BUILDING INFORMATION MODELING (BIM) CULTURAL AND STRATEGIC CAPABILITIES FOR DIGITILISATION IN CONSTRUCTION FIRMS

Kudirat ZAKARIYYAH[1], Iniobong John[2], and Irewolede IJAOLA[3]

[1]University of Lagos
[2]University of Lagos Faculty of Environmental Sciences
[3]Yaba College of Technology

May 5, 2020

Abstract

As digitilisation is being applied in redefining products and business models world-wide, evidence abound in the construction industry as a sector that is slow to its adoption. While digitilisation tools have been applied in modifying processes/procedures in the global North; a larger percentage of the sector in the global South is yet to be disrupted. For indigenous firms to join the rapid transformation wheel, this study reviews the interrelationship between digitilisation and building information modeling. The study objectives are to examine the prevalence of cultural and strategic capability, evaluate the relationship between cultural orientation and strategic capability as well as predict a model of building information adoption from culture and strategy. The study population was drawn from the list of construction firms registered with the Lagos State Tender board, list of registered construction firms from the Institute and specific listed firms on the internet. Factor Analysis, Correlation and Regression were the adopted statistical tools. The results revealed production; task and goal attainment; information/communication technology; workforce; innovation, learning and knowledge management as well as conflict and dispute resolution as the prevalent cultural orientations. The availability of resources to communicate, interact and collaborate digitally and leadership capability to organise and coordinate digitally are the top two strategic capabilities. Consequently, 3 out of every 5 firms have moderate awareness on BIM implementation. It was concluded that the level of agreement on the adoption of the culture and the strategy did not reflect on the level of BIM adoption model. Since the results revealed that the existing orientation and strategy contribute about a tenth of BIM adoption model; the firms' leadership need cultural re-orientation from the client angle and from business environment. On strategy, the firms need support from institutions/government on policies that will cushion the effect of the provision of resources for transformation.

INTRODUCTION

The construction sector is coming lately in the adoption cycle due to its characteristics. *1* infer that poor, unclear and dis-jointed information, segmentation into silos the interest of stakeholders, duplication of efforts, non-alignment of interest with objectives, mismanagement of resources have contributed to inefficiency and waste which require re-orientation and re-drafting of business models. There is an urgent need to adopt modern business models either in conjunction with the conventional ones or jettison the conventional methods in its entirety as the case may demand. Different technological advancement has been employed in construction. Right from the beginning of civilisation around 1800, when steam engine became the major driving force for industries, to the second industrial age when electricity was discovered. During this period, electrification was employed to accelerate and automate production processes *2* . With the advent of the third industrial revolution in the 1970s; further advancement was made on electronics and information technology. During this period, extensive use of computers and internet facilities became widespread with human labour gradually replaced with machines.

The current dispensation, tagged ‘industry 4.0’ is an era of information technologies and the advent of machines powered by artificial intelligence (AI). According to *3 & 4* , the introduction of AI is a great difference between the fourth industrial revolution and the third. Artificial intelligence describes a technology whereby work processes that would require a great deal of intelligence if performed by human beings are taken over by machines, commonly referred to as ‘intelligent agents’. These intelligent agents deploy systems that perceive the surroundings and take actions that maximise the chances of success (*5* ; *6*). Through the development of theories, methods, procedures, techniques, applications on intelligence, machines are enhanced to perform complex tasks. The machines after programming through computer systems are equipped with the ability to behave, reason, learn, communicate and act in complex environments and therefore perform in a better way, tasks that demand intelligent human intervention (*7;8; 9* ; *3*).

Artificial intelligence require machines programming, however, with ‘machine learning’ (ML), a step ahead of AI, machines are not programmed but become cognitive, having learnt autonomously acquiring computing skills (*10*). Thus, with AI and ML, tasks are semi-automated or fully-automated, that is numerically controlled on-site or off site (*11*). Automation in the industry started about four decades ago. This was initiated to reduce safety and health challenges and hindrances in working with chemicals or radioactive elements, remote job sites, highly contaminated jobsites and high-risk environments (*12*). AI has a number of tools, divisions or domains for different activities.*6* submitted that AI has been employed in a number of fields as artificial neural networks (ANN), Genetic Algorithms (GA), case-based reasoning (CBR), fuzzy theory, game theory (GT) and Multi Criteria Decision Making (MCDM). These are further categorised as formal tasks (such a mathematics and games) and expert tasks (such as scientific and precision analyses in the realms of engineering and medicine). In the fields of construction and engineering, genetic algorithms, neural networks, fuzzy logics, expert system, natural language, robotics, computer vision, case-based reasoning, k-means clustering, qualitative reasoning model and so on have been successfully integrated to ease production and management systems. Some of the applications of AI in the fields of engineering and construction abound in the literature (*11* ;*13*). For competitive advantage and sustainability, leadership is important, so also is firm resources and capability, this study thus looks at the culture and strategy of firms from leadership perspective with a view to promoting and instilling cultural orientation and strategy for BIM and automation among indigenous construction firms.

2.1. APPLICATION OF AUTOMATION IN CONSTRUCTION WORKS

The importance of site planning to all types of projects irrespective of its magnitude has been stressed. The correlations among site layout, temporary facilities, production time and cost are well emphasised.*14* express useful insights on the enhancement of site facilities, space allocation and routing of materials through genetic algorithm system. The strength, self-compacting capability, maximum dry density (MDD), self-healing/cleansing ability of concrete is predictable and enhanced through artificial neural network (ANN). These properties are versatile in concreting works and in maintenance and have been employed in multi-criteria quest for optimal concrete mixes (*15*). Expert opinions and fuzzy sets are versatile in the analysis of structural integrity, especially for buried structures and earthmoving (*16*). 3D printing allows enhances the printing of constructed facilities or components in a three-dimensional format through an additive manufacturing process comprising material layer accumulation and selective solidification (*17* ;*18*). 3D Laser scanning (LS) has the capability to produce an as-built model of as low as 6mm accuracy thus enhancing material optimisation and precision (*19*). Sensor modes have been employed to collect data from the surrounding environment of as-built model and share with a designed model to reveal discrepancies when comparing as-built models with designed models. This application is promoted through the use of Wireless Sensor Network (WSN) (*20*). Robotisation is gradually replacing human efforts as more précised task that cost less, in the long run are certain (*21*). Autonomous/unmanned vehicles (UMVs) and autonomous drones are taking over certain activities that require human endeavours. Consequently, drones have been deployed to control crowd, to garner information or retrieve data in real estate and on collapse structures and so on especially in hard-to-reach areas (*8;10*). Augmented reality and virtual reality employ 3D with computergenerated graphics and inputs to develop, map images thereby making such interactive with the user in the physical world. For instance, with mounted head display and hand-held devices, in a digital laboratory where images are projected onto the wall, one can move through building structures to make and effect certain changes (*22* ;*23*).

