Big Data Analytics in Facilities Management Higher Education: A Way Forward

Sumanarathna, N.[1], Dahanayake, K. C.[2], & Adhikari, A.[3]

[1] School of the Built Environment, London Metropolitan University
[2] AGFS Consultancy LLC, Dubai
[3] School of Applied Management, University of Westminster
Contact: n.sumanarathna@londonmet.ac.uk

ABSTRACT

Background and aim. In this digital era, the facilities management (FM) industry tends to apply Big Data analytics (BDA), employing machine learning for functions such as predictive maintenance, energy management and workplace management. Therefore, it is essential to discuss the digital transformation of facilities management higher education (FMHE) and the requirements for FMHE to be future-proof. This paper aims to explore the extent to which BDA is applied in FM and how it is manifested within FMHE.

Methods. This viewpoint paper is developed based on the industry, academic and research experience of the authors. Prior literature findings are also incorporated to develop and support the views regarding the application of BDA in the industry and its representation in FMHE.

Results. Based on the experiential learning perspective, recommendations for BDA-related teaching and learning in FMHE are delivered.

Originality. This study addresses the potential gaps between the FM industry and higher education by discussing the advanced approaches which have not yet been extensively recognised in FMHE. Hence, this paper contributes to developing new FM capabilities among students within the context of digital transformation in FM.

Practical or social implications. The recommendations derived from the experiential learning perspective add depth to the discussion, offering suggestions for understanding and advancing FMHE. This study can also serve as a guide for conducting future research in this area.

Type of paper. Viewpoint

Keywords. big data analytics, digital transformation, facilities management, higher education

INTRODUCTION

Like every other industry, Facilities Management (FM) has also been affected by recent digital tendencies or digital transformation. Due to technological advancement, managing the building life cycle has become more efficient and straightforward. Facilities operate with enormous amounts of data throughout their life cycle. Thus, big data analytics (BDA) offers significant opportunities to enhance FM processes (Ahmed et al., 2017; Yang & Bayapu, 2020). FM tasks, such as predictive maintenance, energy management and workplace management has have been enhanced due to BDA techniques (Ahmed et al., 2017; Yang & Bayapu, 2020). For instance, Big Data gathered from sensors and Internet of things (IoT) devices, Building management Systems (BMS), computer Aided Facilities Management (CAFM) Systems and smart devices are taken to develop machine learning (ML) models and predictive analytics.

These ML models and algorithms can predict the maintenance regimes, spatial requirements, and energy requirements of the building, which enables reducing wastage and conforms to sustainable practices (Carvalho et al., 2019).

The term “Big Data” can be defined as a collection of large amounts of data (Volume), that contains various information (Variety) and are generated, processed and updated in high speeds (Velocity) (Dagan and Wilkins, 2023). These data can be generated through the sources such as social media (Wilkins et al., 2021) and mobile devices (Creany et al., 2021). Big Data are digitally generated, passively produced, automatically collected, location traceable and available in real life or in some time (Laux et al., 2017). Dahanayake and Sumanarathna (2021) elaborated on the FM functions such as Energy management, Operations and maintenance management, Space management, FM Project management, Emergency management and Quality management and how each function explains digital transformation in FM. Dahanayake and Sumanarathna (2021) have further explained the process of each FM function, which is carried out via tools such as Internet-of-Things (IoT) and Building Information Modeling (BIM). These IoT-BIM-based smart FM functions produce massive amounts of big data and are analysed for future reference.

The architecture, engineering and construction (AEC) sector is lethargic in adopting the Big Data concept in which the operation and maintenance (O&M) phase is barely researched (Yang and Bayapu, 2020). Although BDA is an emerging concept in FM, it is evident that minimal initial investments in BDA assure considerable savings in FM operations in the long term (Gingue, 2022). BDA ensures informed decision-making in FM service delivery (Demirdöğen et al., 2023). In recent years FM service providers have shown interest in moving towards BDA to improve strategic decision making (Gingue, 2022).

