Structural equation model for the assessment of Big Data Value proposition in the UK Facilities Management

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Abstract

Big data analytics (BDA) has been introduced in the past few years in most industries as a factor capable of revolutionizing their operations by offering significant efficiency opportunities and benefits. To compete in this digital age, businesses must adopt a client centric service model, founded on data delivering continuous value, achieving optimal performance whilst also upgrading their own decision making and reporting processes. This study focuses on value outcomes (i.e. the end results of the implementation process) associated with the BDA adoption in the Facilities Management (FM) sector in United Kingdom (UK). Drawing upon qualitative case-study findings and an industry-wide questionnaire survey, a novel fifteen-variable model for BDA outcomes was developed and validated. This paper further uses the Confirmatory Factor Analysis (CFA) to establish the relationships between the variables and reveal the model's principal dimensions. The identified themes focus on improved client experiences and efficient resource management and planning. In the current dynamic market environment, the findings of this study will help FM organisations to formulate effective data-driven strategies and client facing business models.

1.0 INTRODUCTION

The vision of the fourth industrial revolution (Industry 4.0) is nowadays spreading at exponential rates across multiple fields and emerges as a universal trend which affects almost every area of business and society. The range of benefits associated with the integrated, smart and automated manufacturing environment typifying the implementation of Industry 4.0 technologies, is particularly broad; it includes increases in the organisations’ productivity, operational efficiency, overall performance and competitiveness, among others [1]. In the field of construction in particular, the Industry 4.0 paradigm, also known as ‘Construction 4.0’, has dynamically spread as a digital transformation vision capable to reverse the current poor performance of the sector in a range of crucially important metrics associated with safety, quality, efficiency and sustainability [2]. In this context, an overly enthusiastic discourse focused on the perceived implementation benefits of the Construction 4.0 vision has emerged during the past few years, accompanied by an exponentially growing relevant literature trend in the area of construction management [3].

Regardless the field of application, the digital transformation process involves the application of engineering knowledge to create electronic devices and systems such as the internet of things (IoT), digital twins and blockchain that enable more precise and flexible communication and thus, efficient and effective operations [4]. The aforementioned technologies are inextricably linked to the generation of Big Data (BD), i.e., massive datasets that exceed the capacity of standard database software tools for capturing, storing, managing, and analyzing. BD mark a significant advancement from conventional data analysis and have the potential to be stored, retrieved, integrated, pre-processed, selected, transformed, analyzed and interpreted to uncover new insights [5]. Furthermore, the speed at which large datasets are produced and accumulated through disruptive digital technologies has created a demand for effective tools and methods for their management and processing [6]. These tools and methods, also known as Big Data Analytics (BDA), rely on machine learning mechanisms such as pattern recognition, statistics and ANNs which are capable to reveal meaningful insights, patterns, and trends. By scrutinizing key processes, roles, and functions within a company, BDA have the capacity not only to facilitate understanding of current process or operations but also to question if a process is relevant to the business and suggest innovative ways for solving issues [7].
The most crucial properties of BD are their volume, variety, velocity and veracity. According to IBM's handbook [8], the dimension of Volume is self-explanatory and mainly emerges from two sources: social-mobile-cloud and the IoT. The IoT represents an evolution in which objects are capable of interacting with other objects. For example, hospitals can monitor and regulate pacemakers from afar, factories can automatically address production line issues, and hotels can adjust temperature and lighting according to their guests’ preferences. Further to the above, variety refers to trying to capture all of the data relevant to our decision-making process while Velocity, one the least understood characteristics, represents the rate at which data arrives at the enterprise and the time that it takes them to process and understand it. Finally, veracity refers to the quality or trustworthiness of the data; tools that help handle Big Data’s veracity discard “noise” and transform the data into trustworthy insights [8].

Facilities management (FM) is the discipline that involves managing and maintaining the physical assets and infrastructure of an organization. This can include buildings, grounds, equipment, and other resources that are necessary for the organization to function. The goal of FM is to ensure that these assets are well-maintained, safe, and efficient, and that they effectively support the core business activities of the organization. In this context, FM involves a wide range of activities related to the buildings, including maintenance and repairs, safety and security, energy management, space management and environmental sustainability. However, buildings have tremendous differences in size, function, construction, design, and other attributes while presenting varying levels of potential hazards and risks to the occupants and the surrounding environment [9]. Therefore, a data management system that can create data and share information can have a substantial effect on the performance of buildings [4]. Such a system is a Computer-Aided Facilities Management (CAFM) software which typically includes a range of tools and features for managing maintenance schedules, work orders, space utilization, asset management, energy usage, and building security. Such software can also help to automate many routine tasks e.g., generating reports and sending notifications helping organisations to streamline their operations and improve their FM practice. Furthermore, the FM discipline also includes, beyond the built assets, information management related to procurement, inventory and manufacturing e.g., transactions, purchases, requests and warranties, typically accomplished using an Enterprise Resource Planning (ERP) software [10].