These and other AI technologies have their merits, demerits and challenges; however, an interface known as building information modeling (BIM) is inevitable. This is more so due to the challenges resulting from the unique nature of every project, mobile site, traditional procurement methods, site terrain and highly competitive market, which has resulted into heightened lack of interest in automation in the industry. Building information modeling (BIM) remains an overarching software and technology that supports the interaction and practicality of most of the technological transformation with disruptive impact in the construction industry. While the domains of AI are numerous and still undergoing extension; the demand for precision of time, cost and quality of a project is ever increasing: the answers to the numerous complex questions arising from design and construction will be resolved through BIM. Literature is replete with the integration of BIM in construction activities resulting into higher productivity, efficient management of information, ease of amendment, feedback/progress reporting/monitoring, continuity and greater control from conception to close-out (*24* ;*25*). Construction firms thus need to be poised for the needed requirements for proper implementation. Some of the merits of BIM as a digitilisation-enhancement interface are as discussed below.

2.2 MERITS OF BIM ADOPTION AND ITS IMPLICATION FOR THE DIGITAL RACE

Building Information Modeling (BIM) is a three dimensional (3D) digital model showing the physical and functional characteristics of a facility. BIM allows information (such as materials and components' specifications, their locations, manufacturers' details, construction techniques, maintenance, e.t.c.) to be fed into a model right from the conceptualisation stage, thereby providing a platform on which subsequent information can be presented for further improvement and project objective. As BIM incorporates information management, the technology has remained an overarching one that collaborates the efforts of the stakeholders in the supply chain in the industry and thus has been implemented by construction and engineering firms based on its numerous advantages As a digital diary- BIM presents a repository of knowledge resource that can be adopted, upgraded, re-cast and shared to enhance decisions and policy throughout a project life cycle (*18*).

The traditional or semi-traditional methods of building production are not only slow, but involve several design review meetings, resulting into series of drafts and reworking which eventually lead to increase in production time and cost (*26*). Through BIM, basic building elements replicated throughout a building life cycle thereby integrating all the requirements for a sound and sustainable structure. This is made available through a series of processes that offer a variety of themes and designs that can be presented for approval and/or comment as the need arises As a result, a project owner experiences how the facility will look and how its operation tend to relate with its surroundings prior to detailed design, in a three-dimensional format. Unlike the old models that are line-oriented, BIM object-oriented nature offers 'walk-through visualisations' to assist clients in the decision-making process (*27* ;*28* ;*29* ;*30*).

BIM is beneficial to a project promoter, the construction and the design team .Through BIM, the appropriate data and views for respective users are obtained and evaluated to aid decisions.

The visualisation of construction sequence, when supplemented with practical information from the construction site and information from health, safety and environment (HSE) directives and legislation, is invaluable in health and safety programs and preparedness, thereby enhancing the safety of operatives and processes which will eventually contribute to quality (*31* ;*32* ; *33*).With these information, construction process can be examined, simulated and scenario-tested to eliminate or reduce risk of hazards and incidences. With these information and other related ones in the archive, a knowledge tank can be gradually built for the firm improved performance (*34*).

Time and cost savings are enhanced as BIM models provide additional information that reduces unnecessary information clarifications or requests (*28* ; *35*). Still on the part of the contracting team, communication with the workforce is enhanced. For instance, 4D BIM displays animated construction processes on screen thereby enhancing the series/stages of operations that operatives are required to adhere to or follow through. In addition, with the facility of visual representations, animation and simulation, buildability and constructability is enhanced in all its shades and hues (*36* ;*22* ; *37*).

BIM models and levels offer medium through which the wicked challenges that often result into alterations can be resolved. The data bound to a virtual building model can be defined, analysed and parameterised by the designer, with the ultimate goal of positively influencing building sustainability. The availability of all these features at a go allows the project stakeholders to keep track of the relationships between the building elements and their respective details when the need for usage sets in. Rather than having a series of meetings with design team for a compromise to be reached, with a 5D BIM application, the client, project manager, contractors and designers meet remotely to identify knotty issues and resolve such timely and appropriately (*38* ;*39*).

.

At handover, it is incumbent on the contractor to make available to the client a series of documents relating to the way he structure is built. These will enhance the operation and maintenance of the facility to reduce encumbrances. Nevertheless, it is the tradition to loose valuable information regarding the optimal maintenance and operation of that facility during this transition (*38* ; *40; 41*). BIM models take care of these challenges. in addition, the traditional facilities management systems can be linked to an existing facility management (FM) system to provide an accurate and complementary data set, that makes asset management faster, more accurate and worthwhile (*31*). BIM's data-laden, real-time platform is an ever-ready avenue for maintenance scheduling, maintenance works which inevitably reduces money that would have been spent should reactive maintenance becomes the order of the day (*42* ; 41; *43*).

2.3 BIM ADOPTION LEVELS AND THE NEEDED CAPABILITY

The transition from the traditional usage of the 2D environment to Computer Aided Design (CAD) and drafting to BIM requires extensive efforts to migrate. One of the requirements is the adoption of a new culture of using BIM. These cover a range of activities which are not limited to building new libraries/ templates of BIM models specific to a firm's need, paying attention to certain legal risks, liabilities and challenges that come with the benefits of using BIM, development of training programs for both new and existing employees, developing standards and a common language and adopting new policies/procedures for creating and sharing BIM models (*44* ;*45*;*33* ;*46*).

Culture has been defined, described and conceptualised differently depending on the context, the concept, the systems/school of thought, the discipline, time and period surrounding its circumstances (*47*). *48* referring to the UNESCO (1982),widely recognised definitions for culture, sumarised it as the entirety of complex but distinctive cognitive, immaterial, intellectual and emotional features that distinguish a group. The authors further depicts culture as that concrete whole that allows critical judgment and a sense of moral commitment, encourages discerning values, permits choices and decision making, enhances self-awareness and tolerates seeking achievements untiringly and transcending limits.