Facilities operate with structured and unstructured data (Konanahalli et al., 2020). FM information systems, including Computer Aided Facility Management (CAFM), Computerised Maintenance Management Systems (CMMS), and Integrated Workplace Management Systems (IWMS), provide access to a wide variety of facility data (Mawed et al., 2017). CAFM enables the capture of the majority of unstructured data such as photos, graphics, videos, and scanned documents (Konanahalli et al., 2020). On the other hand, BIM models provide structured facility data (Konanahalli et al., 2020) and Construction operations building information exchange (COBie) enables the transfer of data from the construction phase to the operations phase (Mawed et al., 2017). BIM models can provide a visual platform for data analytics (Ahmed et al., 2017). In addition, Building management systems (BMS) generate a massive volume of building operational data (Konanahalli et al., 2020). Traditionally, all data obtained through CAFM, BMS and COBie are handed over to facility managers as hard copies/ electronic documents (Mawed et al., 2017). Hence, an extensive amount of facility data was accumulated idle (Mawed et al., 2017). Thus, informed decision-making was challenging with SQL database or spreadsheet statistics due to the inefficiencies associated with data analytics (Konanahalli et al., 2020). Technological innovations, including the IoT, BIM, and Digital Twins, together with advancements in computational analytics and processing power, have transformed the ability of data-driven decision making, enabling smarter and innovative delivery of FM functions (Konanahalli et al., 2020; Dahanayake

& Sumanarathna, 2021). Konanahalli et al. (2020) highlighted that integrating IoT and BDA provides efficiency savings, sustainable growth, and key performance indicators (KPIs), adding value to building operations and maintenance, sustainability and energy management, and workplace design and optimisation. Although BDA in FM is still in the experimental phase (Mawed et al., 2017), it is noted that the efficiency of key FM functions, Operations management, maintenance management, and energy management, can be improved by incorporating suitable supporting technology (Ahmed et al., 2017). Under the umbrella of BDA, four major types can be discussed, namely, 1. Descriptive Analytics, 2. Diagnostic Analytics, 3. Predictive Analytics and 4. Prescriptive Analytics (Riahi & Riahi, 2018). Since FM deals with corrective, preventive and predictive maintenance functions, the utilisation of the full spectrum of BDA has become a necessity. Thus, to meet the requirements of today's FM industry, BDA has become one of the FM competencies (RICS, 2018; Konanahalli et al., 2018).

Even though the industry is transforming to digitalised practices, the status of higher education has not been thoroughly researched. Whether the applied degree education (i.e., FM higher education / FMHE) covers such content sufficiently and is updated promptly is questionable. While highlighting the importance of bridging this gap between HE and industry demand, this paper also argues that FMHE should be shaped in providing experiential learning to students. For instance, researchers and educators such as Memon et al. (2022) signify the importance of experiential learning to improve students' learning experience in applied degree education. If students are missing out on the knowledge received from the real world (i.e., the COVID-19 pandemic), Memon et al. (2022) have further discussed the potential of simulated environments as an alternative. This aligns with Kolb's (1984) experiential learning perspective, where knowledge through experience and reflection is recommended.

A little research has been conducted to explore the take on FM applied degree higher education regarding digital transformation, particularly on BDA to carry out FM functions. In order to address this gap, a brief literature study on how BDA is applied in FM and how it is manifested within FMHE is incorporated into the paper. Journal and conference papers were searched on several online platforms such as Google Scholar, Web of Science, ResearchGate, ScienceDirect, ProQuest and EBSCO using keywords such as "Facilities Management" AND ("Higher Education" OR Curriculum") AND ("Data Analytics" OR "Big Data" OR "Machine Learning" OR " Big Data Analytics". A total of 360 research articles were filtered after removal of duplicates. A larger portion of articles discusses the facilities management of universities or other Institutes to enhance Higher Education in General. There are only a handful of the most relevant research articles that could be extracted to discuss in this paper. The literature findings have been used to explore the use of BDA in the FM sector and how FMHE has incorporated BDA when the applied degree education is concerned. Due to limited papers published in this direction, publications on BDA in other higher education streams have also been considered in writing this paper (e.g., Idris et al., 2023).

Ultimately, this paper explores the extent to which BDA is applied in FM and how it is manifested within FMHE, incorporating literature findings and the authors' industry, academic, and research experience.

Furthermore, the paper emphasizes the need to explore future-proof FM by proposing comprehensive and innovative suggestions for understanding and advancing FMHE.

LITERATURE STUDY

Facilities Management

Big data applications have the potential to revolutionize various aspects of facilities management by providing valuable insights, optimizing operations, and enhancing decision-making processes. Dahanayake and Sumanarathna (2021) have considered FM functions to elaborate on their relevance regarding IoT-BIM-based digital transformation. The FM functions are as follows: Energy management; Operations and maintenance management; Space management; FM Project management; Emergency management, and; Quality management. Figure 1 illustrates some key FM functions and how BIM and IoT can be utilised to effectively implement these FM functions in buildings.

