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Abstract

Purpose – This study aims to avail architects with the potentials of knowledge management (KM) principles towards an optimal and effective procedural mechanism for the choice of building materials during design and construction processes.

Design/methodology/approach – In all, 202 questionnaire forms were distributed in a survey. They were administered to practicing architects and Architectural firms in Nigeria. Thereafter, ANOVA, regression analysis and exploratory factor analysis with reliability and Cronbach's alpha coefficient of 0.861 identified KM principles in specification writing for architects.

Findings – These findings show that the building material selection procedure can be optimized with efficient and conscious consideration of KM principles imbibed by architects in tune with global trends. The study serves as a guide to architects and other stakeholders on the effect of KM principles in deepening reflectiveness of the surpassing role of effective KM in specification writing in the construction industry.

Originality/value – This is perhaps the first empirical research that sought to understudy knowledge sharing strategies in architectural firms within the context of the study location Nigeria. The value of the research lies in optimization of architects' building materials' specification strategy through KM principles.

Keywords Knowledge management, Design

Paper type Research paper

1. Introduction

Innovative tendencies and accomplishments rely on talents to develop novel and improved products as well as procedures (Koops *et al.*, 2017; Gentler, 2003). So, advancement in technology with rapid growth in the inventions of building materials aimed at solving existing and future challenges abound. In contrast to the voluminous literature on building materials, little analysis has been undertaken on the contribution of knowledge management (KM) on the optimization of building material specification. Meanwhile, architects' managerial skills are usually broadly limited to firm management and project management, leaving a gap on specifics such as KM within and across colleagues in practice. Project manuals with detailed written specifications are required to explain drawing provisions, particularly in large projects for successful project execution and site operations. Advantageously materials liable to failure are detected from the onset as shared experiences and information could be obtained from repositories during specification writing by

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architects. This entails a proactive approach by architects in improving materials' specification for building constructions, which KM procedures offer. Specification is expected to enhance clarity and value in bid estimation as well as efficient supervision of construction projects. Because performance of buildings are often assessed with the quality and durability of its materials particularly as it appear in the finishes. Specification thus relates what the designer wants as well as expresses it in a clearer form. However, the tendency that many specifications fail has been attributed to the lack of knowledge (Willis and Willis, 1983; Heijstek, 2012; Atsrim *et al.*, 2015). The absence of this knowledge could come from inexperience, never handled such task previously or even lack of documentation of previous understandings and transactions. Just as firm management, KM is integral to an architect's successful practice. It is in this regard that the study focuses on the influence of KM in the strategies adopted by architects during selection of building materials for construction. Therefore, the need to progressively understand unharnessed strategies in dealing with this phenomenon is increasingly becoming necessary, as building designs tend towards complexities in its configuration. As the profession progresses in the characterization of knowledge and architect's competence, this paper sets forth to examine strategies used in selecting building materials for construction.

Towards explaining the phenomenon, the paper focuses on the influence of KM in the strategies adopted by architects in building materials' specification in the construction industry. These strategies are usually based on the explicit knowledge of materials, the tacit knowledge gained through the experience acquired with the application of these materials and the tacit knowledge based on available information about obtainable building materials (Arif *et al.*, 2017; Cohen and Olsen, 2015). After all, tacit knowledge creates the most significant source of innovation-based value creation in social contexts to develop unique capabilities and products (Gertler, 2003). Therefore, architects' ability to express knowledge of building materials' performance and its utilization is usually determined by the consistency of interaction with the materials. It also conveys the competency and progressive growth of the architect's dynamic capabilities. However, these capabilities are limited by rapid advancement in technology aimed at improving the durability, workability and usability of these material products.

The principal concept that ensures adequate resource management linking human and material resources through storage, sharing and creating knowledge lies in KM (Costa *et al.*, 2016; Donate and de Pablo, 2015). So, it becomes inevitable to relate KM with architecture particularly in organizing knowledge, experience and information on building materials. Still associated with this phenomenon is the need to unveil architects' strategies for the search for building materials in the dimensions of knowledge, experience and information within the realms of KM principles (Håkansson and Waluszewski, 2014). Consequently, the study operationalized the search for building materials as the dependent variable, whereas knowledge about the materials, experience in its application and available information are the independent variables. In the process, measures were developed for the knowledge dimension, information dimension and experience dimension hypothesized to effectively influence the choice of building materials in specification writing during the design process. Furthermore, factors that evolved via dimension reduction from the analytical process were subjected to statistical techniques to establish the hypothesis. There has been relatively little research that focuses on KM principles towards enhancing architects' strategies in optimizing specification writing. More so is that architects often ignore or make presentations with inadequate clarity on material specification in the contract documents. Therefore, examining this phenomenon is appropriate, particularly focusing on the optimization of specification writing through proper building material choices.