Organisational culture is the culture of a social group which springs from the underlying assumptions and beliefs of its members about what they share in common, how the group operates and consequently, how they relate. This shapes their attitudes and their resultant behaviour, interpretation for better understanding hence successful outcome in their environment (*49*). Consequently, firms transform through a combination of intentional, unintentional processes; dynamic phenomenon created, enacted or shaped by leadership behaviour; with a set of structures, routines, rules and norms that guide the group towards a new situation (*50* ;51; *47*). As leadership behavioural changes are necessary to achieve the goals and objectives set in any organisation, their underlying beliefs though unconscious, but expressed in learned responses to problems of external adaptation and internal integration, are of utmost importance (*52* ;*53*).

Based on the impact of leadership on firm performance, the culture exhibited is considered as cultural orientations. Cultural orientations are practices that are prevalent among construction firms' leadership as part of the capability needed for internal and external integration. Based on a review of literature, fifty (50) sentences describing different orientation of construction firms' manager, founder or owner (leadership) are set out under eight (8) major headings thus: client service orientation (CSO), conflict/dispute resolution (CDR), environmental/external orientation (ENV), information and communication technology (ICT), innovation, learning and knowledge management (ILKM), production orientation (PRO), task and goal accomplishment (TAGA) and workforce orientation (WKF) (*54* ;*55* ;*56*).

Briefly, external/environmental orientation relates with the scanning of the business environment, gathering information and making the provisions for the needed changes by matching the information received with organisational capabilities and converting such to feedback that can be turned into adaptive capabilities, hence competitive advantage (*57*). Innovation, learning and knowledge management entails the recognition of both technological and non-technological innovation, transformation through research and development (R&D) and upkeep with recent and best industry practices that are critical to the construction industry. A major constraint to project execution is lack of awareness and knowledge. Therefore, knowledge repository development and maintenance are of importance as the need for innovation will only be successful when different stages of knowledge are fully communicated and understood through continuous learning .There are supports on innovation as a major cultural factor affecting construction companies intention to digitilisation (*58* ;*59*).

Client orientation examines leadership dispensation towards achieving overall improvement. This capability includes consideration for clients' objectives, interest and satisfaction (*60*). Task and goal accomplishment entails all firm's contributions towards best practice and global competitiveness which requires investment on autonomous systems rather than adherence to traditional methods. Consequently, goal accomplishment is task-related and centres on management decision on the level of commitment or input to the task or work to be executed as well as the decisions on what is right. Planning, job structuring, monitoring, working environment and project benchmarking are subsets of accomplishment.

For production orientation**,** management leadership style in organising and controlling the production process will be enhanced through automation. Issues relating to project plans and schedules, materials management, safety, harmonious relationships, subcontracting and performance standards will be enhanced thus resulting into less wastage, less time, better quality and better image .

The workforce of industry 4.0 requires better education, improved training, up-skilling and retraining. A workforce that is adequately trained is better equipped, so will do more in less time. Factors such as commitment, training and development, rewards and recognition, teamwork /team building and supportiveness, employees' participation are the variables in this orientation (*61;56*). Digitalisation enhances data assemblage; therefore, communication channels should be unambiguous and reflect what is valued. Information and communication technology considers the availability or lack of relevant information on materials, labour and technology adoption, sophisticated tools for computerisation of office and site activities (*62*). Conflicts are inevitable in construction and are destructive when not properly managed; however, a number of AI variants are available for dispute handling and resolution (*6*). The variables for CDR include harmonious relationship/interaction, clearly defined and allocated functions, building of relationships, means of conflicts resolution are (*26*).

Apart from the culture requirements, the organisational/corporate strategy of the firm is of utmost importance. In the field of strategic studies, it is imperative that firms determine factors that hinder or drive performance (*63*). The adaptive capability within the context of this paper is the strategy that is set for digitilisation with the main framework. Such ability is employed to acquire new resources, combine both old and new in a value creating model(*64*) . It describes a firms' competence in knowing what the market expectations are, altering its understanding in response to such alterations, expanding its boundaries and putting in place the required resources that will correspond to the latest developments or expected developments (*65* ;*66*). It is a measure of the presence of available opportunity with the degree of preparedness in the firm as well as the understanding of what the digital phenomenon requires as far as information and knowledge exchange is concerned. The variables adopted are eight (8) namely: willingness and the resources to scan, retrieve, organise, share and store information digitally; the ability and resources to communicate, interact, maintain relationships and collaborate using digital tools; the ability and resources to produce tasks/jobs requirements with digital tools for the required level of understanding; the ability and resources to communicate, collaborate, cooperate and network in a digital environment; the ability and resources to enhance and promote autonomous learning and embed such in the vision statement; willingness and readiness of leadership to organise, coordinate, manage team with multicultural diversity and spread in a digitally-coordinated platform/environment; the ability to seek and engage clients that are digitally-oriented or canvass clients to adopt digitally-oriented designs and construction techniques/products (*67* ;*68*).

According to (37,39,71) with reference to the Efficiency and Reform Group (2011), the definition of the BIM levels in the UK is as follows:

* Level 0 (also referred to as the Unmanaged CAD stage) employs 2D models using paper (or electronic paper) as the exchange mechanism.

* Level 1 (also known as the Managed CAD in 2 or 3D format using BS1192:2007) uses a collaboration tool that provides a common data environment with few standard data structures and formats.

* Level 2 (which is referred to as the Managed 3D environment) entails BIM tools with attached data, that is commercially managed by an ERP. Level 2 extends into 4D programme data and 5D cost elements as well as feed operational systems.

* Level 3(is the full-blown process of data integration that is enabled by web services compliance in conjunction with IFC/IFD standards. This is managed by a collaborative model server known as integrated BIM, that is iBIM.

