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A unified BIM adoption taxonomy: Conceptual development, empirical validation and application

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ABSTRACT

Building Information Modelling (BIM) is an innovation that is transforming practices within the Architectural, Engineering, Construction and Operation (AECO) sectors. Many studies have investigated the process of BIM adoption and diffusion and in particular, the drivers affecting adoption at different levels, ranging from individual and team through organisations and supply chains to whole market level. However, in-depth investigations of the stages of the BIM adoption process and the drivers, factors and determinants affecting such stages are still lacking. A comprehensive classification and integration of adoption drivers and factors is absent as these are disjointedly identified across disparate studies. There is also limited attention to the key terms and concepts (i.e. readiness, implementation, diffusion, adoption) in this area of study.

This aim in this paper is twofold: (1) to develop and validate a Unified BIM Adoption Taxonomy (UBAT); and (2) to identify the taxonomy's constructs (i.e. three driver clusters and their 17 factors) that have influence on the first three stages of the BIM adoption process namely, awareness, interest, and decision stages, and compare their effects on each of the stages. The research uses: a systematic literature review and knowledge synthesisation to develop the taxonomy; a confirmatory factor analysis for its validation; and an ordinal logistic regression to test the effect of the UBAT's constructs on the BIM adoption process within the UK Architectural sector using a sample of 177 organisations.

The paper is primarily intended to enhance the reader's understanding of the BIM adoption process and the constructs that influence its stages. The taxonomy and its sets of drivers and determinants can be used to perform various analyses of the BIM adoption process, delivering evidence and insights for decision makers within organisations and across whole market when formulating BIM diffusion strategies.

1. Introduction

Construction is challenged more than ever with significant opportunities for innovation. Competitive pressures, digitalisation and automation, and owner demands for cost effectiveness and best value for money are key trends challenging the innovation status quo within the construction sector. Building Information Modelling (BIM) represents a significant opportunity to change the sector rigidness in attitudes towards change and innovation which have been hindering the modernisation of the construction sector. BIM is now considered as a key enabler of digital transformation that provide opportunities to harmonize the construction sector with emerging paradigms within our built environment such as the Internet of Things (IoT), smart sensors, connectivity and big data [1]. To date, BIM is still one of most widely discussed innovations that have ever occurred in construction as evidenced from recent science mapping and bibliometric analyses of literature [2–4].

BIM is referred to as an expansive knowledge domain [5], a “boundless” ([6], p.51) or “systemic” innovation ([7], p.84). BIM is causing concurrent evolutionary and revolutionary changes across several tiers ranging from individuals and groups, through organisations and project teams, to industries and whole markets [8].

At macro market level, a number of studies have (1) identified the conceptual constructs of Macro-BIM adoption that can be used to assess the maturity of whole markets [9]; (2) examined the financial and cultural issues related to BIM adoption across markets [10]; (3) investigated the barriers to BIM adoption [11]; (4) examined awareness of the technology among industry stakeholders [12]; and (5)

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investigated the dynamics of BIM adoption within a specific market [13].

Studies examining BIM adoption at project level (i.e., Meso-level), have addressed (1) the changing relationships among project stakeholders and in particular the multi-disciplinary collaboration among them [14]; and BIM implementation motivations and the related project contextual factors [15].

Investigating BIM adoption at organisational level (Micro-level) has also attracted significant attention in recent years. Research has been focussed on three key areas: (a) understanding the process of BIM adoption and diffusion by proposing approaches for predicting BIM diffusion [16] or investigating the diffusion phase that follows BIM adoption [17]; (b) identifying the drivers and factors that affect innovation adoption [18], and (c) investigating relationships between organisation characteristics (e.g., size, age, resources, etc.) and the inclination of organisations to adopt innovation [19].

One key opportunity to enhance upon existing literature is to address the dispersion of BIM adoption drivers and factors and develop appropriate theoretical constructs that synthesise this important knowledge domain. To address this opportunity, this paper will develop and validate a Unified BIM Adoption Taxonomy, and demonstrate its application in investigating the process of BIM adoption by organisations within the UK architectural sector. To deliver this aim, the research questions that are used as a point of departure are:

- RQ1 - what are the drivers and factors affecting BIM adoption by organisations within the construction industry?;
- RQ2 - what are the theories, frameworks, and models adopted by scholars for examining BIM/innovation adoption and diffusion in construction?; and
- RQ3 - How the results from addressing RQ1 and RQ2 above can be used to develop a new conceptual framework for investigating the effects of the taxonomy's constructs on the different phases of the BIM adoption process (i.e. awareness, interest, and adoption decision)?