The above show that the FM discipline heavily relies on efficiently gathering and analyzing vast and varied amounts of data that are continually generated by crucial operational resources. In this context, and since decisions taken by facility managers always have a vast impact on the effectiveness of facilities [11], the smooth and cost-effective operation of an organization can undoubtedly benefit from leveraging the power of BDA. Nevertheless, BD management is in its nascency and research studies on construction and its management in relation to big data are scarce [6]. This article aims to explores how UK FM organizations are currently capitalizing on BDA to drive innovation and ‘added value’ in their operations. The objective is to shed light on the initial BDA adoption efforts within the UK's FM sector, and particularly use mixed research methods to capture the benefits experienced by FM organisations in relation to customers value and improved decision-making processes.

The remainder of this article is organized as follows: Section 2 will review literature on the potential of the BDA integration in FM business; Section 3 provides detailed discussion on research methodology; and Section 4 discusses empirical Exploratory and Confirmatory Factor Analysis results. Finally, the paper presents a discussion and the conclusions from the findings.

2.0 LITERATURE REVIEW
The vast field of BDA applications as well as the tremendous potential they hold to help organizations gain and sustain a competitive edge in the market, are well acknowledged in the industry in the last decade [12, 13]. The successful integration of BDA and business processes provides the organizations the opportunity to extract valuable insights that would otherwise remain hidden and help the top-performing ones redefine their business and dominate in their field [14]. A preliminary survey by IBM confirms that organizations using BDA within their innovation processes are 36 percent more likely to beat their competitors in terms of revenue growth and operating efficiency [13]. This results from the fact that innovative BDA-based approaches allow organizations to anticipate customer requirements and respond to them more efficiently and eventually gain a competitive edge over other organizations. In fact, benefits emerging from the use of BDA can be classified into two main categories, i.e., strategic and operational, where the first relates to providing better services and achieving a competitive advantage in the market and the second focuses on time, cost, quality, safety and overall efficiency in the organisation [15]. Furthermore, BD applications can be used in the context of organizational competitive intelligence processes to enable organizations to get meaningful on real-time market fluctuations, competitors’ moves, and customer mobility [16].

Despite the fact that the construction industry is historically among the least digitized sectors of the economy, BDA opportunities are getting increasingly noticed and explored as the industry is currently facing a data tsunami [17]. The systematic literature investigation by Madanayake and Egbu [18] identified that the common themes representing the industry’s expectations from BDA include value creation, informed business decisions, visualisation of patterns and correlations between factors, enhancing supply chain flexibility, optimized resource and process management and productivity growth. On a deeper level of analysis, [15] emphasized the contribution of BD to efficiency through better claims management, improved accuracy for project pricing tasks and tenders, effective project progress monitoring based on near to real-time communications and updates between site and head office, quick response to issues and defects, improved relations between stakeholders and informed supply chain decisions.

Furthermore, emerging IT applications are getting increasingly popular in construction, as a result of the advances brought by the establishment of Building Information Modelling (BIM) in the industry. BIM applications have the potential to change the landscape of project management by offering the unique opportunity of integration for people, processes, business systems, and information. This, in turn, enables the optimal management of capital costs, time constraints and resource planning [19]. Furthermore, when combined with a network of sensors, BIM applications can work as real-time operation models, also known as digital twins. Digital twins are commonly defined as up-to-date digital representations of the physical and functional properties of a system, which emerge from BIM models as the system enters its operational phase [20]. The digital twin model-still in nascent stage in construction-takes advantage of the use of sensors (e.g., RFID, video cameras, and laser scanners) and interacts in real time over the IoT, while the relevant operational data are analysed by machine learning entities (e.g., ANNs). This way, BIM becomes the backbone of a digital platform at the service of efficient decision making [21, 22].