3.0 MATERIALS AND METHODS

This study examines automation in construction firms as one of its readiness to the transformation in industry 4.0. It relates building information modeling to digitilisation and presents it as a necessary platform/software/technology that will aid the construction sector in attaining most of the advantages of artificial intelligence as obtainable in other industries. As a result, a quantitative research approach was adopted. This approach enhances determination of the relationship between facts derived in a study and the findings/theories from previous studies, therefore paving ways for further inquiries. Leadership, culture, structure, strategy and the environment are some of the major factors that determine firms' outcome, growth, competitive advantage and sustainability. This study therefore assesses construction firms' awareness and adoption of building information modeling as a platform for the enhancement of digital transformation, through the leadership of the firms. Construction firms thus become the population with construction managers/owners/CEO as the sampling elements. The population was drawn from three lists of construction firms totally 166. The sample size was calculated as 116 which were randomly selected.

Based on the review of the literature, a research instrument was developed. Culture was assessed as cultural orientation. Eight orientations each with a number of sentences describing its contents were set up. The statements range from 3 to 8 for all the eight sub-headings. A total of 50 statements were arrived at for the eight orientations. For the strategic capability, eight sentences describing a firm's awareness and preparedness for transformation were developed. The transformation was measured as the level of awareness and adoption of BIM. For this, three Likerts scales of low awareness, moderate awareness and high awareness (1-3) was adopted. For the culture and structure, the respondents were requested to express their level of agreement or disagreement on a 5point-Likert scale of 1-5 indicating strongly disagrees to strongly agree.

The Cronbach's Alpha values for cultural orientation and strategic capability are 0.946 and 0.637 respectively. The lower value obtained for strategic capability might be due to the lower number of the items measuring the construct. The value of 0.637 though questionable is neither poor nor unacceptable (*69*). For further reliability, the Bartlett's test was conducted on the variables and were found satisfactory based on significance. The results are hereby presented.

4.0 RESULTS AND DISCUSSIONS

4.1 Tables 1 and 2 illustrate the result of the KMO and Bartlett's Test for cultural orientation and strategic capability respectively.

Table 1: KMO and Bartlett's Test of Strategic Capability for Sample Adequacy

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.711
Approximate Chi-Square	425.386
Bartlett's Test of Sphericity	**28**
Sig.	0.000

Table 2: KMO and Bartlett's Test of Strategic Capability for Sample Adequacy

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	.484
Approximate Chi-Square	2691.854
Bartlett's Test of Sphericity	1225
Sig.	.000

The results indicated that the research instrument was reliable with high internal consistency among the items.

4.2. Factor Analysis On Cultural Orientations

Factor analysis was conducted on the 50 cultural orientations in order to test the factorability, as well as to reduce the number of orientations to be considered in further analysis. Principal components analysis was used because the primary purpose was to identify and compute composite scores for the factors underlying the orientation. The orientations were tested for sample adequacy. The result of the factor analysis is presented in Table 3.

Table 3: Factor Analysis on Extraction of Culture Orientations Component

Cultural Orientation Components 1 2 3 4 5 6 7 8	**Cultural Orientation Components 1 2 3 4 5 6 7 8**	**Cultural Orientation Components 1 2 3 4 5 6 7 8**	**Cultural Orientation Components 1 2 3 4 5 6 7 8**	**Cultural Orientation Components 1 2 3 4 5 6 7 8**	**Cultural Orientation Components 1 2 3 4 5 6 7 8**	**Cultural Orientation Components 1 2 3 4 5 6 7 8**	**Cultural Orientation Components 1 2 3 4 5 6 7 8**	**Cultur Orientation Components 1 2 3 4 5 6 7 8**
Good working relationship with subcontractors	.747							
Emphasising clients interest	.731							

Cooperation and assistance is strongly encouraged	.685		
Being accountable for the quality of work done	.672		
Satisfying the need of client	.669		
Amicable resolution of challenges, etc is encouraged	.606		
Availability of sophisticated ICT tools		.812	
Automation of site production activities		.761	
Computerisation of construction activities		.757	
Practicing seamless communication throughout		.731	
Compensation for a job well done			.772

Improving employees skills for better performance	.750	
Capability for developing employees potentials	.736	
Communication btw and among members	.700	
Emphasising team building / committed team	.681	
Recognition of leaders priorities and beliefs towards		.743
Sourcing for information /alternative ways		.703
Imbibing cultural values to aid goals attainment		.637
Building trust by listening, and accepting failure		.618

Responsiveness to changes in the business environment	.741		
Emphasising economic as well as social impact	.660		
Venturing into some opportunities in the market	.636		
Providing training in knowledge		.739	
Provisions of workshops on knowledge management		.702	
Punishment for immoral and/or unethical conduct		.660	
Reward for a new achievement or knowledge		.603	
Conformance to legal provision in contract document			.778

Adherence to project plans and schedules							.775	
Implementing periodic site meetings								.758
Encourage outsourcing/subcontracting								.631
Eigen Values.	15.5	3.35	2.82	2.52	2.07	1.88	1.54	1.48
Percentage of Variance	29.9	6.99	5.62	5.33	4.16	3.81	3.19	3.13
Number of Factors	6	4	5	4	3	4	2	2
New Components	CSO	ICP	WFM	FLB	EO	KM	PRO	TGA
Extraction Method: Principal Component Analysis; Rotation Method: Varimax With Kaiser Normalization:Rotation Converged in 8 Iterations	Extraction Method: Principal Component Analysis; Rotation Method: Varimax With Kaiser Normalization:Rotation Converged in 8 Iterations	Extraction Method: Principal Component Analysis; Rotation Method: Varimax With Kaiser Normalization:Rotation Converged in 8 Iterations	Extraction Method: Principal Component Analysis; Rotation Method: Varimax With Kaiser Normalization:Rotation Converged in 8 Iterations	Extraction Method: Principal Component Analysis; Rotation Method: Varimax With Kaiser Normalization:Rotation Converged in 8 Iterations	Extraction Method: Principal Component Analysis; Rotation Method: Varimax With Kaiser Normalization:Rotation Converged in 8 Iterations	Extraction Method: Principal Component Analysis; Rotation Method: Varimax With Kaiser Normalization:Rotation Converged in 8 Iterations	Extraction Method: Principal Component Analysis; Rotation Method: Varimax With Kaiser Normalization:Rotation Converged in 8 Iterations	Extract Method Principal Component Analysis; Rotation Method Varima With Kaiser Normal iza- tion:Ro Converged in 8 Iteratio