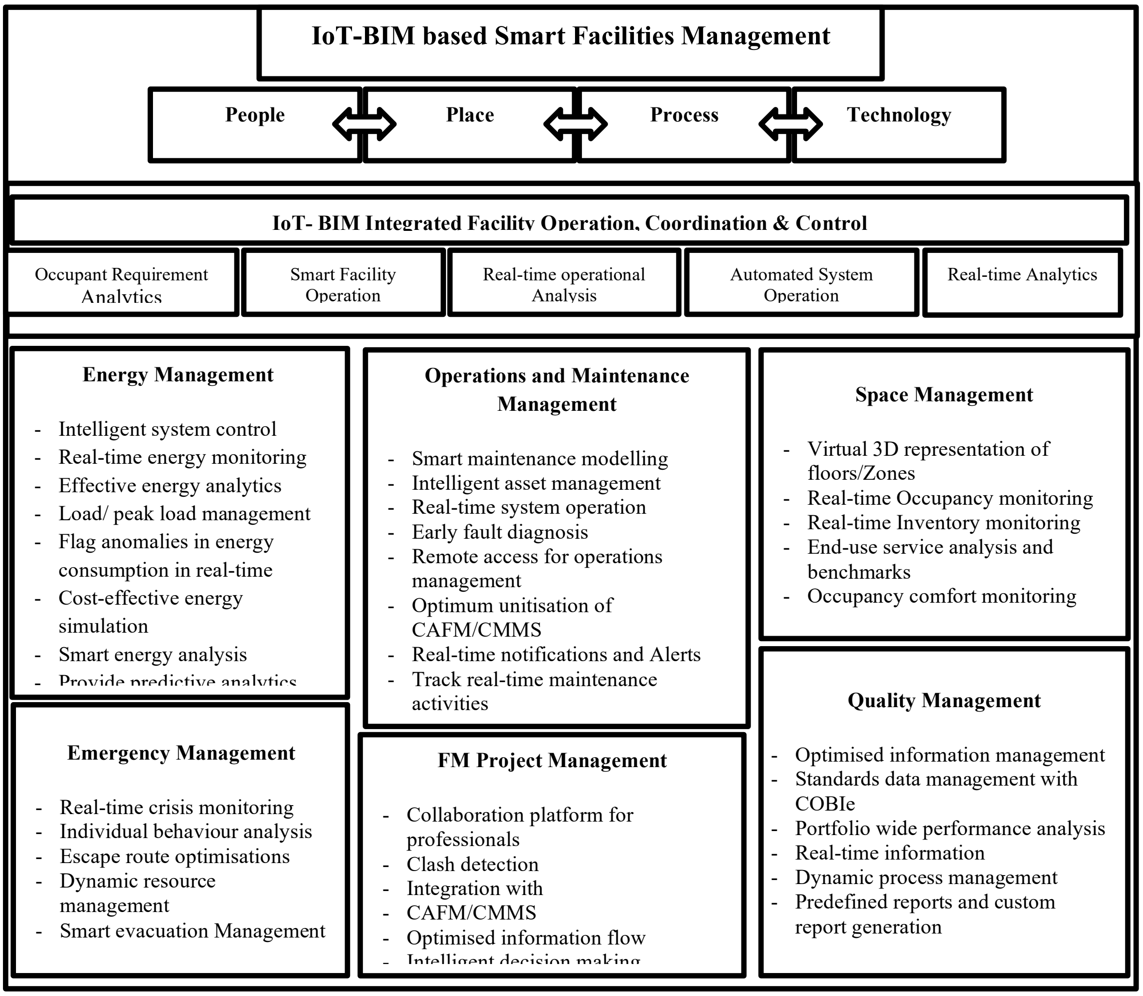

Figure 1 Proposed conceptual framework for smart FM in buildings.
Source: Dahanayake and Sumanarathna (2021, p. 11)

Junghans (2011) mentioned the ten most relevant FM research fields derived as research findings as follows: Sustainability; Knowledge; Added value; Workplace; Demand and Supply; Built Environment; Usability; Future; Health care, and; Work organisation. Among these, workplace, knowledge, health care, built environment and sustainability were found to have the highest number of scientific papers from a keyword-based advance search using Google Scholar. Lok et al. (2022) explained how facilities management is shifting towards sustainability (i.e., Strategic Sustainable FM) and adopting sustainable practices, which are various aspects of the seventeen Sustainable Development Goals (SDGs) at different organisational levels. For example, the recent ISO FM standards (i.e., (ISO/TC 267) are also aligning with SDGs by ensuring consistency of features of FM goods and services. Lok et al. (2022) further argue that the pursuit of Sustainable FM can enhance the effectiveness and efficiency of FM. The integration digitalisation in FM enables data-driven decision-making processes that optimise resource utilisation, enhance operational efficiency and ultimately facilitate sustainable FM. Big data plays a pivotal role in digitalised FM as BDA uncover patterns and insights in FM leading professionals to achieve sustainability through smart FM (McArthur, 2015).