Especially in the FM field, coupling BIM models and sensors has the potential to transform traditional FM systems into smart systems which can continuously monitor the built environment in an automated way. This creates extensive improvement opportunities in various fields. According to Dahanayake and Sumanarathna [23] the greatest improvement potential for FM emerges from the following six functions i.e., energy management, operations and maintenance management, space management, emergency management, FM project
management and quality management. For instance, comprehending the energy consumption habits of a building represents the first and most critical step to achieve energy efficiency. BDA can play an essential role in this with the development of AI models capable to predict energy usage based on constantly collected smartmeter data reflecting load patterns and ambient conditions [9]. Furthermore, in the field of maintenance operations, which is of crucial importance, Industry 4.0 has brought significant change in monitoring techniques: visual inspections and manual data processing are increasingly being replaced by high-frequency sensors generating real-time BD on a variety of measurements including vibration, temperature, and thermography [24]. Furthermore, the literature also highlights how BDA boost predictive maintenance capabilities such as the ability to determine appropriate maintenance intervals, improved asset condition prognosis and early anomalies detection [25, 26]. Moreover, – apart from energy and maintenance- critical for building owners BDA potential applications concern safety management, accidents prevention, disaster response operations, environmental conditions monitoring, procurement management and quality inspection [11, 17]. Additionally, BDA enables the dynamic, real-time monitoring of building occupancy, system alarms, fire safety alerts, water usage and indoor environment quality parameters [23, 9]. The above-mentioned potential BDA benefits in FM are summarized in Fig. 1.

Despite BDA's enormous potential towards helping organizations make data-driven decisions, improve operational efficiency and gain a competitive advantage in their respective markets, there is still limited understanding on how firms translate the potential of such technologies into business value [16]. Moreover, the industry has a long way to go to mature and overcome issues hindering BDA application in practice [6, 11, 27].

3.0 RESEARCH METHOD

Due to lack of literature on actual BDA adoption cases in FM sector, qualitative case study research methodology was employed at the first stage of the study to explore BD applications for FM organisations in the UK. The second stage involved a questionnaire survey and factor analysis (both exploratory and confirmatory) to test the initial relationship established through the use of qualitative study and literature review. As such, the study was carried out in two stages in line with exploratory sequential mixed method approach.

A list of factors associated with BDA implementation (Drivers, Challenges, Strategies, Outcomes and Future initiatives), as emerged from the first phase of the study (qualitative case study) was produced in the form of a comprehensive questionnaire. The authors have elaborately analysed the part of Drivers and Challenges in a previously published paper [10], therefore this study specifically focuses on the quantitative analysis of the “outcomes” as presented in Table 1. The relevant survey instrument asked the respondents to rate their agreement with regards to the potential occurrence of various benefits as a result of BDA practice as per their experience, using a 1 to 5 Likert scale where 1 represented “strongly disagree” and 5 represented “strongly agree”. In order to prevent ambiguity in the research instrument, a pilot study was carried out with several experts to test the clarity of language, layout, the degree of depth, the logic of the questions, and to perform a preliminary check of the proposed analysis.

MEASUREMENT OF CONSTRUCTS
### Table 1
Outcome Variables

<table>
<thead>
<tr>
<th>Code</th>
<th>Outcomes</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>OT1</td>
<td>Evidence-based decision making</td>
<td>3.92</td>
</tr>
<tr>
<td>OT2</td>
<td>Better understanding of asset life-cycle</td>
<td>3.82</td>
</tr>
<tr>
<td>OT3</td>
<td>Optimisation of stock management</td>
<td>3.35</td>
</tr>
<tr>
<td>OT4</td>
<td>Accurate pricing for tenders</td>
<td>3.37</td>
</tr>
<tr>
<td>OT5</td>
<td>Accurate quantification of cost savings for the client</td>
<td>3.75</td>
</tr>
<tr>
<td>OT6</td>
<td>Seamless data/information mobilisation between contracts</td>
<td>3.33</td>
</tr>
<tr>
<td>OT7</td>
<td>Lower the cost of asset ownership for the client</td>
<td>3.55</td>
</tr>
<tr>
<td>OT8</td>
<td>Greater transparency in reporting to the client</td>
<td>4.04</td>
</tr>
<tr>
<td>OT9</td>
<td>Evidence of engineering compliance</td>
<td>3.88</td>
</tr>
<tr>
<td>OT10</td>
<td>Reduced asset downtime</td>
<td>3.73</td>
</tr>
<tr>
<td>OT11</td>
<td>New benchmarks for facilities/assets/site performance</td>
<td>3.75</td>
</tr>
<tr>
<td>OT12</td>
<td>Demonstrable return on investment for the client</td>
<td>3.65</td>
</tr>
<tr>
<td>OT13</td>
<td>Productivity in workflow management</td>
<td>3.67</td>
</tr>
<tr>
<td>OT14</td>
<td>Better route planning for sub-contractors i.e. optimisation of field crews</td>
<td>3.53</td>
</tr>
<tr>
<td>OT15</td>
<td>Connected business operations</td>
<td>3.71</td>
</tr>
</tbody>
</table>