The result of the test of sample adequacy is as presented in Table 1. The KMO was 0.711 (which was above the commonly recommended value of 0.6) with the Bartlett's test of sphericity as significant ($\chi^2 = 2691.854$, df 1225, $p < 0.05$). This is an indication that factor analysis was deemed to be suitable with all the 50 items of cultural orientation (CO). The factor loadings of each statement of CO are as shown in Table 3. From the Table, all the items have a factor loading value greater than .5 (which is the minimum acceptable value for each item as implied by 70 Samuels (2017). Overall, the rotated component matrix indicates sufficient loading on eight components described thus. The highly loaded factors on component 1 are six (6) as follows: good working relationship with subcontractors (0.747), emphasising client's interest (0.731), coordination and assistance is encouraged (0.685), accountability for the quality of work done (0.672), satisfying the need of client (0.669) and amicable resolutions of challenges (0.606). These factors have a common theme (Client interest); this component is thus termed Client service orientation. The 2nd component loadings are 4 and include availability of sophisticated ICT tools, (0.812), automation of site production activities (0.761), computerisation of construction activities (0.757), and practicing seamless communication. (0.731). These factors are tagged Innovative construction processes. The 3rd component comprises 5factors ranging from compensation for a job well done (0.772), improving employees' skill for better performance (0.750) capability for developing employees potentials (0.736), communication between and among members (0.700) and emphasising team building/supporting committed team (0.681). The central notion here is on team management, so the 3rdcomponent is referred to as Workforce management.

Component four consists of 4 factors namely: recognition of leader' s priority and belief towards recruitment (0.743), sourcing for information/alternative way of doing things (0.703), building trust by listening (0.637) and enhancing user acceptance (0.618). This component is referred to as Founders/leader's belief.

On component five, 3 factors were loaded thus, responsiveness to changes in the business environment (0.741), emphasising economic as well as social impact (0.660), and venturing into some opportunities in the market (0.636). This is termed External orientation.

Component six covers 4 loadings described thus: providing training in knowledge (0.739), provisions of workshops on knowledge management (0.702), punishment for immoral and/or unethical conduct (0.660) and reward for a new achievement /sharing knowledge (0.603). This component is referred to as Knowledge management.

The 7th component loadings were conformance to legal provision in contract document (0.778) and adherence to project plans and schedules (0.775). This is termed Production orientation .The 8th component factors are also 2. These are implementing periodic site meetings (0. 77) and encouraging outsourcing /subcontracting (0.631). This revolves round Task and goal accomplishment.

4.3 Prevalence of Strategic capability

Table 4: Prevalence of Strategic Capability in Construction Firms

Strategic Capability Variables	SD (1)	D (2)	MOD (3)	AGR (4)	SAG (5)	MEAN	STD	SUM	RA
Communicate, interact and collaborate using digitally a digital environment	2	5	5	53	51	4.26	0.866	494	1

Strategic Capability Variables	SD (1)	D (2)	MOD (3)	AGR (4)	SAG (5)	MEAN	STD	SUM	RA
Leadership capability to organise, coordinate, manage team digitally	4	3	10	55	44	4.14	0.932	480	2
Produce job requirement with digital tools and understanding	4	3	5	65	39	4.14	0.884	480	2
Commitment to human capital for digital transformation	2	5	13	56	40	4.09	0.884	475	4
Search for and organise or share information digitally	4	3	4	81	24	4.02	0.813	466	5

Strategic Capability Variables	SD (1)	D (2)	MOD (3)	AGR (4)	SAG (5)	MEAN	STD	SUM	RA
enhance, manage and promote autonomous learning and embed it in vision	4	9	1	71	31	4.00	0.951	464	6
Seek and engage clients that are digitally-oriented or canvass clients to adopt digitally-oriented techniques/products	4	3	13	68	28	3.97	0.879	461	7
Produce communicate, collaborate, cooperate and network on a digital platform	9	2	12	62	31	3.90	1.066	452	8

Note:N=number of respondents (116). Interpretative scale: 1.00 [?] MS < 1.49 means strongly disagree (SD), 1.50 [?] MS < 2.49 disagree (D), 2.50 [?] MS < 3.49 moderately disagree (MOD), 3.50 [?] MS < 4.49 means agree (AGR) and 4.50 [?] MS [?] 5.0 strongly agree (SAG). STD=Standard Deviation.

Table 4 shows the prevalent dimensions of strategic capability**i** n construction firms. The results show a general agreement among the firms' leadership on the variables as measures of strategic capability to automation and transformation in the industry. The first three most prevalent variables are the ability and resources to communicate, interact and collaborate digitally , willingness and leadership capability to organise, coordinate, manage team digitally as well as the ability and resources to make job requirements with digital tools and enhance understanding. These first three variables are inter-woven, a firm that possess the readiness and willingness to scan the environment for the needed information will only do so if there is a leadership capability that supports such initiatives. Such information when gathered will then be implemented to reflect positively in the business.

4.4 Level of awareness of BIM and Automation in Construction firms

The level of BIM awareness and adoption is as depicted in Figure 1.

[CHART]

Figure 1 shows that the ratio of low awareness to medium awareness and high awareness is 2:7:2. That is for every five firms, at least one is on a low awareness, one on a high awareness level and 3 on medium awareness level. This result is a bit promising as it is a shift on the results of laggards as recorded by previous studies (*39*;*71*).

4.5. Test For Significant Relationship among Cultural Orientation, Strategic capability and BIM Awareness/Adoption in Construction Firms

The objective is on the significant relationship among cultural orientation, strategic capability and BIM awareness/adoption. The analysis was done using Pearson's Product Moment Correlation. Apart from the correlation between cultural orientations, no significant relationship exists between cultural orientations and BIM awareness or between strategic capability and BIM awareness. Since a significant correlation could not be established among the constructs, regression analysis was conducted on the variables, rather than the constructs wholly, as presented in Table 5.