Big Data analytics in facilities management

SUSTAINABILITY AND ENERGY MANAGEMENT: BDA enable real-time tracking and generation of ML models to predict energy consumption accurately. Gaining customised energy profiles assists in the introduction of controlled actions and tactics (Moreno et al., 2016). Smart energy meters and sensors enhance the BDA applications based on realistic data. Efficient data management using BDA algorithms can yield energy cost savings by implementing strategies such as load shifting and peak load reduction (Konanahalli et al., 2020). The emergence of IoT technology has enhanced real-time monitoring of significant energy-consuming assets in facilities, providing opportunities for big data analytics. These analytics provide insights into excessive energy consumption, abnormal consumption, and trends and patterns in energy usage. Thus, it helps facilities to run in energy-efficient terms. Mainly, BDA enable energy savings through building operational efficiencies (Dahanayake & Sumanarathna, 2021).

MAINTENANCE MANAGEMENT: BDA and machine learning have transformed traditional scheduled-based maintenance into more innovative strategies. Preventive and corrective maintenance strategies were commonly practised in facilities where maintenance is carried out on a schedule-based disregarding the actual maintenance requirement. However, IoT and real-time monitoring, along with BDA, enable smart monitoring of the performance of the assets and identifying exact maintenance requirements, promoting predictive and reliability-centred maintenance (Dahanayake & Sumanarathna, 2021). Big Data in FM enhances understanding of building, asset, and process performance through historical analysis and pattern recognition. By correlating issues and events in building subsystems, predictive technologies can identify potential maintenance issues, leading to extended equipment life, reduced operating costs, and minimized disruptions (Mawed *et al*, 2017).

OPERATIONAL MANAGEMENT: Sensor data is valuable for optimising cleaning schedules, restocking washroom supplies, and timely bin emptying. Predictive analytics can proactively identify potential issues before they lead to failure, maximizing asset utilization. Early warning notifications aid in prioritizing tasks and provide lead time for strategic planning of job activities (Konanahalli et al., 2020). BDA provides a clear understanding of the building occupancy, including peak occupancy hours, occupancy patterns, and floor heat maps, which enable the FM team to organise their staffing and provision of consumables to best match with the building operation (Gingue, 2022; Dahanayake & Sumanarathna, 2021). Continuous monitoring in real-time can enhance internal security, and dedicated weather sensors can offer early alerts for adverse weather conditions.

Facilities management higher education

Before the emergence of dedicated FM programs, the principles and practices of FM were often integrated into engineering or business-related disciplines. University of Strathclyde in the United Kingdom and Cornell University in the United States were among the pioneering universities to introduce dedicated FM programs in 1980’s (Roper, 2017; Price, 2007). In recent decades, the number of universities around the globe offering education in FM has surpassed 50, with programs available at undergraduate, postgraduate, and even Ph.D. levels. This significant growth underscores the rapid advancement of the field.

In 1999, the journal 'Facilities' became the inaugural peer-reviewed publication exclusively dedicated to FM. A decade later, the 'Journal of Facilities Management' followed suit. Continuous research endeavours by the CIB W070-Facilities Management work group and professional associations like the European Facility Management Network (EuroFM), Institute of Workplace and Facilities Management (IWFM), International Facility Management Association (IFMA), and Royal Institution of Chartered Surveyors (RICS) have significantly enriched the body of knowledge in FM (Junghans & Olsson 2014; Roper, 2017). EuroFM currently has 22 universities and universities of applied sciences as members from ten countries (European Facility Management Network, 2024; Junghans & Olsson, 2014).