### 3.1 SAMPLE PROFILE

Key decision-makers within UK FM companies involved with BDA adoption formed the population of this study. From 150 email requests sent, a total of 52 complete responses were returned, yielding an effective response rate of around 35%. The 40% of the participants were directors with considerable number of years of experience, followed by Project managers (15%) and technical managers (14%). The remaining 23% of the respondents held various titles that included Innovation Manager, Bid Manager, IT partner, Sales Manager, Marketing Manager, Head of Data Governance to name a few. More than half of the sample population (56%) had an industry experience of over 15 years. Significant effort was made by the researchers to ensure that only those individuals who had sufficient experience of BDA implementation were involved in the study.

Interestingly, only 29% of the respondents held the British Institute of Facilities Management (BIFM) membership, whereas a substantial 47% of the respondents did not hold any professional memberships. It should be noted that it is very common for BIFM members to hold additional memberships with other professional bodies/institutions. As for the education and qualifications of the respondents’, a third (33%) held a first degree, 15% held Masters, 4% held Doctorate, 27% reported Pre-Degree qualifications and, 17% had various other qualifications. Bulk of the responses were from larger FM organisations with 5000 + employees at 66%, whereas the participation of small businesses (less than 50 employees) was restricted to 7.5%.

### 3.2 ANALYSIS
The Statistical Package for Social Sciences (SPSS) 26.0 was used to conduct preliminary statistical analysis that included Exploratory Factor Analysis (EFA) and Cronbach's Alpha followed by Confirmatory Factor Analysis (CFA) to establish constructs path models and validate the confidence and reliability level of the PCA results. The EFA analysis helped to identify the variable structure that explained each of the specified underlying items of Outcomes associated with BDA Adoption. Since there is no reliable theory articulating variable relationships, Principal Component Analysis (PCA) was adopted by the researchers to explore the patterns in data using variance analysis and reduce dimensions to obtain the comprehensive and key indicators that explain most of the variables of the original set. PCA extraction method and varimax rotation were employed to generate the uncorrelated extracted component with eigenvalue greater than 1.0. As recommended by [28, 29] the accepted threshold value of standardized factor loading was set at 0.50, while Cronbach alpha was set at 0.70. In EFA, the Kaiser–Mayer–Olkin (KMO) test was adopted to measure the sampling adequacy for each constructed variable and Bartlett's Test of Sphericity was used to examine the null hypothesis i.e. whether the correlation matrix based on the collected data is an identity matrix, which indicates that the sample is unsuitable for structure detection. The threshold for KMO values is set between 0.8 and 1 and the significance level of Bartlett’s Test of Sphericity is recommended to be less than 0.05.

For the next stage of the analysis, the researchers performed the first and second order CFA. The CFA is conducted to establish confidence in the measurement model, which specifies how the hypothetical constructs are measured in terms of the observed variables [30]. The AMOS 22 software programme was used to test both the above-mentioned models. Second order CFA is essential to validate scales (in this case the newly developed construct i.e. the outcomes of BDA adoption) in terms of the convergent and discriminant validity after the component has been identified from the EFA [28, 31]. Convergent validity is a measure of internal consistency which is estimated to ensure that the measurement variables provide true measures of the respective latent variables in entirety. As per [28] it can be examined with reference to standardised factor loadings, composite reliability (CR) and Average Variance Extracted (AVE). Threshold values for factor loadings, CR, and AVE should be higher than 0.5, 0.7, and 0.5, respectively.

Discriminant validity on the other hand represents the extent to which a construct is truly different from other constructs [28] To examine discriminant validity of a measurement model, Henseler et al., [32] and Fornell & Larcker’s [33] criteria were used to evaluate the discriminant validity. These respectively foresee that the covariance among unobserved variables should be lower than 0.85 and that the inter-construct correlations should be less than the square roots of AVEs.

Construct reliability analysis of the measurement variables was assessed through Cronbach's reliability test and composite reliability coefficient.