2. Background studies

2.1 Knowledge management principles

KM is complex and multi-faceted with broad spectrums, as it relates with the ontology and epistemology of diverse disciplines. However, its basics comprise distinct interdependent procedures of knowledge creation, storage, retrieval, transfer and application. Essentially, it has been broadly classified into tacit and explicit (Malhotra, 2000; Pemsel and Wiewiora, 2013). Similarly, KM includes creative inventions attained through knowledge formation, possession and sharing (Graham *et al.*, 2007). In effect, the rise in global economic rivalry as a result of technological progression, which has improved the knowledge spread (Donate and Guadamillas, 2010; Todorović *et al.*, 2015). Innovative inventions attained through the process of knowledge formation, possession and sharing have been acknowledged as KM (Graham, *et al.*, 2007; Tong *et al.*, 2015). Eventually, it has grown into KM system advocated based on consistent interest and information systems (Alavi and Leidner, 2001; Tyagi *et al.*, 2015).

Furthermore, knowledge in its tacit or explicit expression could be several forms. These include object, form, cognitive state, skill, methods, documents, policies, physical settings or information technology-based repositories (Alavi and Leidner, 2001; Valmohammadi *et al.*, 2015). Hence, knowledge actuates progression in disciplines towards advancement in research and development, particularly in problem-solving activities such as material specifications for buildings (Ahmad, 2011; Yeung *et al.*, 2016).

It is to be noted that global motivations with technological advancement have enhanced knowledge dissemination (Cohen and Olsen, 2015; Donate and Guadamillas, 2010). As such to facilitate efficiency, universal trends in KM are centred on knowledge acquisition, creation and sharing, therefore enabling the transferability, editing and reuse of knowledge in progressing organizational goals. This perhaps is the reason for KM to be described as a set of procedures (Alashwal *et al.*, 2011), and also as a diverse process of unifying ideas and strategies (Alekseev, 2010; Chen, 2012; De Angelis, 2012; Sajeva and Jucevicius, 2010).

Accordingly, previous knowledge of constructions and material performance to be specific is viewed as assets for future advantages (Forcada *et al.*, 2013). In particular, firms that engage in procurements and need to improve workers' and managerial knowledge to strategically innovate new visions value the resource potentials of knowledge (Fugate *et al.*, 2009; Griffith, 2012; Hashim *et al.*, 2013; Khuzaimah and Hassan, 2012). In this regards, the impact of social setting on KM has been affirmed as significant (Alavi and Leidner, 2001; Campbell and Manicom, 2015). Explicit knowledge, which is generally regarded as common knowledge, is acquired by architects in the course of learning and training as Architects during university education career development. Whereas tacit knowledge, which is rooted in actions, experiences and contextual engagements, is better acquired through working experiences and on-the-job training during postgraduation professional practices. Such tacit knowledge can be insights from previous projects, groups' norms in building material applications as well as best practices (Alavi and Leidner, 2001).

Familiarity within people has been acknowledged as crucial in knowledge transfer, and it has been proven to be more effective within than across firms. Furthermore, interest and ability are significant potentials in the transfer of tacit knowledge, hence limitations arise owing to the level of expertise, worthwhile experience and the network process of transferring the knowledge (Reagans and McEvily, 2003). According to Kaur (2014), attributes of effective knowledge sharing include teachability, codifiability, age of technology during sharing, number of repeated transfers and knowledge complexity.

This view was earlier held by Kogut and Zander (1993). As such the aforementioned attributes contribute to KM on preparations of building material specifications and schedules.

2.2 Building material specification and schedules

Arguably, the level of an architect's expertise, his worthwhile experience and network of the process can conveniently be considered under knowledge, information and experience dimensions. These dimensions are necessary to equip architects with skills in specification writing. Essentially, a designer should express what he wants clearly in drawings for other professionals and stakeholders to understand the construction process. However, drawings with complexities in configuration usually require more and detailed specifications and schedules to describe clearly the quality of materials, procedures and workmanship. Technical specifications occasionally referred to as trade preambles are contract documents that spell out details on materials, workmanship and procedures that cannot be spelt out on drawings. Besides, the non-availability of this information implies that such work should not be part of the contract (job description) and can result in variations, delay, materials' failure, construction error, cost overrun and claim for extra payment which may lead to litigation. Hence, specifications are a contract document that conveys information on construction and architectural items, particularly building materials, which the architect is unable to show on the drawing.

In this regard, design and construction problems could largely be linked to lack of clarity in specifications, thus the need for a paradigm shift in architect's approach to its preparation. Optimization thus becomes necessary in the detailed specification on diverse elements of architecture and its practices to enhance well-informed design solutions. However, with the availability of a broad spectrum of knowledge and advanced technology, researchers have focused on achieving improved performance and outcomes. In this regard, alternative building materials are expected to provide best solutions upon consideration. Bouchlaghem (2000) established a computer model that determines optimum design variables of building envelopes for achieving best thermal performance conditions. Also, Wang *et al.* (2006) established a floor shape optimization model that reveals critical shape-related variables and envelop-related variables. Even though these are mathematical models, the concepts of efficiency and effectiveness in material specifications are proven to be essential in proffering design solutions.

Meanwhile, this study is limited to building material specification, as performance specifications pose different challenges to architects. This is because, building materials performance would require measurement over a length of time and also depends on the level of experiences acquired by architectural firms. As a result of its significance, further research is recommended in this direction.