Table 5: Regression Analysis on Cultural Orientation and Strategic Capability Variables

	Unstandardised Coef.
Variables	**B**
(Constant)	12.276
Strategic vision for Digitilisation	-0.085
Communicating interacting and collaborating digitally	-0.896
Production Orientation	
Facilitating harmonious relationship with other professionals	-1.049
Workforce Development	
Improving employees skills fo better performance	-1.514
Compensation for a job well-done	1.157
Innovation, Learning and Knowledge Management	**Innovation, Learning and Knowledge Manage**
Sourcing for information /alternative ways of getting job done	-1.223
Building trust by listening, taking risk and accepting failure	-1.232
Information /Communication Technology (ICT)	**Information /Communication Technology (IC**
Automation of site production activities	0.83
Availability of sophisticated and integrated ICT tools	-0.555
Task / Goal Accomplishment	
Inculcation of research and development in business plan	0.872
setting targets by comparing performances on projects	1.846
Setting target by comparing organization with similar structure	-1.453
Conflicts and Disputes Resolution	**Conflicts and Disputes Resolution**

	Unstandardised Coef.
Cooperation and assistance is strongly encouraged	-1.31
Amicable resolution of challenges, claims, conflicts, etc is encouraged	2.195

The results on Table 5 depict the constructs as well as the variables that are significant in BIM and automation. Starting with the strategy, communication, interaction and collaboration digitally is significant. For the orientations, production, workforce development innovation, learning and knowledge management, information /communication technology, task/goal accomplishment, conflicts and disputes resolution are all significant. For production orientation, facilitating harmonious relationship with other professionals is significant. With workforce, two variables: improving employees skills for better performance and compensation/reward for a job well-done are both significant. Likewise, two variables namely: sourcing for information /alternative ways of getting job done and building trust by listening, taking risk and accepting failure are highly significant for innovation, learning and knowledge management. Information /communication technology (ICT) as an orientation also has two variables. These are automation of site production activities as well as availability of sophisticated and integrated ICT tools.Task and goal accomplishment however has three variables which are inculcation of research and development in business plan, setting targets by comparing performances on projects and setting target by comparing organisations with similar structure. In addition, encouraging cooperation and assistance with amicable resolution of challenges, claims and conflicts are significant in conflicts and disputes resolution. These results imply that organisational factors in form of resources and adapative capability are precursors of firms' outcomes. These results seek credence in previous studies within the industry (*63* ;*68*).

4.6 Regression Model for BIM Awareness

Table 6: Regression Model for BIM awareness

	UnstandardizedCoef.	**UnstandardizedCoef.**	**Stand.Coef.**	**T**	**Sig.**	**F**	**R**	**R^2**
Variables	**B**	**Std. Error**	**Std. Error**					
(Constant)	3.923	1.092		3.592	0.001	0.696	0.328	0.107
SRA	0.253	0.189	-0.205	-1.339	0.186			
PRO	0.135	0.334	0.092	0.406	0.686			
WKF	-0.094	0.196	-0.097	-0.482	0.632			
CSO	-0.445	0.293	-0.348	-1.519	0.135			
ILKM	-0.193	0.31	-0.159	-0.623	0.536			
ICT	0.039	0.184	0.046	0.211	0.834			
ENV	0.204	0.166	0.215	1.232	0.223			
TAGA	0.19	0.228	0.187	0.835	0.407			
CDR	-0.038	0.188	-0.04	-0.203	0.840			

*P<0.05, 95% Confidence level, P<0.01, 90% Confidence level. SRA =strategy, PRO=production orientation, WKF= workforce orientation, CSO=client service orientation, ILKM=information, learning and knowledge management, ICT=information and communication technology, ENV=environmental/external orientation, TAGA= task and goal accomplishment, Durbin-Watson =1.534

The result of regression model for BIM awareness is shown on Table 6. Though the Durbin-Watson value is greater than 1 (DW=1.534), the constructs only explain 10.7% of BIM awareness and adoption. This result implies that despite the general agreement among the respondents on the various orientations and strategic capability, the effect on automation and transformation is still at the infancy stage. This is evident from the regression model whereby only 11 percent of the digitilisation efforts are from the culture and the strategy adopted. This is also explained by the lack of significant correlation among the constructs.

5.0 CONCLUSION AND FURTHER STUDIES

This study examined the culture and structure that could enhance BIM adoption for transformation of the construction industry. The results revealed a general agreement on the variables as measures of cultural orientations and strategic capability. However, there was no significant relationship between the present orientation, that is the culture and the transformation drive or between the strategy and the digitilisation requirements. The awareness is low for some firms but medium for more than 50 percent of the firms. Consequently, a model of digital transformation could not be developed based on the existing culture and strategy. The study has just been able to establish that the awareness and adoption of BIM as a tool for transformation depend partly on the firm's leadership and partly on the client and the prevailing construction environment.

Based on this, the firms need to harmonise culture with strategy. For instance, the strategy adoption in communication, interaction and collaboration should be enhanced more digitally. While specific variables of production management; workforce development; innovation, learning and knowledge management; information /communication technology; task /goal accomplishment; conflicts and disputes resolution are significant, the case is different for client service orientation as well external/environmental orientation. The near 89 percent contribution that is deficient in the model prediction could be partly from clients' and environmental orientations. BIM as advancement on 2D and Autocard requires newer skills and a cultural change, a situation in which the environment or the client is not supportive will not yield the necessary result. There is a need therefore for joint awareness on importance as well as the provision of training for all and sundry on the need to adopt BIM while the government and other relevant bodies make provisions to cushion the effect of the cost-inherent in the transition journey.

5.1. Limitation of the Study

This study briefly reviews literature on transformation tools in the industry and argues that the introduction of BIM will facilitate the adoption. The study is limited to the views of selected professionals on fewer variables culture and strategy as parameters of BIM adoption. Future researches are to be conducted objectively for better understanding and insights.

CONFLICT OF INTEREST

The authors have no conflict of interest relevant to this article.