The number of institutions offering FM programs varies by region and is increasing due to the growing demand for FM professionals. Facility Planning and Design, Asset Management, Maintenance Management, Sustainability Management, Financial Management for Facilities, Workplace Management, Health and safety Management, Technology and Innovation in FM and Leadership and Strategic Management are a few of the key modules commonly included in the FM curriculumEuropean Union is collaborating with higher education institutes and supporting them in adapting to rapidly changing dynamic environments to thrive and ultimately contribute to Europe’s resilience and recovery. The reason is that the HE plays a critical role “in shaping sustainable and resilient economies, and in making our society greener, more inclusive and more digital” (European Commission, 2021). Hence, HE institutions such as universities and technical institutions in Europe and globally are expected to design their education (curriculum) and research programs to meet such targets. Applied sciences disciplines such as facilities management should be perceived in HE by such expectations. Particularly with ‘going digital’ or ‘digital transformation’. In their study, Junghans and Olsson (2014) explored and discussed facilities management as an academic discipline. Furthering their discussion, challenges faced in the academic world are discussed. In order to analyse the current FM curriculum offered in HE, a list of undergraduate and postgraduate FM/FM-related degrees offered by different universities around the UK is compiled. The following Table 1 summarises such degrees along with the core modules offered.

The information compiled in the Table is extracted from each university's website and is assumed to be accurate and up-to-date.

Table 1 FM courses/programs offered by the UK universities

No	University	Degree	Level	Core Modules
1	Brunel University	Building Services Engineering with Sustainable Energy	M.Sc.	Energy Conversion Technologies, Electrical Services and Lighting Design, Building Heat Transfer and Air Conditioning, Acoustics, Fire, Lifts and Drainage, Building Services Design and Management, Renewable Energy Technologies, Energy Efficient Ventilation for Buildings, Dissertation,
2	Brunel University	Building Services Engineering	M.Sc.	Energy Conversion Technologies, Electrical Services and Lighting Design, Building Heat Transfer and Air Conditioning, Acoustics, Fire, Lifts and Drainage, Building Management and Control Systems, Design of Fluid Services and Heat Transfer Equipment, Building Services Design and Management, Dissertation,
3	Leeds Becket University	Facilities Management	M.Sc.	Facilities Information and Operations Management, Commercial and Financial Management, Project Management, Managing the Property Asset, Facilities Management Strategy & Procurement, Environment, Services and Maintenance Management, Dissertation
4	Leeds Becket University	Facilities Management (Top-Up)	B.Sc.	Financial and Commercial Management, Facilities Management - Professional Practice, Work-based Learning, Facilities & Maintenance Management, Major Project
5	University of Central Lancashire	Facilities Management	M.Sc.	Project Planning, Control and Analysis, Risk and Value Management, Health and Safety Management, Project Team and Leadership Development, Facilities Management Practice, Asset and Property Management, Dissertation
6	University of Central Lancashire	Facilities Management	B.Sc.	Construction Technology, Sustainability and Science, Management and Economics, Introduction to Law and Procurement, Professional Practice, Interdisciplinary Project, Building Services, Production Economics, Contract Administration, Management and Project Planning, Health and Safety Management, Professional Practice - CPM, Maintenance Management, Facilities Management, Project Analysis and Appraisal, Business Practice and Law, Dissertation
7	University of Greenwich	Facilities Management	M.Sc.	Facilities Management, Management Principles, Critical Thinking, Delivering Sustainable Built Environments, Property Appraisal, Research Methods, Project Management, Dissertation (Built En't), Property Development & Finance
8	University of Wales Trinity Saint David	Property and Facilities Management	M.Sc.	Building Maintenance and Asset Managament, Building Services and Energy Performance in Buildings, Management of the Intergrated Working Environment, Strategic Property, Finance and Procurement, Energy and Resource Management, Research Methods and Professional Development, Master's Project
9	Edinburgh Napier University	Facilities Management	M.Sc.	Building Economics, Dissertation, Facilities Management, Health and Safety, Law and Administration: Property and Construction, Property Asset Management

As highlighted in Table 1, all the core modules offered in different degree programs have been focused on traditional FM competencies and there is a lack of incorporation of Big Data Analytics into their curriculum.

AUTHORS' VIEWPOINTS

Big Data analytics in FMHE: the experiential learning perspective

Experiential learning is defined as the learning as "*the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience*" (Kolb, 1984, p.41). Thus, the experiential learning perspective emphasises the significance of hands-on experiences and reflective learning. According to Kolb's (1984) experiential learning cycle, the learning process has four major stages: I) Concrete Experience, II) Reflective Observation, III) Abstract Conceptualisation and IV) Active Experimentation.

The first stage is the Concrete Experience, where a student encounters a new experience, situation, or even a new interpretation of an existing experience. The second stage, Reflective Observation, involves students reflecting on an experience and considering its significance and drawbacks. Subsequently, the third stage consists of deriving a new idea or modifying an existing one based on reflective observation. Finally, these new ideas, concepts, or modifications can be applied or tested as illustrated in the fourth stage, Active Experimentation.

