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Review

The building information modelling trajectory in facilities management: A review

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ABSTRACT

There is a paucity of literature that examines building information modelling (BIM) for asset management within the architecture, engineering, construction and owner-operated (AECO) sector. This paper therefore presents a thorough review of published literature on the latest research and standards development that impact upon BIM and its application in facilities management (FM) during the operations and maintenance (O&M) phase of building usage. The purpose is to generate new ideas and provide polemic clarity geared to intellectually challenge readers from across a range of academic and industrial disciplines. The findings reveal that significant challenges facing the FM sector include the need for: greater consideration of long-term strategic aspirations; amelioration of data integration/interoperability issues; augmented knowledge management; enhanced performance measurement; and enriched training and competence development for facilities managers to better deal with the amorphous range of services covered by FM. Future work is also proposed in several key areas and includes: case studies to observe and report upon current practice and development; and supplementary research related to concepts of knowledge capture in relation to FM and the growing use of BIM for asset management.

Contents

1. Introduction

The proliferation of advanced computerisation throughout industry has revolutionised the way that buildings are designed, constructed, operated and maintained [1]. Today, computerisation is firmly embedded within a building's lifecycle from earliest concept through to occupation and operation, a transition made possible via disruptive technologies such as building information modelling (BIM) which have displaced traditional approaches and created virtual communities of practice (CoP) [2]. A virtual CoP represents an extensive 'multiple stakeholder' collaboration platform that is generated during design and construction through a single integrated BIM [1]. The dynamic, open access, digital environment afforded by BIM enables storage, sharing and integration of information for buildings' operations and management (O&M) (*ibid.*). BIM can embed key product and asset data within a three-dimensional computer model to effectively and efficiently manage building information [3]. Consequently, BIM deployment becomes extremely invaluable to organisations that seek to reap inherent value and efficiency gains from the technology [4,5].

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However, capturing a building's intricate and expanding portfolio of data requirements for facilities management (FM) is complex and requires facilities managers with tenacious strategic and tactical skills [6, 7]. These skills encompass diverse roles and duties may include the strategic planning and management of: plant operations; computer systems analysis; building assets; interior operations; and day-to-day tactical operations of assets and staff [8]. The problems related to optimising O&M are further exacerbated by the vast complexity and volume of data and information generated during a building's whole life cycle [9]. Automating this amorphous range of roles and duties, and engendering intelligent decision support, are feasible with the aid of BIM-FM integration [10,11,12]. However, within the UK, practitioners[1] reside within a transition period of adopting BIM and the extant literature simultaneously discloses limitations in: related procedures [13]; established standards [12]; and computerised FM system integration [11]. Many practitioners have sought bespoke pathways to adopting new technologies in a climate of exponential technological advancement but few have sought guidance from more technologically advanced sectors as aerospace and automotive manufacturing [14]. Inconsistencies in technology adaptation are complicated by a paucity of standardisation within FM procedures and processes. At present, the literature contains limited evidence of applied studies of hybrid BIM-FM environment development and the tangible benefits to be accrued from such [12,9].

To provide polemic clarity of the emergent hybrid BIM-FM environment, this research aims to: i) conduct a critical synthesis of extant literature and identify key challenges around BIM-FM integration; and ii) investigate state of-the-art tools used for BIM-FM knowledge capture. In realising these aims, the objectives are to argue the case for greater BIM-FM integration and stimulate wider debate and software development amongst academics and practitioners from a broader range of industrial sectors (including aerospace and automotive manufacturing). Knowledge transfer from these more technologically advanced industries will be beneficial to the AECO sector.

2. Facilities management: definitions, influences and challenges

FM represents an integrated approach to maintaining, improving and adapting an organisation's buildings to promote a fertile environment that supports the organisation's primary objectives [15,16]. Literature is replete with FM definitions, for example, Alexander [17] defines FM as: "*the process by which an organization delivers and sustains support services in a quality environment to meet strategic needs*." McGregor and Then [18] further proffer that FM is: "*a hybrid management discipline, which combines the management expertise of people, property and process(es). (p.1)*", whilst Nutt [19] defines FM as: "*a supporting tool to obtain sustainable and operational strategy for an organisation over time through management of infrastructure resources and services. (p.462)*". Chotipanich [20] elucidates the benefits derived from FM, highlighting improvements in managing facility resources, support services and working environment.