REFERENCES

1. Hampson K, Kraatz JA, Sanchez AX. The global construction industry and R&D. In *R&D Investment and Impact in the Global Construction Industry.2014:* 42-61. Routledge.
2. Alaloul WS, Liew MS, Zawawi NAWA, Mohammed BS. Industry revolution IR 4.0: future opportunities and challenges in construction industry. In *MATEC Web of Conferences,* 2018;203: 02010).EDP Sciences.
3. Wisskirchen G, Biacabe BT, Bormann U, Muntz A, Niehaus G, Soler GJ, von Brauchitsch B. Artificial intelligence and robotics and their impact on the workplace. *IBA Global Employment Institute* , 2017:2012-2017.
4. Wisskirchen G, Biacabe B T, Bormann U, Muntz A, Niehaus G, Soler GJ, von Wang WC, Weng SW, Wang SH, Chen CY. Integrating building information models with construction process simulations for project scheduling support. *Automation in Construction* , 2014, 37: 68-80.
5. Russell SJ, Norvig P. *Artificial Intelligence: A Modern Approach* . New Jersey: Prentice Hall, 2003.
6. Ilter D, Dikbas A. A review of the artificial intelligence applications in construction dispute resolution. *Managing IT in Construction/Managing Construction for Tomorrow* , 2009:*449* -455.
7. Cheung SO, Tam CM, Harris FC. Project dispute resolution satisfaction classification through neural network. *Journal of Management in Engineering* , 2000;*16* (1):70-79
8. Bellucci E, Lodder AR, Zeleznikow J. Integrating artificial intelligence, argumentation and game theory to develop an online dispute resolution environment. In *16th IEEE International Conference on Tools*

with Artificial Intelligence, 2004: 749-754.
9. Zavadskas EK. Automation and robotics in construction: International research and achievements. *Automation in Construction* , 2010;*19* (3):286-290.
10. Casares AP. The brain of the future and the viability of democratic governance: The role of artificial intelligence, cognitive machines, and viable systems. *Futures* , 2018; *103:* 5-16.
11. Elattar SMS. Automation and robotics in construction: opportunities and challenges. *Emirates Journal for Engineering Research*, 2008;*13*(2):21-26.
12. Pachon AG. Construction Site Automation: guidelines for analyzing its feasibility, benefits and drawbacks. *Advanced Construction and Building Technology for Society*, 2012:38-42
13. Zhang X, Bakis N, Lukins TC, Ibrahim YM, Wu S, Kagioglou M, Aouad G, Kaka AP, Trucco E. Automating progress measurement of construction projects. *Automation in Construction* , 2009; 1*8* (3):294-301.
14. Mahdjoubi L, Yang JL. An intelligent materials routing system on complex construction sites. *Logistics Information Management, 2001:* 227-236.
15. Nehdi ML, Bassuoni MT. Fuzzy logic approach for estimating durability of concrete. *Proceedings of the Institution of Civil Engineers-Construction Materials*, 2009; *162*(2):81-92.
16. Lu P, Chen S, Zheng Y. Artificial intelligence in civil engineering. *Mathematical Problems in Engineering* , *2012: 1-22*
17. Raji IO. 3D Printing Technology-Applications, benefits and areas of opportunity in Nigeria. *International Journal of Advanced Academic Research| Sciences, Technology & Engineering* , 2017; *3:* 21-30.
18. Sakin M, Kiroglu YC. 3D Printing of Buildings: Construction of the sustainable houses of the Future by BIM. *Energy Procedia* , 2017;*134:* 702-711.
19. Buchanan C, Gardner L. Metal. 3D printing in construction: A review of methods, research, applications, opportunities and challenges. *Engineering Structures* , 2019;*180:* 332-348.
20. Cheung WF, Lin TH, Lin YC. A real-time construction safety monitoring system for hazardous gas integrating wireless sensor network and building information modeling technologies. *Sensors* , 2018;*18* (2):436-448.
21. Grehl S, Mischo H, Jung B. Research perspective-mobile robots in underground mining. *AusIMM Bulletin* , (Feb 2017):44-53.
22. Popov V, Juocevicius V, Migilinskas D, Ustinovichius L, Mikalauskas S. The use of a virtual building design and construction model for developing an effective project concept in 5D environment.*Automation in Construction* , 2010; 19(3):357-367.
23. Piroozfar A, Farr ER, Essa A, Boseley S, Jin R. Augmented Reality (AR) and Virtual Reality (VR) in construction industry: An experiential development workflow, 2018:1-9.
24. Schabowicz K, Hoła B. Application of artificial neural networks in predicting earthmoving machinery effectiveness ratios. *Archives of Civil and Mechanical Engineering* , 2008; *8* (4):73-84
25. Masera G, Muscogiuri M, Bongiovanni A, Colombo M. Towards a new digital craft. Potential and limitations of 3D printing in architecture and construction. *ISTeA.* Re-shaping the construction industry. *Maggioli Editore* , 2017:83-92.
26. Kurwi S. *Integrating BIM and GIS for design collaboration in railway projects* (Doctoral dissertation, Loughborough University, 2019).
27. Sattineni A, Bradford RH. Estimating with BIM: A survey of US construction companies. Proceedings of the 28th ISARC, Seoul, Korea, 2011:564-569.
28. Wang WC, Weng SW, Wang SH, Chen CY. Integrating building information models with construction process simulations for project scheduling support. *Automation in Construction,* 2014; 37:68-80.
29. Wang X, Truijens M, Hou L, Wang Y, Zhou Y. Integrating Augmented Reality with Building Information Modeling: Onsite construction process controlling for liquefied natural gas industry. *Automation in Construction*, 2014; 40: 96-105.
30. Osunsanmi T, Aigbavboa C, Oke A. Construction 4.0: the future of the construction industry in South Africa. *World Academy of Science, Engineering and Technology, International Journal of Civil and Environmental Engineering* , 2018;*12* (3):206-212.