After assessing the measurement model, a variety of fit indices were used to assess the structural model. The model fit was evaluated for both first and second order models using a number of fit indices, including the ratio of $\chi^2$ to degrees of freedom, goodness-of-fit index (GFI), root mean square error of approximation (RMSEA), Tucker–Lewis index (TLI), and comparative fit index (CFI) [34, 35]. Sivo et al., [36] have recommended inclusion of a number of fit indices since different indices reflect a special aspect of model fit. Section 3.3.3.1 indicates the recommended fit values for the various indices.

3.3 RESULTS AND FINDINGS
The results for both PCA and CFA formalized three dimensional models for BDA Adoption Outcomes. The value of the KMO test for sampling adequacy is 0.812, (p > 0.50), and Bartlett’s Test of Sphericity is 468, with the significance level of 0.000, which imply that the population correlation matrix is not an identity matrix and thus the sample is adequate for factor analysis. Following this confirmation, Components with Eigenvalue > 1 were extracted by PCA with Varimax rotation. Table 2 (Rotated component matrix extracted from SPSS) displays the variables onto each factor with loadings exceeding 0.50. The weighting of the factor loading reflects the substantial degree of contribution of each variable to its extracted factor. Based on the correlation among the variables, each extracted factor was labelled with an overarching title. Three principal factors were identified and therefore labelled as “Client-centric added value”, “FM business end-to-end added value”, and “Efficient Resource Management and Planning”.

### Table 2
Rotated Component Matrix

<table>
<thead>
<tr>
<th>Collective Label</th>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Cronbach's ( \alpha )</th>
<th>Variance explained</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Client centric added value (Outcomes Group 1 – OTGP1)</strong></td>
<td>Greater transparency in reporting to the client</td>
<td>.813</td>
<td></td>
<td></td>
<td>0.91</td>
<td>27.74%</td>
</tr>
<tr>
<td></td>
<td>Reduced asset downtime</td>
<td>.811</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Evidence of engineering compliance</td>
<td>.709</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Better understanding of asset life-cycle</td>
<td>.669</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Evidence-based decision making</td>
<td>.630</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>New benchmarks for facilities/assets/site performance</td>
<td>.630</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accurate quantification of cost savings for the client</td>
<td>.600</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Demonstrable return on investment for the client</td>
<td>.579</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FM business end-to-end added value (Outcomes Group 2 – OTGP2)</strong></td>
<td>Seamless data/information mobilisation between contracts</td>
<td>.798</td>
<td></td>
<td></td>
<td>0.82</td>
<td>22.18%</td>
</tr>
<tr>
<td></td>
<td>Optimisation of stock management</td>
<td>.738</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accurate pricing for tenders</td>
<td>.737</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower the cost of asset ownership for the client</td>
<td>.659</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Efficient Resource Management and Planning (Outcomes Group 3 – OTGP3)</strong></td>
<td>Productivity in work-flow management</td>
<td>.839</td>
<td></td>
<td></td>
<td>0.82</td>
<td>17.87%</td>
</tr>
<tr>
<td></td>
<td>Better route planning for sub-contractors i.e. optimisation of field crews</td>
<td>.802</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Connected business operations</td>
<td>.684</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.3.1 FIRST AND SECOND ORDER CFA

Following the EFA, the 15 observed outcome variables were divided into three latent variables (OTGP1, OTGP2 and OTGP3). Maximum likelihood estimation method in AMOS 22 was used to evaluate the distinctiveness of the measures used in the present study. Overall, there are three factor structures, OTGP1 has 8 variables, OTGP2 has 4 and OTGP 3 has have three indicator variables (See Table 2).
Before assessing the structural model, the measurement scales of the first-order factors of BDA Adoption Outcomes were estimated. Table 3 summarises the results of construct validity and reliability. Construct reliability was assessed by analyzing the CR and Cronbach α values which should be greater than .60 and 0.7 respectively [28]. As indicated in Table 3, these conditions were met, evidencing reliability. The factor loadings for each indicator range from 0.67 to 0.89. All the 15 variables indicators achieved the assumption requirements that the factor loadings ≥ 0.50. Additionally, all path coefficients are significant at 0.001 level, indicating that all the factor loadings in the model were significant. CR and AVE for all the latent constructs are shown in Table 3.