2.3 Architects' specification writing strategies

Knowledge, experience and information are important to professional development of an architect, which he expresses in his work. A clear expression of what the architect implies is essential in specification writing. However, many fail owing to insufficient thought and knowledge of building construction (Willis and Willis, 1983). The prior knowledge of building materials is thus necessary for the architect. In effect, explicit knowledge is a foundation to skill development in specification writing. More so, there is an increasing diversity of materials available for architects to make choices; however, architects need to put into consideration other factors such as economic and technical properties of these materials (Wastiels and Wouters, 2012). This is because materials' specification and its

knowledge of application constitute one of the main considerations of design right from the beginning of human history (Ashby and Johnson, 2013). It therefore becomes important that the architect's knowledge of material which relies on the experience of others is sustained. Also, there is the fact that most building material selection processes usually adopted by architects are solely dependent on the product design and its technical performance as well as manufacturability (Karana *et al.*, 2008). In addition, architects also need very comprehensive knowledge overview of materials aside from the technical aspect but to also include its aesthetics as well as people's perception (Wastiels and Wouters, 2012). By and large, the desire of architects is to ensure that materials are selected in a manner that thoughtfully balances functional and expressive product concerns (Pedgley, 2014). This showcased the multi-attribute decision-making associated with the choice of building materials by the architect. Some of these attributes include cost, performance as well as the decision and comparison against alternative material in the market. Exclusively, more expanded explanation on the optimal materials' selection process for designers has been provided by Jahan *et al.* (2016).

Additionally, architects gain experience over time with acquaintance to site operations. It is a systemic process of tacit knowledge acquisition which enhances skill development. The process that involves "on the job learning" helps in the development process of an architect where in addition to the explicit knowledge acquired, practice ensures practical skill development. Architects and firms utilize this to improve specification writing skills. Importantly, experiences are in-built knowledge. it includes skill and wisdom acquired through human personal contact and self explored activities which are difficult to fully express (Horvath, J. A.1999).

Also, information plays a great role in human development. Scholars such as Willis and Willis (1983), Lopez (2014) and Paulin and Suneson (2015) have recommended constant site visits as a way of maintaining updated information on new building materials. Information building enhances tacit knowledge acquisition in skill development, as architects are updated with building material applicability that would guide making choices as the need arises. Numerous sources of information for the technical behaviour of material such as performance, durability as well as user's experience form part of the knowledge chain. However, there exists no comprehensive material information available to architects on the experiential qualities of material, thus creating a knowledge gap for the architects. It is also to be noted that architects also need information on the non-technical aspects of material such as aesthetics, the dimension of use as it relates to ergonomics and the effects of the material on the environment (Ashby and Johnson, 2013).

Similarly, other criteria such as the general perception of people about the material as well as the cost implications also form part of the knowledge architects need to be equipped with in the choice of materials (Fuchs *et al.*, 2008). Notably, architects just like most designers in other disciplines select materials not just for the physical attributes but also to convey their ideas in the built form. Some of the questions that arise during material selections are centred on whether the material conveys the intended meaning and purpose of use, or if it fits the need of the targeted group. As such it becomes imperative that such knowledge is beyond those given by the material manufacturers themselves (Karana *et al.*, 2010). Consequently, architects are therefore faced with the challenge in the lack of parameters which can effectively describe the sensory, perceptual or experiential aspects of materials that will enable them to compare new materials with familiar ones (Wastiels and Wouters, 2012).

In sum, initial knowledge, experience and available information direct the understanding of building materials' potentials. According to Kim (2008), building materials' life cycle are

phased into pre-building, building and post-building stages. Appropriately, building materials are expected to be sustainable across these phases and can be determined by the architects' expertise, knowledge, experience and the information at his disposal. Hence, showcasing his skill in building material selection and specification writing in particular.

2.4 Operationalization of research variables

The trainings that architects engaged in while on a job allow them to acquire knowledge which enhances the update of professionalism and improves their skills (Bouchlaghem, 2000). Gatherings of professionals such as architects are opportunities for sharing such experiences. For example in Nigeria, architects' colloquiums and Archi-Built exhibition are prominent national programmes associated with the Nigerian Institute of Architects. It is a place where professionals exchange experiences gathered over time and get information and knowledge while interacting with building material manufacturers. In these fora, architects are appraised with the existing as well as new trends in building materials and latest construction technology. Therefore, "on the job training" such as attending conferences and workshops avails opportunities to acquire and transfer knowledge from shared experiences with colleagues and associates. Also, interactions with building material manufacturers during exhibitions provide practical sessions for tacit knowledge exchange among stakeholders, with architects as the major beneficiary. Similarly, industry-based sources like catalogues and brochures are usually given to architects as souvenirs, pre-informing them of the potentials of available materials for their patronage. Beyond these, architects adopt the use of advanced technology (information and communication technology [ICT]) through multi-media sources and engaging in research and development to advance the knowledge of building materials. For instance, the Nigerian architects operate the WhatsApp social platform, where relevant information is transmitted to members. On this platform, various activities and practices are shared in addition to creating awareness about the knowledge on building materials and the associated performance.

Even though some scholars have criticized KM due to the reward and penalty actions engaged by some organizations to inspire knowledge sharing, however, it has proven to be positive in effecting organizational goal (Hendriks, 1999). Meaningfully, the use of ICT for KM particularly for storing and sharing of knowledge as well as creating and transferring new knowledge has proven significant owing to time efficiency and overcoming spatial barriers. Therefore, architects are encouraged to harness the KM potentials particularly with regards to tacit knowledge using the platform of ICT in optimizing the choice of building materials. These attributes defines the variables that were adopted for this study.