The paper addresses in the following sections: clarification of key terms and concepts underpinning the BIM adoption domain; the systematic literature review and knowledge synthesisation process adopted to develop the taxonomy; the confirmatory factor analysis performed to validate the taxonomy's constructs and assess the reliability of measurements; the application of the taxonomy to analyse the BIM adoption process by organisations within the UK Architectural sector; and the theoretical implications and practical uses stemming from this study.

2. Key terms and concepts

This research investigates BIM adoption at organisational level while considering the pertinent market-wide aspects. Several of the terms used across this scale of investigation may have competing or complementary definitions. This section clarifies the position of this research in relation to these terms after briefly illustrating some of their existing interpretations:

- **Innovation**: The term refers to "*an idea, practice, or object that is perceived as new by an individual or other unit of adoption*" ([20], p.457). Within an 'organisational' context innovation can be understood as "the development and implementation of new ideas by people who over time engage in transactions with others within an institutional order" ([21], p.590), and "the implementation of an internally generated or a borrowed idea – whether pertaining to a product, device, system, process, policy, program or service – that was new to the organisation at the time of adoption" ([22], p.392). These complementary definitions are suitable for this study purpose which adopts the definition of BIM as "the current expression of digital innovation in the construction sector" [9].
- **Adoption vs. Implementation vs. Diffusion**: a universal agreement on the definitions of these terms is lacking in the literature. Adoption and implementation are often used interchangeably (as in, ([23–27]; and [28]. This blurs the distinction between interrelated concepts such as adoption, implementation, and diffusion. Rogers [20] defines 'adoption' as "a decision to make full use of an innovation as the best course of action available" and 'Implementation' as that phase which occurs once an innovation has been put into use ([20], p.457). In Rogers's Innovation-Decision Process [20], 'adoption' is one of the two outcomes (i.e. adoption, and rejection) of Stage 3 (i.e. decision stage). Succar and Kassem [9] defines BIM adoption as the successful implementation whereby an organisation, following a readiness phase, crosses the 'Point of Adoption' into one of the BIM capability stages, namely modelling, collaboration and integration. Moreover, the authors propose to overlay the connotation of both 'implementation' and 'diffusion' unto the term 'adoption' within the context of macro (i.e. market wide) adoption. These varying definitions indicate that 'adoption' could be considered as a more holistic term than 'implementation', which refers to either a specific phase (e.g.,[20]) or a milestone (e.g.,[5]). Although this study adopts Rogers's multi-stage Innovation-Decision Process due to its explicit itemisation of the first three stages (i.e. awareness, intention, decision) preceding adoption decisions, it recognises the need for a more holistic definition of the term 'adoption' as proposed in Succar and Kassem [5].
- **Diffusion Dynamics**: Combination of directional mechanics (i.e., Downward, Upward and Horizontal) and isomorphic pressures (i.e., Coercive, Mimetic and Normative) that allow innovation to contagiously pass from 'transmitters' to 'adopters' [9].
- **Macro-Meso-Micro**: analytical levels [29] or clusters of organisational scales [30]. The *Macro cluster* includes subdivisions, sectors, industries and specialities at market wide level. *Meso cluster* includes project-centric organisational teams that are aggregated at a project level; and the *Micro cluster* includes individuals and groups at an organisational subdivision level.

3. Methodology and research methods

There seems to be a consensus among scholars that new knowledge can be created by building upon existing literature [31–34]. This can be achieved by adapting existing theories, building new theories or synthesizing multiple theories [33,35–43]. However, the literature review must have certain properties in order to produce new knowledge. According to Schryen et al. [44], there are three key properties: 1. *synthesis and interpretation* of existing literature through framing existing research in theory or identifying existing gap; 2. *focus on domain knowledge* as the realm of knowledge about a particular field, and 3. *Comprehensiveness* through the inclusion of representative and pivotal studies. To satisfy the three characteristics (i.e. synthesis and interpretation, focus on domain knowledge; and comprehensiveness), a systematic literature review approach was adopted. The systematic literature review aggregates the existing studies on a certain topic; provides clarification of potential inconsistencies; and validates existing research findings [33]. It helps to minimise bias (systematic error); address clear research questions, and understand the reasons for heterogeneity between apparently similar studies [45]. Accumulating knowledge of several different but related studies is considered an efficient approach to achieve a generalised and comprehensive overview on a particular issue [46]. The systematic literature review also (1) helps to recognise gaps and suggest opportunities for future research, and (2) is considered a trustworthy, rigorous, and auditable methodology for collecting and combining existing research knowledge [47].

Well-structured taxonomies allow "the meaningful clustering of experience" ([48], p. 24) and are a means towards a number of different ends including the expansion generalisation of knowledge ([49],