In terms of discriminant validity, covariance among unobserved variables is lower than the threshold of 0.80 proposed by [28] and, 0.85 proposed by [32] (see Fig. 2). Fornell and Larcker [33] criterion can also be used to assess Discriminant validity: the square root of the average variance extracted by a construct must be greater than the correlation between the construct and any other construct. Once this condition is satisfied, discriminant validity is established. Since none of the values exceeds 0.80 and, in all three instances AVE ≥ r², discriminant validity of the Outcomes measurement scale can be established. The following section provides an assessment of second-order CFA.
Table 3
First and Second Order EFA results

<table>
<thead>
<tr>
<th>OT1 – OGP1</th>
<th>Estimate</th>
<th>AVE</th>
<th>CR</th>
<th>CR &gt; AVE</th>
<th>Cronbach α</th>
<th>OGP1 – Outcome</th>
<th>Estimate</th>
<th>AVE</th>
<th>CR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.67</td>
<td>0.57</td>
<td>0.91</td>
<td></td>
<td>0.914</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| OT 2 - OGP1 | 0.81     |     |    |     |            |               |           |     |    |
| OT 5 - OGP1 | 0.84     |     |    |     |            |               |           |     |    |
| OT 8 - OGP1 | 0.72     |     |    |     |            |               |           |     |    |
| OT 9 - OGP1 | 0.69     |     |    |     |            |               |           |     |    |
| OT 10 - OGP1| 0.84     |     |    |     |            |               |           |     |    |
| OT 11 - OGP1| 0.76     |     |    |     |            |               |           |     |    |
| OT 12 - OGP1| 0.69     |     |    |     |            |               |           |     |    |
| OT3 – OGP2  | 0.74     | 0.55| 0.83|     | 0.82       |               |           |     |    |
| OT4 – OGP2  | 0.76     |     |    |     |            |               |           |     |    |
| OT6 – OGP2  | 0.78     |     |    |     |            |               |           |     |    |
| OT7 – OGP2  | 0.67     |     |    |     |            |               |           |     |    |
| OT13 – OGP3 | 0.76     | 0.63| 0.83|     | 0.82       |               |           |     |    |
| OT14 – OGP3 | 0.89     |     |    |     |            |               |           |     |    |
| OT15 – OGP3 | 0.71     |     |    |     |            |               |           |     |    |

**STRUCTURAL MODEL ASSESSMENT**

<table>
<thead>
<tr>
<th>Threshold</th>
<th>MODEL FIT INDICES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>χ²</td>
<td>112.98</td>
</tr>
<tr>
<td>df</td>
<td>84</td>
</tr>
<tr>
<td>χ²/df</td>
<td>&lt; 3</td>
</tr>
<tr>
<td>GFI</td>
<td>≥ 0.80</td>
</tr>
<tr>
<td>IFI</td>
<td>0.94</td>
</tr>
<tr>
<td>TLI</td>
<td>≥ 0.90</td>
</tr>
<tr>
<td>CFI</td>
<td>≥ 0.90</td>
</tr>
<tr>
<td>RMSEA</td>
<td>≤ 0.08</td>
</tr>
<tr>
<td></td>
<td>FIRST ORDER CFA</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>P-Close</td>
<td>&gt; 0.05</td>
</tr>
</tbody>
</table>

For the second order model, the standardized factor loadings were substantially high, ranging from 0.72 to 0.93, and all were significant at $p < 0.001$. These indicators, i.e., factor loading along with acceptable AVE, provide support for the convergent validity of the model. The 1st and 2nd measurement models have established an acceptable level of reliability as both Cronbach $\alpha$ and CR values are well above the recommended levels, as shown in Table 3.

**STRUCTURAL MODEL ASSESSMENT**

Fit indices for both the first and second order models (presented in Table 3) for the outcome constructs suggest that the model fits the data well. The model was considered to have acceptable or good fit, as $\chi^2 / df = 1.35$ was less than 5, CFI = 0.93 was higher than 0.8, RMSEA @ 0.08 was lower than 0.1 and TLI = 0.92 is higher than 0.9. However, the GFI index value of this study is 0.80 which is lower than 0.90 recommended by researchers. This could be explained by the fact that both GFI and AGFI indices are significantly affected by the sample size [37]. This could be one of the reasons why the popularity of this index has taken a hit in recent times. In fact [38], have even suggested abandoning this index all together. Overall, all other essential indices provide evidence that the fit between the measurement model and the data is certainly acceptable.

As suggested by [39], attention was diverted to assess the explanatory power i.e. squared multiple correlations ($R^2$ values) of the structural model. Among the individual components of Outcomes, OTGP1, OTGP2 and OTGP3 explained 86%, 66% and 52% variation in Outcomes respectively (see Fig. 3). Values in the range of 0.75, 0.50 are considered high and moderate respectively [39].