Additionally, variables deduced from previous studies widely were found to thematically fit into three dimensions. Consequently, reliable search for appropriate building materials and its application was operationalized as the dependent variable, whereas knowledge, experience and information dimensions form the independent variables.

3. Methodology

The quantitative approach using statistical techniques was used to realize the goal of this research. The study seeks to examine architects' strategies using the principles of KM towards guiding the choice of building materials to optimize building material specifications. Thus, data were collected by means of a survey of architects conducted at an architects' colloquium hosted in Abuja, Nigeria, in 2016 and later across architectural firms

to attain a reasonable sample appropriate for statistical analysis in 2017. In analysing the data, first, dimension reduction process through exploratory factor analysis and reliability testing using Cronbach's alpha were performed. Significantly independent variables that accounted for the phenomenon being investigated were thus observed. Next, the operational procedure of factor analysis preparing the data matrix followed swiftly with the principal component factor analysis to determine the group of factors that best fit interrelations among the set of variable measures. These set of variables relate the underlying dimensions or factors that predict the phenomenon. Afterwards, confirmatory factor analysis conducted further presented the results that led to the composition of the composite indices. Finally, stepwise multiple regression analysis was performed to evaluate the measures of knowledge, information and experience on the search for appropriate building materials as means of optimizing architects' strategy of materials' specification. This was done to test the hypothesis towards predicting the dependent variable as well as establishing the best predictor independent variables.

3.1 Respondents of the study

The respondents considered for this study are architects practicing in Nigeria. A trial survey was first conducted with a focus group in Niger State, Nigeria, where 15 registered architects were randomly selected for the exercise. This focused group later verified the effectiveness of the hypothesis and finally confirmed the validity of the research findings. Subsequently, the study considered architects across Nigeria and questionnaire forms were adequately distributed through hand-to-hand delivery at the national architects' colloquium programme for 2016 held at the nation's capital Abuja. A greater part of the exercise was conducted at the programme which was attended by a widely distributed group of architects from across the regions of the country. In addition, more architects selected across the country were later considered towards achieving an appropriate sample size. As a result, both representativeness and illustrativeness were achieved in the sample chosen for the study. Still, to ensure adequate variation among the responses, the random sampling technique was adopted using a face-to-face questionnaire form delivery method. The final sample projection comprises a total of 180 architects. A projection made on the premise that each state among the 36 states is represented by at least five architects. However, a total number of 202 questionnaire forms were distributed; of which, 123 responded adequately to the questionnaire forms. The sample size of 123 respondents is adequate for statistical analysis, as minimum of 100 is recommended by Hair *et al.* (2010).

3.2 Questions used in the survey

The study developed a questionnaire instrument from attributes that are related to specification writing background and guide architects' selection strategies. They were derived from previous studies with adjustments that include using KM principles subsumed into three dimensions. Consequently, it operationalized indicators using architects' strategy in building material information management. In this regard, on the job training, ICT as well as industry-based sources are considered critical to architects' strategy in building material selection. These factors were measured after they guided the composition of the independent variables. The outcome variable or dependent variable is the architects' search for appropriate building materials for building construction towards an optimized specification. Hypothetically, the significant influence of KM principles on the architects' strategies for specifying building materials for construction was studied. In the process, the study contextualized search and application of building materials as the dependent variable,

whereas the independent variables include acquired explicit knowledge, tacit knowledge expressed in experience and tacit knowledge based on available information about building materials.

4. Results and discussion

4.1 Exploratory factor analysis

Tabachnick and Fidell (2007) recommend that studies should adopt an exploratory approach while experimenting on factors until a satisfactory level is attained. Thus, this research explores dimensions that influence building material specification by architects using KM principles. The KM principles considered include knowledge identification, organizing knowledge, knowledge sharing and utilization of knowledge. Factor analysis exhibits both differentiation pattern and structural modelling in the form of scores and loadings, respectively, which could be represented cartographically to display pictorial impression. Psychometrically, 40 questionnaire item measures were considered and subjected to principal component factor analysis with factor loadings output >0.40 (ranging from 0.418 to 0.817) and grouped to establish the underlying factors for each of the three dimensions of knowledge, information and experience. These results are displayed in Tables I, II and III, respectively. Subsequently, the process later generated 13 factors that were considered for further analysis. Meanwhile, the reliability value of 0.861 Cronbach's alpha presented in Table IV was achieved when the questionnaire item measures were subjected to the internal consistency reliability test. Alpha coefficients are significant indicators in assessing the quality of instruments (DeVellis, 2011). Justly, alpha threshold minimum value of 0.70 is acceptable (Nunnally *et al.*, 1967; Pallant, 2005), whereas 0.80 and 0.90 are considered good values (Bride, 2004; DeVellis, 2011). This indicates a sufficient reliability of the measurement scale used in soliciting data.