31. Ogwueleka AC, Ikediashi DI. The future of BIM technologies in Africa: prospects and challenges. Integrated Building Information Modelling, 2017.
32. Onungwa IO, Uduma-Olugu N. Building information modelling and collaboration in the Nigerian construction industry. *Journal of Construction Business and Management,* 2017; 1(2): 1-10.
33. Roger B. Turning point for the construction industry: the disruptive impact of building information modeling (BIM), 2017.
34. Hosseini MR, Azari E, Tivendale L, Chileshe N. Barriers to adoption of building information modeling (BIM) in Iran: Preliminary results. In The 6th International Conference on Engineering, Project and Production Management (EPPM2015), Gold Coast, Australia.
35. McCuen T. BIM adoption within Australian small and medium-sized enterprises (SMEs): an innovation diffusion model. *Construction Economics and Building,* 2016;16(3):71-86.
36. Goedert JD, Meadati P. Integrating construction process documentation into building information modeling. *Journal of Construction Engineering and Management* , 2008; 134(7):509-516.
37. Ding L. Zhou Y, Akinci B. Building Information Modeling (BIM) application framework: The process of expanding from 3D to computable nD.*Automation in Construction* , 2014;46:82-93.
38. Azhar S. Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. Leadership and Management in Engineering, 2011;11(3): 241-250.
39. Ayinla KO, Zulfikar A. Bridging the digital divide gap in BIM technology adoption. *Engineering, Construction and Architectural Management, 2018;1-31,* DOI: 10.1108/ECAM-05-2017-0091
40. Hartmann T, Van Meerveld H, Vossebeld N, Adriaanse A. Aligning building information model tools and construction management methods. Automation in Construction, 2012; 22: 605-613.
41. McGuire B, Atadero R, Clevenger C, Ozbek M. Bridge information modeling for inspection and evaluation. Journal of Bridge Engineering, 2016;21(4): 04015076.
42. Kassem M, Brogden T, Dawood N. BIM and 4D planning: a holistic study of the and drivers to widespread adoption. *Journal of Construction Engineering and Project Management* , 2012; 2(4): 1-10.
43. Tan K. The framework of combining artificial intelligence and construction 3D printing in civil engineering. In MATEC Web of Conferences (2018; 206:01008). EDP Sciences.
44. Imoudu EW, Godwin AU, Nita AK. Preliminary building information modeling adoption model in Malaysia: A strategic information technology perspective. *Construction Innovation* , 2014;14(4): 408-432.
45. Amuda-Yusuf G. Critical success factors for building information modeling implementation. Construction Economics and Building, 2018;18(3):55-61.
46. Abaza H, Smith J. Case study based BIM, course delivery for construction management students, Proceedings of BIM, 2018, Las Vegas.
47. Soini K, Dessein J.Culture-sustainability relation: Towards a conceptual framework. *Sustainability* , 2016;8(2):167-178.
48. Nas P M, Talal HP, Claessen H M, Handler R, Kurin R, Olwig K, Sears L, Nas PM. Masterpieces of oral and intangible culture: Reflections on the UNESCO World Heritage List. *Current Anthropology* , 2002;43(1):139-148.
49. Duygulu E, Özeren E. The effects of leadership styles and organizational culture on firm's innovativeness. *African Journal of Business Management* , 2009;*3* (9):475-482.
50. Ahmed M, Shafiq S. The impact of organizational culture on organizational performance: A case study on telecom sector.*Global Journal of Management And Business Research.* 2014:22-33.
51. Schein EH. Organisational culture and leadership. 3rd ed. San Francisco: Jossey- Bass, Wiley Imprint
52. Feldman MS, Orlikowski WJ. Theorizing practice and practicing theory. *Organization Science* , 2011;*22* (5):1240-1253.
53. Schein EH. The corporate culture survival guide: Sense and nonsense about culture.San Francisco, CA: Jossey-Bass, 2009.
54. Liu AM, Shuibo Z, Meiyung L. A framework for assessing organisational culture of Chinese construction enterprises. *Engineering, Construction and Architectural Management* , 2006:1-12.

55. Ankrah NA. An investigation into the impact of culture on construction project performance. (Doctoral dissertation, University of Wolverhampton, UK).
56. Abiola-Falemu JO. Organisational culture, job satisfaction and commitment of Lagos-based construction workers, *Journal of Business and Management* , 2013;*13* (6): 108-120.
57. Zeebaree MRY, Siron RB. The impact of entrepreneurial orientation on competitive advantage moderated by financing support in SMEs. *International Review of Management and Marketing* , 2017;*7* (1):43-52.
58. Cheung S O, Wong PSP Lam AL. An investigation of the relationship between organisational culture and the performance of construction organisations.*Journal of Business Economics and Managemen* t, 2012;*13* (4):688-704.
59. Bamgbade JA, Kamaruddeen AM, Nawi MNM. Malaysian construction firms' social sustainability via organizational innovativeness and government support: The mediating role of market culture. *Journal of Cleaner Production* , 2007;*154:* 114-124.
60. Bello WA, Soyingbe A A, Akinwamide, B. An assessment of the implementation of quality culture in construction RICS COBRA, 2012 September, Las Vegas, Nevada USA.
61. Yilmaz C, Ergun E. Organisational culture and firm effectiveness: An examination of relative effects of culture traits and the balanced culture hypothesis in an emerging economy. *Journal of World Business*, 2008;43: 290-306.
62. Cabrera A, Cabrera EF, Barajas S. The key role of organisational culture in a multi-system view of technology-driven change.*International Journal of Information Management* , 2001;21: 245-261.
63. Oyewobi LO, Windapo AO, Cattell KS Rotimi JOB. The effects of business environments on corporate strategies and performance of construction organisations, 2013:1-11.
64. Rauch A, Wiklund J, Lumpkin JT, Frese M. Entrepreneurial orientation and business performance: an assessment of past research and suggestions for the future. *Entrepreneurship Theory and Practice* , 2009; 33(3):761-787.
65. Petrini M, Pozzebon M. Integrating sustainability into business practices: learning from Brazilian firms. BAR-Brazilian*Administration Review* . 2010 Dec;7(4):362-78.
66. Eshima Y, Anderson BS. Firm growth, adaptive capability and entrepreneurial orientation. *Strategic Management Journal* , 2017; 38(3):770-779.
67. Suliman LK, Omran A. Sustainable development and construction industry in Malaysia. Manager (University of Bucharest, Faculty of Business & Administration). 2009 Dec 1(10).
68. Dang CN, Le-Hoai L, Peansupap V. Linking knowledge enabling factors to organizational performance: Empirical study of project-based firms.*International Journal of Construction Management* . 2019 Jul 5:1-4.
69. Tavakol M, Dennick R. Making sense of Cronbach's alpha.*International Journal of Medical Education* . 2011; 2:53.
70. Samuels P. Advice on exploratory factor analysis, 2017.
71. Zulfikar A, Emmitt S, Soetanto R. Social BIM: Co-creation with shared situational awareness. *Journal of Information Technology in*Construction (ITcon), 2015; *20(16):* 230-252.

Hosted file

`ENGINEERING -INSERT TABLES AND FIGURE.docx` available at https://authorea.com/users/295792/articles/424665-building-information-modeling-bim-cultural-and-strategic-capabilities-for-digitilisation-in-construction-firms