**4.0 DISCUSSION OF FINDINGS**

The main objective of this study was to validate a newly developed scale to measure Outcomes of BDA adoption. Building on the three qualitative case studies followed by an industry-wide questionnaire survey from 52 respondents heavily involved with BDA implementation, the researchers validated a three-factor and 15 -item scale that was extracted through EFA and established through CFA. This is the first empirical study that takes a step forward towards capturing the potential of FM organisations to deliver a host of value enhancing benefits to its customers and improve their own decision making based on BDA.

From a theoretical perspective, the results suggest that outcomes of BDA Adoption in an FM context can be conceptualized meaningfully as a multi-dimensional construct. The newly developed construct captures the principal elements of BDA Outcomes; as expected, the highest factor loading ‘Client centric added value’ (OTGP1) emerged at the top, with a factor loading of 0.93. Suggesting that increased focus on performance measurement and adoption of analytical tools are to helping FM organizations to become integral part of the value creation process [40]. This is closely followed by OTGP2 with $\beta$= 0.82 and OTGP3 with $\beta$= 0.72, indicating that infusing analytics in critical FM tasks/operations enables organizations to efficiently plan and manage resources.

**4.1 OTGP 1- CLIENT-CENTRIC ADDED VALUE**
The findings suggest that organisations leveraging BD capabilities can now focus on client centricity and reinvent the customer experience. This opportunity to not only create value but share it with clients could be regarded as the raison d’
 être of collaborative customer-supplier relationship [41]. FM BD brings new opportunities for discovering ‘value’. With emphasised focus on cost savings, FM organizations are increasingly expected to offer comprehensive reporting propositions, benchmarking, engineering compliance of assets/equipment etc. In a bid to support these objectives, a growing number of FM organizations are investing in BDA and IoT technology to remotely monitor and collect sensor data to better understand the performance of the buildings. Self-monitoring ‘smart’ equipment can measure their own performance and spot even the minutest change by comparing historical operational footprint of an asset to its real-time operating data [42]. Gaining unprecedented visibility and transparency into critical asset performance through condition-based maintenance approach is not only de-risking FM operations but providing valuable insights on client’s energy profile, demonstrating statutory compliance, evidencing decision making and reducing the cost of asset ownership [43]. As highlighted by [27] this newfound ability to extend BDA capabilities to its clients allows facilities managers to see the bigger picture and defend their decisions based on supporting information, tracking trends for preventive maintenance and provide insight during budget calls. Granular visibility provides FM with direct control over all aspects from the location to the enterprise level [44].

The current trends suggest that value of data and analytics has completely upended the traditional FM-client relationship. Increased connectedness is creating unique opportunities for businesses to focus on proactive customer service and innovativeness enhancing the value of the firm’s offering in business-to-business contexts [45]. As highlighted by [46], this aspect is relevant to FM industry where customers are often an integral part of the service production process. Therefore, it is not surprising to note that companies at the forefront of the data analytics implementation are able to achieve higher rate of return than other recent technologies have yielded. Going forward, FM sector is compelled to make BDA a critical business priority to face the challenges of digitization and make the business more customer centric.

4.2 OTGP2- FM BUSINESS END-TO-END ADDED VALUE
Seamless data/information mobilisation between contracts
Optimisation of stock management
Accurate pricing for tenders
Lower the cost of asset ownership for the client

Increased connectedness and BDA adoption are creating unique opportunities for FM businesses to make huge strides in carrying out tasks and processes more efficiently (streamline existing labour-intensive maintenance improve the work they currently do) and freeing up time to spend on value-adding or strategic activities [47]. Specifically, the FM industry is actively involved in developing advanced strategies and techniques to maintain its assets. As such, Condition-based and predictive maintenance are emerging to be major trends in the digitized FM industry. Primarily because these maintenance strategies enabled by ‘Internet of Things’ (IoT) offer remote monitoring of typical FM systems (HVAC, Power, Air Quality, Temperature, Lighting etc.) [48] providing granular visibility into an asset’s history, optimise FM operations and in turn lower the Total cost of asset ownership for client organisations [43].

Another aspect reported by organisations was the newly acquired capability to seamlessly mobilise and transfer of data between FM contracts. Currently, data standardisation approach is positively streamlining the whole process of data accumulation for submitting tenders/contracts. The positive implications are the generation of value and the contribution to data mobilisation i.e. the transfer of a standardised data set from previous contracts to the following ones and providing supporting statistics. This onset of analytics journey has transformed the traditional FM process delivering significant benefits like, improved resource and stock management, and greater accuracy in tender pricing [43].