Consistently, four attributes of explicit knowledge comprising manufacturers' catalogue, television adverts, alert from market situation and knowledge on new materials provided by the manufacturers' accounted for 59.003 per cent of the total variance on the knowledge dimension. Hence, largely responsible for variation measure of knowledge in the search for appropriate building material selection by architects. This suggests that these attributes significantly influence the explicit knowledge dimension of architects in the search for

Table I. Knowledge dimension rotated component matrix[a]

Knowledge attributes	Component 1	2	3	4
Forum to share materials' information	0.772			
Manufacturers provide new knowledge of application	0.663			
Performance knowledge of new materials from manufacturer	0.445			
Software applications to store knowledge		0.674		
Knowledge revealed at procurement		0.817		
Knowledge alert on market situation		0.619		
Suppliers provide expertise knowledge about materials			0.690	
Television adverts for information			0.596	
Knowledge gotten from manufacturers' catalogues				0.627
Exhibitions at colloquiums				0.698
Knowledge based on physical assessment				0.588

Notes: Extraction method: principal component analysis; Rotation method: varimax with Kaiser normalization; [a]Rotation converged in seven iterations

Information attributes	Component 1	2	3	4	5
Media and other agencies communicate bad materials	0.673				
Certified materials from standard organization	0.712				
Electronic repository on building materials	0.639				
Information from professional bodies	0.542				
New options when challenged		0.759			
Searching websites for information		0.773			
Professional bodies update information		0.623			
Repository updating documentation of materials			0.513		
Meetings to evaluate previous projects			0.635		
Presentation by manufacturers			0.735		
Dropbox, shared folders and emails to exchange information			0.569		
Marketers and suppliers relate industries' production output				0.500	
Questions sent to colleagues				0.456	
Standards to verify genuine materials				−0.418	
Phone contacts to seek for information				0.804	
Information from other professionals				0.621	
Research to obtain information					0.662
Reliance on print media for information					0.582

Notes: Extraction method: principal component analysis; Rotation method: varimax with Kaiser normalization; [a]Rotation converged in 17 iterations

Table II. Information dimension rotated component matrix[a]

Experience attributes	Component 1	2	3	4
Sharing experiences at conferences	0.791			
Knowledge from conference and workshop materials	0.797			
Dialogue with manufacturers and exhibitors	0.667			
Visitation to colleagues' project sites	0.642			
Platform to rate materials' performance		0.760		
Transfer of record on failed materials by experts		0.731		
Sharing experiences with colleagues			0.722	
Latest information from travelling abroad			−0.659	
Network of professional associates				0.782
Experiences on best practices are shared at conferences				−0.504

Notes: Extraction method: principal component analysis; Rotation method: varimax with Kaiser normalization; [a]Rotation converged in eight iterations

Table III. Experience dimension rotated component matrix[a]

building materials for specification. Similarly, the use of drop-box, email and shared folders to exchange information on building materials as well as conveying meetings to evaluate previous projects are among the six attributes that accounted for 59.109 per cent of the total variance on the information dimension. Others include updates and information provided by professional bodies, information on certified materials from standardization organizations and information from repository on materials as well as relevant agencies such as Standard Organization of Nigeria, which communicates bad building materials to stakeholders. They form the major influencers to the information dimension in accounting for the association between information and search for building

materials by architects. Also, four attributes accounted for 63.239 per cent of the total variance on the experience dimension. These attributes are experiences as a form of implicit knowledge derived or shared at conferences and workshops. It also includes experiences on best practices shared at conferences, visitation to other colleagues' project sites as well as dialogue with manufacturers and exhibitors during relevant events. These results signify that these attributes influence the experience dimension in architects' strategy for building material choices.

4.2 Confirmatory factor analysis

4.2.1 Data transformation. Subsequently, the 40 questionnaire measures distributed among the three dimensions and as classified by the factor analysis were statistically summed up through data transformation. The summation was done to establish factors for each of the three dimensions of knowledge, experience and information. As a result, the knowledge dimension comprises four factors outlined in Table V. Whereas, experience and information dimensions transformed and consist of five and four factors, as shown in Tables VI and VII, respectively. Altogether, 13 factors evolved from this process and were effectively used for further analysis.

4.3 Regression analysis

The analytical trail proceeded with regression analysis conducted to reveal how the factors influence the choice of building materials as strategies used by architects. The models developed were considered in two phases.

First, the regression analysis shown in Table VIII related three regression equations showing the relationship between the dependent variable and the three dimensions – independent variables. The first equation shows the explanatory power of knowledge in influencing the search for appropriate building material. The second equation relates the relationship between information and search for appropriate building materials, and the third equation relates experience with search for appropriate building materials. The *p*-values are significant and within the acceptable threshold, effectively showing that the models fits the data. The multiple correlation coefficients ($R = 0.564$, 0.775 and 0.581) show a positive and strong significant relationship between the predictors and the outcome, respectively. In addition, the result shows R^2 values for these three models. These values

Table IV. Reliability statistics

Cronbach's alpha	Cronbach's alpha based on standardized items	No. of items
0.861	0.867	40

Table V. Knowledge dimension

Manufacturer-driven knowledge acquisition	Transaction-based knowledge acquisition	Entrepreneur-driven knowledge acquisition	Self-directed knowledge acquisition
New knowledge from manufacturer	Use of software	Suppliers' expertise	Physical assessment from suppliers
New materials in stock	Knowledge at contract procurement	Television advert	Manufacturer's catalogue
Knowledge sharing forums	Market alert		Knowledge from exhibitions

