of Construction: From Mortar to Modular Systems and Markets. *In*: Chan, P W and Neilson, C J (Eds.), *Proceedings of the 32nd Annual ARCOM Conference*, 5-7 September 2016, Manchester UK. Association of Researchers in Construction Management, 3-12.

Greenhalgh, T, Robert, G, Macfarlane, F, Bate, P and Kyriakidou, O (2004) Diffusion of innovations in service organizations: Systematic review and recommendations. *The Milbank Quarterly,* **82**(4)**,** 581-629.

Hooper, M (2015) BIM standardisation efforts-the case of Sweden. *Journal of Information Technology in Construction (ITcon),* **20,** 332-346.

Kale, S and Arditi, D (2006) Diffusion of ISO 9000 certification in the precast concrete industry. *Construction Management and Economics,* **24**(5)**,** 485-495.

Kassem, M, Succar, B and Dawood, N (2015) Building Information Modeling: Analyzing noteworthy publications of eight countries using a knowledge content taxonomy. *In*: R Issa and S Olbina (Eds.) *Building Information Modeling: Applications and practices in the AEC industry.* Reston, VA, USA: ASCE Press, 329 - 371.

Khosrowshahi, F and Arayici, Y (2012) Roadmap for implementation of BIM in the UK construction industry. *Engineering, Construction and Architectural Management,* **19**(6)**,** 610-635.

Laakso, M and Kiviniemi, A (2012) The IFC standard: A review of history, development, and standardization. *Journal of Information Technology in Construction,* **17**(9)**,** 134-161.

Larsen, G D (2005) Horses for courses: relating innovation diffusion concepts to the stages of the diffusion process. *Construction Management and Economics,* **23**(8)**,** 787-792.

Leiringer, R and Cardellino, P (2008) Tales of the expected: Investigating the rhetorical strategies of innovation champions. *Construction Management and Economics,* **26**(10)**,** 1043-1054.

Linderoth, H C (2016) From visions to practice-The role of sensemaking, institutional logic and pragmatic practice. *Construction Management and Economics***, 25**(6), 1-14.

Liu, Y, Van Nederveen, S and Hertogh, M (2016) Understanding effects of BIM on collaborative design and construction: An empirical study in China. *International Journal of Project Management*, **35**(4), 686-698.

McGraw-Hill (2014a) The business value of BIM for Construction for Owners. *In*: S A Jones and H M Bernstein (Eds.) *Smart Market Report.* McGraw Hill Construction.

McGraw-Hill (2014b) The business value of BIM for construction in major global markets: How contractors around the world are driving innovation with building information modeling. *In*: H M Bernstein (Ed.) *Smart Market Report.* McGraw Hill Construction.

Morris, P W G (2004) Project management in the construction industry. *In*: P W G Morris and J K Pinto (Eds.) *The Wiley guide to managing projects.* Hoboken, NJ: John Wiley & Sons, 1350-1367.

Papadonikolaki, E (2016) *Alignment of Partnering with Construction IT: Exploration and Synthesis of network strategies to integrate BIM-enabled Supply Chains*. Delft: Architecture and the Built Environment Series.

Peansupap, V and Walker, D H (2006) Innovation diffusion at the implementation stage of a construction project: A case study of information communication technology. *Construction Management And Economics,* **24**(3)**,** 321-332.

Rijksgebouwendienst (2012) *Rgd BIM Standard, v. 1.0.1* Available from https://goo.gl/sFK21g [Access 22md July 2017].

Rogers, E M (2003) *Diffusion of Innovations 5th Edition*. New York: Free Press.

Rogers, E M, Medina, U E, Rivera, M A and Wiley, C J (2005) Complex adaptive systems and the diffusion of innovations. *The Innovation Journal: The Public Sector Innovation Journal,* **10,** 1-26.

Son, H, Lee, S and Kim, C (2015) What drives the adoption of building information modeling in design organizations? An empirical investigation of the antecedents affecting architects' behavioral intentions. *Automation in Construction,* **49**(Part A)**,** 92-99.

Statsbygg, 2011. *Statsbygg Building Information Modelling Manual Version 1.2.* Available from https://goo.gl/f8RsfS [Accessed 22nd July 2017].

Succar, B and Kassem, M (2015) Macro-BIM Adoption: Conceptual Structures. *Automation in Construction,* **57,** 64-79.

Succar, B, Sher, W and Williams, A (2012) Measuring BIM performance: Five metrics. *Architectural Engineering and Design Management,* **8,** 120-142.

Taylor, J.E and Levitt, R (2007) Innovation alignment and project network dynamics: An integrative model for change. *Project Management Journal,* **38**(8)**,** 22-35.

Whyte, J and Berente, N (2008) Professional pluralism and institutional change: Appropriation and elaboration of new logics. *Conference on Managing the Building Process*, Copenhagen, Denmark.

Widén, K, Olander, S and Atkin, B (2013) Links between successful innovation diffusion and stakeholder engagement. *Journal of Management in Engineering,* **30**(5)**,** 04014018.

Winch, G M (2002) *Managing construction projects 1st Edition*. Oxford, UK: Blackwell.

Winch, G M (2015) Project organizing as a problem in information. *Construction Management and Economics,* **33**(2)**,** 106-116.

Wong, A K D, Wong, F K W and Nadeem, A (2010) Attributes of building information modelling implementations in various countries. *Architectural Engineering and Design Management,* **6**(4), 288-302.