According to Kolb and Kolb (2017), a classroom lecture might become an abstract conceptualisation or a concrete experience if students repeat what the lecturer says. Instead, facilitating students with site visits, internships, and virtual learning environments may provide them with a better opportunity to experience experiential learning. As the FM industry is adopting machine-learning-based data analysis (i.e., BDA) in several FM functions such as sustainability and energy management, maintenance management (i.e., preventive maintenance) and operational management, FMHE students need to engage with BDA platforms as part of their experiential learning journey.

Big Data in academia

With the digital transformation happening in many business organisations, in recent years, Big Data has also attracted the interest of academia. An argument placed by academia is that the facilities required for teaching BDA in HE, including the experts, are not sufficient. However, researchers claim that many academic institutions are moving to cloud architectures and creating ecosystems that facilitate BDA decision-making. Despite the growing interest, this may not be the same in developing countries (Murumba & Micheni, 2017). However, this paper argues that teaching BDA in the FM discipline would not be an issue if the curriculum were designed using the latest research outcomes and research-informed teaching was practised in HE.

Big Data Analytics in Facilities Management Higher Education: a way forward

There can be barriers for HE institutions when integrating BDA into the FM curriculum. For instance, Dewua and Barghath (2019) revealed that issues such as lack of resources (i.e., faculty expertise and technological infrastructure) and lack of awareness of the importance of BDA among students and educators are the major barriers. In Idris's et al. (2023) study, a blended approach has been mentioned to overcome such issues. Accordingly, a framework consisting of theoretical and practical components to teach BDA in FM effectively can be recommended. The involvement of industry experts in developing the curriculum has also been suggested by prior studies (Dewua & Barghath, 2019; Idris et al., 2023).
The following steps are suggested to include BDA in the FM applied degree curriculum;

- Conducting surveys in the industry to understand FM functions in which BDA is incorporated and identifying gaps in the FM curriculum
- Designing a common module as ‘BDA in FM’ and provide FM undergraduates with a basic knowledge of Big Data and machine learning-based data analytics
- Knowledge of Big Data Analytics also requires students to be knowledgeable about statistics and develop algorithms to construct predictive models; Knowledge of coding is also required (Picciano, 2012).
- Research-informed teaching in the area of BDA in FM
- Visits to FM organisations that use BDA to carry out FM functions
- Analysis of real-world case studies
- Classroom activities related to BDA
- Designing coursework that requires students to obtain Big Data and analyse them to make decisions (e.g., energy requirements based on BDA obtained from sensors and smart devices)
- Considering SDGs in curriculum development

Most importantly, some standardisation and consistency should be maintained to ensure the credibility and reliability of the FM curriculum.

CONCLUSIONS

This paper has delved into the incorporation of Big Data analytics (i.e., BDA) in Facilities Management Higher Education (FMHE), emphasising the importance for FMHE to evolve alongside the emerging digital transformation in the FM industry. The application of BDA in FM in various FM functions, such as energy management, maintenance management, and operational management in the building context, has been investigated through a brief literature study. Then, the status of FMHE, particularly the incorporation of BDA in the FM curriculums, has been explored. The paper reveals the lack of representation of BDA in FM curriculums even though it has become (or is becoming) an FM competency. Findings echo the necessity for FMHE to incorporate BDA into its curriculum to equip students with the skills and knowledge required to thrive in the digitalised FM landscape. Drawing from the experiential learning perspective, the paper advocates for a hands-on approach to teaching BDA in FMHE, emphasizing the importance of practical experiences, site visits, and real-world case studies to complement theoretical learning (i.e., blended approach). Moving forward, the following directions are suggested as future research to extend research in the area of BDA and FMHE. Firstly, an empirical study tracking the status and evolution of the FMHE curriculum and its alignment with industry trends in BDA adoption. Research can be further extended by exploring the required modifications to FMHE in providing future-proof FM higher education. Secondly, industry-academic research collaboration to co-develop FM curriculum for different undergraduate levels, designing curriculum with real-world data and case studies, and FM internships to bridge the gap between academia and industry. Thirdly, assessing students’ FM learning outcomes related to BDA by introducing pedagogical innovations such as gamification and simulated learning environments. Finally, comparing, and contrasting FM curriculum in the UK with curricula of different countries against learning outcomes, educational policies, industry practices and digital transformation.

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