On-job-training-derived experience	Practice-based experience	Skill and acquaintance-based experience	Professional interaction-based experience
Conference shared experience	Performance rating platforms	Sharing skills with colleagues	Conference shared best practices
Conference and workshop documents	Transfer of records by experts	Travels abroad	Professional networking
Visitation to colleagues' project sites			
Dialogue with manufacturers and exhibitors			

Table VI. Experience dimension

Certification and standardization institutions	Internet facilities-driven information search	Evaluation and documentation-based information	Professional networking	Inquiry-based information
Media and information agencies	Websites' search	Repository updated documentation	Phone contacts	Research-based information.
Certification by standard organizations	Update from professional bodies	Evaluation meetings	Link with allied professionals	Print media-based information
Electronic repository	Search for new options	Manufacturers' presentations	Standard and genuine materials	
Professional institutes		Dropbox, shared folders and emails	Questions directed to colleagues	
			Information derived from marketers and suppliers	

Table VII. Information dimension

indicate that explicit knowledge accounted for 29.8 per cent variation of the search for appropriate building materials. Similarly, 60.0 per cent of the variation in the search for appropriate building materials was explained by information acquired, whereas 33.7 per cent of the variation was explained by architects' experience. Also, the three models are significant, as R^2 values appear significantly different from zero, as indicated by the p-values, hence the models fit appropriately. Similar range of coefficient values have been recorded while observing change in some factors of productivity in agricultural growth over time and space using samples drawn from developing countries (Scandizzo, 1984; Diakosavvas, 1990). The overall measure for sample adequacy for all attributes in the three dimensions had values above 0.5 thresholds, except for "Forums to share materials' information" (with low value of 0.446). Also, the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy recorded values greater than 0.5 for the three dimensions, indicating practical level of common variance – knowledge: KMO = 0.587; information: KMO = 0.703; and experience: KMO = 0.680. The Bartlett's test of sphericity therefore confirms that the items within the dimensions are correlated.

Second, the fourth equation presented in Table IX forms a combined relationship and displays the output association between the 13 predicting variables and the dependent variable. Therefore, the multiple correlation coefficient R between the 13 predictors and the dependent variable stood at $R = 0.855$. The goodness of model fit from the result measuring 0.85 shows that it is significant at 95 per cent, hence a significant relationship exists.

Similarly, the predictors accounted for a total variation where R^2 measure equals 73.1 per cent. Thus, the combined inclusion of explicit knowledge (knowledge dimension) and tacit knowledge (experience and information dimensions) explained a reasonable amount of variation in the search for appropriate building materials in the strategies used by architects. Ideally, it gives a sensible level of illustrativeness and generalization of the model. Again to ensure broadness in representation, this was further confirmed using Stein's equation, which applied the value of R^2 to get the likely value in a different sample of $n = 200$.

Therefore, using Stein's equation:

$$\text{Adjusted } R^2 = 1 - [(200 - 1/200 - 3 - 1)(200 - 2/200 - 3 - 2)(200 + 1/200)] \times (1 - 0.731)$$

$$R^2 = 0.721 \quad \text{(i)}$$

Thus, the value of R^2 (0.721) in sample $n = 200$ is similar to the observed value R^2 (0.731) in $n = 123$, an indication that the cross-validity of the model is quite good. As such illustrativeness is attained and generalization could be made from the outcome. Furthermore, equation (4) (shown in Table X) that combined all the 13 attributes has a

					Change statistics				
Model	R	R square	Adjusted R square	SE of the estimate	R square change	F change	df1	df2	Sig. F change
1	0.546[b]	0.298	0.229	1.519	0.298	4.219	11	111	0.000
2	0.775[c]	0.600	0.531	1.185	0.600	8.671	18	104	0.000
3	0.581[d]	0.337	0.278	1.470	0.337	5.704	10	112	0.000

Notes: [a]Dependent variable: search for new materials; [b]predictors: (Constant), Self_Acquire, Transaction, Software, Entrepreneur; [c]predictors: (Constant), Inquiry, Networking Professionalism, Certification Standardization, Promotion, Evaluation Documentation, Internet; [d]predictors: (Constant), Professional interaction, Practice, On_Job_Training, Networking

Table VIII.
Model summary[a]

					Change statistics				
Model	R	R square	Adjusted R square	SE of the estimate	R square change	F change	df1	df2	Sig. F change
4	0.855[a]	0.731	0.605	1.088	731	5.785	39	83	0.000

Notes: [a]Predictors: (Constant), Professional_interaction, Practice, Transaction, Inquiry, On_Job_Training, Networking_Professionalism, Certification_Standardization, Self_Acquire, Entrepreneur, Software, Networking, Promotion, Evaluation_Documentation, Internet; [b]dependent variable: Search for new materials

Table IX.
Model summary[b]

degree of freedom equal to 83 and the *F*-ratio measures 5.785 and is highly significant at ($p < 0.000$). Thus, this model improved our ability to predict the outcome variable, which is the search for appropriate building materials for construction. Implicitly the model significantly fits the data. Meanwhile, the individual composite of the three dimensions represented by equations 1-3 and presented in Table XI shows a satisfactory prediction ability with significant *p* values, df at 111 for knowledge, 104 for information and 112 for experience dimensions. The *F*-ratios are appreciable, measuring 4.219, 8.671 and 5.704 for knowledge, information and experience dimensions, respectively.