These delineations illustrate that the definition of FM has evolved over time and this can be attributed to several influential, interventional factors which impact upon the configuration of FM regime adopted. These factors can be conveniently allocated to three thematic groupings: i) *business environment* – including organisational structure [16, 21]; business objectives [22]; and company culture and contextual issues [23]; ii) *buildings and facilities characteristics* – for example, facility type [23]; location; and size (ibid.); and iii) *external interventions/factors* – such as business needs and processes [18]; asset maintenance priorities [24,22]; legislation [21]; and interrelationships with other contractors [16]. In synthesising and evaluating the literature, Chotipanich [20] suggests categorising these factors as *internal factors* (i.e. characteristics of the organisation, facility features and business sectors) or *external factors* (i.e. social, economic, legislative and regulative, local culture and context and market context for FM) [25]. Appraising this eclectic mix of definitions and factors illustrates that internal factors have received wider attention vis-à-vis external factors, even though the latter are quintessentially important to organisational resilience and business stability [15].

Information is critical for supporting efficient and effective building maintenance and day-to-day operations [15,24,26]. However, the FM sector continues to grapple with information management, predominantly due to the peculiarity of information and its fragmentation [1, 7]. These two causal factors are attributed as being the leading causes for knowledge loss within the architecture, engineering, construction, owner-operated (AECO) sector [27]. Computerisation alleviates asset information capture and retrieval, but knowledge capture and automated data analysis is limited within computer aided facilities management (CAFM) systems [15,11]. Commonly established CAFM tools are: computer aided design (CAD) (ibid.); integrated workplace management systems (IWMS) [28]; enterprise asset management (EAM) [29]; and computerised maintenance management systems (CMMS) [30]. Although these disparate tools have inherently different capabilities and functions, a vital prerequisite to implementing an appropriate CAFM system is that an organisation perceives data as its most invaluable asset [31]. A recent survey result is juxtaposed against this position and reveals that 43% of UK employees do not understand the value of business data [32].

The performance of FM must be measurable via knowledge management (KM) [33]. However, agreement over a common definition of KM remains a vexatious issue in FM [34,35,36]. For example, Bosch et al. [37] suggest that KM encapsulates a process of managing corporate knowledge to facilitate competitive advantage and organisational success, whilst Bhatt [38] emphasises KM characteristics and traits such as learning, collaboration, experimentation and implementation of powerful information systems. Commonly used FM performance measurement tools include: post-occupancy evaluation [38]; British Institute for Facilities Management (BIFM) measurement protocol [40]; key performance indicators (KPIs) [23]; and the balanced scorecard (BSC) [41] – refer to Table 1. Many of these tools are antiquated, often subjective and frequently client driven – consequently, they may fail to accurately portray issues facing the facilities management team (FMT) [33].

2.1. BIM-FM integration

The UK Government define BIM as: "*a collaborative way of working, underpinned by digital technologies which unlock more efficient methods of designing, creating and maintaining assets*" [63], whilst Succar [3] defines BIM as: "*a set of interacting policies, processes and technologies producing a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle*." The capacity to harness valuable data and information throughout a building's life cycle is integral within these ubiquitous definitions (*ibid.*). BIM has orchestrated a paradigm shift in the way that information is managed, exchanged and transformed to stimulate greater collaboration between stakeholders via a single integrated model during the design and construction phases [1]. This integrated approach to BIM ensures a smooth flow of information between all stakeholders and is specified and articulated through Levels of Development or Design [1,64] The Level of Design (LOD) is classified to range from LOD 100 (covering a conceptual 'low definition' design) to LOD 500 (for an as-built 'high definition' model). In practice, models that provide LOD500 are rare.

BIM and FM integration can be classified as 6D modelling (refer to Table 2) [65], where nD modelling is defined as the addition of supplementary information to three-dimensional model(s) for analysis and simulation purposes. BIM-FM integration is increasingly utilised for

[1] Practitioners in the context of this paper includes all parties involved in construction project development including: client's estates department; construction manager; architect; mechanical electrical plumbing designer; structural engineer; sub-contractor; and consultant.