4.3 OTGP3 – EFFICIENT RESOURCE MANAGEMENT AND PLANNING

Productivity in work-flow management
Better route planning for sub-contractors i.e. optimisation of field crews
Connected business operations

Since maintenance and FM is a complex business area, encompassing different processes and requiring the integration of a wide range of competences [49], it imposes significant responsibilities on managers with regards to day-to-day facility functions and workflow. Most often, companies dealing with rising cost of maintenance seek to cut FM spending by reducing repair interventions to a minimum, delaying preventive maintenance actions, which then leads to a cascade of extra costs in the medium and long term [50]. Also, such delays could be attributed to sub-optimal allocation of resources and unstructured workflow process [51].

Making use of information systems and relevant data, advanced FM organisations are adopting analytics to reform resource intensive service delivery processes. Operationalizing and building on their use of data and
analytics for greatest impact, FM organisations are automating and optimising manual and resource intensive maintenance tasks to maximize productivity. Now managers can set rules to automatically assign tasks to specific technicians and monitor their performance in real-time [52]. As per [27], this data driven approach is not only allowing the FM team to automate the workflow, resolve problems quickly, but also enhancing customer satisfaction through reduced response time, downtime, and claims. Furthermore, the resulting improved information management is also supporting the development initiatives to optimise field crew and better route planning.

Overall, this group/theme addressed how data driven approach to workflow management and planning, is fostering a culture and learning system which values data use for continual improvement.

As suggested, route optimisation planning helps with cost efficiencies in transportation. In this instance, based on BDA mapping, managers can assign tasks to field crew based on traffic situations, distance, weather, efficient real-time-based routes and a host of other factors reducing mileage and identifying opportunities to improve efficiency. However, it should be noted that organisations adopting this data-driven mindset need to cultivate a new culture of decision making, in that they must be prepared to accept what “data” indicate even when the data contradict their observations and experience [53].

5.0 CONCLUSION

This study produced a three-dimensional model of outcomes associated with BDA adoption in FM. Based on the CFA model, the relationships between fifteen variables were established. These outcomes focused on creating unique opportunities for improving client experiences, optimised management of contracts and streamlined workflow. In order to compete in this new industrial age of digital transformation, FM businesses must adopt a consumer-centric service-based business model, founded on data delivering continuous value, achieving better results and performance.

The findings suggest that FM service is getting smarter as the shift moves from reactive to proactive approaches. Organisations with the right data/information management strategy will not only be rewarded with better insights but stronger customer relationships leading to customer loyalty. Since clients expect more personalized services, efficient tools/technology that facilitates the use of real-time data is now critical. No doubt, this adoption is creating a competitive differentiation strategy for FM organisations as they seek to build mutually beneficial customer relationships [54]. In addition, powered by analytics and data-driven insights, FM companies are able to evidence improvement in management of contracts through developing new ways of creating value and transparency from asset data. This comprehensive understanding of contract performance built on accurate data not only leads to risk reduction but best pricing strategy for the business, as well.

Making the most of BDA translates to suitably analysed business and workflow data is providing FM teams with evidence to introduce significant value add changes to their existing work patterns, field crew operations, route planning, thereby extracting best performance and value. One of the key takeaways from this study is the renewed focus on developing strategies and relationships that enhance the firm’s competitiveness in the marketplace. Interestingly [16], introduce the concept of ‘Competitive Intelligence’ where organizations are now capitalising on Big Data initiatives by monitoring their competitors with a view to further buildout their
competitive advantage. This market disruption strategy could certainly help to improve the standing of the FM profession in the world of business and facilitate growth opportunities. However, the developed and validated scale can serve as a tool for FM organisations to foster change through demonstration of ‘added value’. In addition, by revealing the important items and constructs of the scale, this study sheds light on early successes of FM organisations as they evolve into insights-driven organizations.

5.1 Limitations

Through the current study and previous publications [10, and 43], the researchers have provided some insight into how BDA is delivering value enhancing benefits to FM organisations in the UK. Given that BDA adoption is at a nascent stage and limited to larger organisations, the overall sample size was small (though statistically adequate). So, there may be limitations when generalising the findings of this study to other developing economies. As the technology adoption gathers pace, future studies could focus on collecting and analysing larger and diverse sample frames to include developing countries and small and medium sized (SMEs) organisations.

Declarations

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Data Availability Statement:

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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Figures
Figure 1

Benefits of Big Data Analytics for Facilities Management
Figure 2

First order CFA
Figure 3

Second Order Confirmatory Factor Analysis