Finally, experts who comprised registered architects who have been practicing for more than 15 years and participated in the initial test study were asked to validate the outcome. The level of acceptance and ranking of the architects' strategies for building material selection were confirmed using a validation survey form with the result presented in Figure 1. The result shows that experts accept all attributes exhibited in both explicit and tacit knowledge dimensions, as the mean response values are within the range of 1.2 and 2.4, where 2 and 1 stood for agree and strongly agree, respectively, in a five-point Likert scale instrument. In ranking the attributes, experts prioritize knowledge and information dimensions over the experience dimension. In this regard, manufacturer driven promotion,

Model		Sum of squares	df	Mean square	*F*	Sig
1	Regression	266.865	39	6.843	5.785	0.000[b]
	Residual	98.176	83	1.183		
	Total	365.041	122			

Notes: [a]Dependent variable: search for new materials; [b]predictors: (Constant), Professional_interaction, Practice, Transaction, Inquiry, On_Job_Training, Networking_Professionalism, Certification_Standardization, Self_Acquire, Entrepreneur, Software, Networking, Promotion, Evaluation_Documentation, Internet

Table X. ANOVA[a]

Model	Sum of squares	df	Mean square	*F*	Sig.
1 Knowledge					
Regression	108.911	11	9.901	4.291	0.000[b]
Residual	256.130	111	2.307		
Total	365.041	122			
2 Information					
Regression	219.073	18	12.171	8.671	0.000[c]
Residual	145.968	104	1.404		
Total	365.041	122			
3 Experience					
Regression	123.180	10	12.318	5.704	0.000[d]
Residual	241.860	112	2.159		
Total	365.041	122			

Notes: [a]Dependent variable: Search for new materials; [b]predictors: (Constant), Self_Acquire, Transaction, Software, Entrepreneur; [c]predictors: (Constant), Inquiry, Networking_Professionalism, Certification_Standardization, Promotion, Evaluation_Documentation, Internet; [d]predictors: (Constant), Professional_interaction, Practice, On_Job_Training, Networking

Table XI. ANOVA[b]

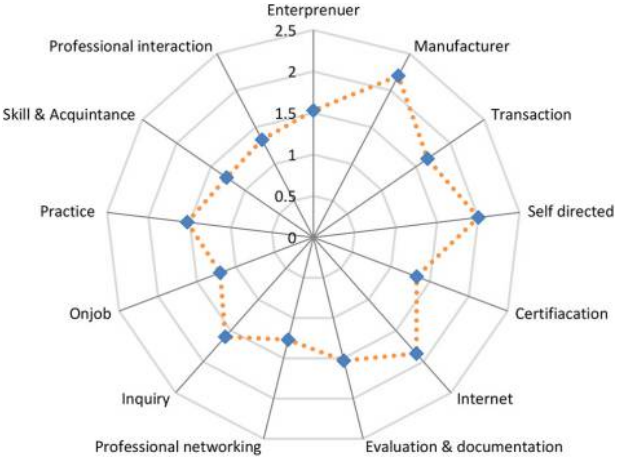

Figure 1.
Experts' validation and ranking of architects' strategies for building material selection

use of internet sources and software, seeking inquiries about building materials particularly self-directed and transaction-based inquests were ranked high.

In sum, knowledge, information and experience clearly have a positive effect on the choice of appropriate building materials. Similarly, based on the data analysis, a combined effect of the 13 established variables that form elements of the three dimensions are essential strategies adopted by architects in specification of building materials appropriate for design specification and construction purposes.

5. Findings and conclusions

The prime goal of this study is to evaluate architects' strategies in specification of building materials towards using KM principles to optimize the search for appropriate building materials for construction. Appropriate choice of building materials has been proven to enhance coherent structuring of specification writing, which is integral to the success of building construction. In the process, KM is established to offer the mechanism for the search and appropriation of tacit knowledge for productive reuse. This is consistent with the outcome of previous studies that have identified tacit knowledge as critical in organizational success. For instance, Gertler (2003) identified the key challenge in KM to be finding and locating appropriate tacit knowledge particularly in its context-specific nature. Also, Zollo and Winter (2002) found that to generate and adapt an operational system, tacit build-up of prior experience, knowledge articulation and knowledge codification procedures are key mechanisms in effecting dynamic capabilities towards organizational success.

In this study, however, the duo of experience and information are recognized to complement explicit knowledge in attaining organizational goals. From the regression analysis conducted on 13 factors, the outcome suggests that tacit knowledge (experience and information) seems to have a significant association with the search for appropriate building materials for construction. Impliedly, the attributes of both explicit and tacit knowledge dimension are crucial and effectively enhance architects' potentials in specification writing. Therefore, architects' skill as an entrepreneur and interaction using software improve their knowledge base on building materials. Similarly, engagement in transactions with merchants and self-directed knowledge-seeking efforts increase their knowledge potential base. Architects gradually develop skills while engaging in professional practice. In the

process, networks are established and expanded, as they choose to acquire training while practicing the profession. In addition, they rely on information from internet facilities, evaluation and documentation gathered from previous records, professional networks and standardization agencies. Therefore, they have the tendency to exhibit a procedure that enhances their skill in appropriate choice of building materials. And over time they attain expertise while optimizing their potentials. However intriguing as it may seem, the inability to consciously align the procedure with KM principles even as their strategies exhibit attributes of KM reduces the expected benefit that could reshape the procedure towards optimization. Consequently, traces of knowledge identification, organizing, sharing, storing and creation useful for specification writing abound in these skills and should be harnessed.

Significant to the finding of this study is the fact that effective specification writing relies on appropriate selection of building materials. The respondents through representativeness have illustrated the significance of KM principles in the process that plans for building material selection. The measurement approach in the process demonstrates the importance of knowledge and its update as an asset to the architect. This is reinforced by the experts' validation of the architects' strategies. Furthermore, the quality and sustainability of the buildings in particular and the built environment in general rely on the effectiveness of this procedure that guides material selection. Undoubtedly, tacit knowledge experience and information prove critical in ensuring appropriate storage, sharing, transfer and creation of building material knowledge as realized in the architects' strategies. Therefore, KM principles provide optimal benefit in this regard.

6. Recommendation

The main implication of this study is that architects should be sensitive to KM principles by harnessing its potentials in creating a procedure for building materials' selection in an optimized form of specification writing. They should ensure that the mechanism that links explicit and tacit knowledge on the one hand and specification writing on the other hand is guided consciously by KM attributes (knowledge search and identification, organizing, storing, sharing, creation and transfer) as seem to be exhibited in the professional practice of specification writing process of a typical architect. Architects are therefore urged to pay attention to professional networks. They should utilize software in networking, organize information chains and link experiences with output through coordinating tacit knowledge toward expressing its gains in quality and use of building materials towards a sustainable built environment, thereby ensuring optimization in construction project management and delivery.

References

Ahmad, H.S.M. (2011), *Development of KM Model for Knowledge Management Implementation and Application in Construction Projects*, University of Birmingham.

Atsrim, F., Buertey, J.I.T. and Boateng, K. (2015), "Managing the design process in the construction industry: a literature review", *Architecture Research*, Vol. 5 No. 1, pp. 16-30.

Alashwal, A.M., Rahman, H.A. and Beksin, A.M. (2011), "Knowledge sharing in a fragmented construction industry: on the hindsight", *Scientific Research and Essays*, Vol. 6 No. 7, pp. 1530-1536.

Alavi, M. and Leidner, D.E. (2001), "Knowledge management and knowledge management systems. Conceptual foundations and research issues", *MIS Quarterly*, Vol. 25 No. 1, pp. 107-136.

Alekseev, A. (2010), "Knowledge management in project-based organisations: the success criteria and best practises".

Arif, M., Al Zubi, M., Gupta, A.D., Egbu, C. and Walton, R.O. (2017), "Knowledge sharing maturity model for Jordanian construction sector", *Engineering, Construction and Architectural Management*, Vol. 24 No. 1, pp. 170-188.

Ashby, M.F. and Johnson, K. (2013), *Materials and Design: The Art and Science of Material Selection in Product Design*, Butterworth-Heinemann.

Bouchlaghem, N. (2000), "Optimizing the design of building envelopes for thermal performance", *Automation in Construction*, Vol. 10 No. 1, pp. 101-112.

Campbell, M. and Manicom, A. (2015), *Knowledge, Experience, and Ruling: Studies in the Social Organization of Knowledge*, University of Toronto Press.

Chen, J.H. (2012), "A hybrid knowledge-sharing model for corporate foreign investment in China's construction market", *Expert Systems with Applications*, Vol. 39 No. 9, pp. 7585-7590.

Cohen, J.F. and Olsen, K. (2015), "Knowledge management capabilities and firm performance: a test of universalistic, contingency and complementarity perspectives", *Expert Systems with Applications*, Vol. 42 No. 3, pp. 1178-1188.

Costa, R., Lima, C., Sarraipa, J. and Jardim-Gonçalves, R. (2016), "Facilitating knowledge sharing and reuse in building and construction domain: an ontology-based approach", *Journal of Intelligent Manufacturing*, Vol. 27 No. 1, pp. 263-282.

De Angelis, C.T. (2012), "A knowledge management and organisational intelligence model for public sector administrations", *Proceedings of the 2012 ECKM Conference*, *Cartagena, Spain*.

DeVellis, R.F. (2011), *Scale Development: Theory and Applications*, Sage Publications, Vol. 26.

Donate, M.J. and de Pablo, J.D.S. (2015), "The role of knowledge-oriented leadership in knowledge management practices and innovation", *Journal of Business Research*, Vol. 68 No. 2, pp. 360-370.

Donate, M.J. and Guadamillas, F. (2010), "The effect of organizational culture on knowledge management practices and innovation", *Knowledge and Process Management*, Vol. 17 No. 2, pp. 82-94.

Forcada, N., Fuertes, A., Gangolells, M., Casals, M. and Macarulla, M. (2013), "Knowledge management perceptions in construction and design companies", *Automation in Construction*, Vol. 29, pp. 83-91.

Fuchs, M., Hegger, M., Stark, T. and Zeumer, M. (2008), *Energy Manual: sustainable Architecture*, Walter de Gruyter.

Fugate, B.S., Stank, T.P. and Mentzer, J.T. (2009), "Linking improved knowledge management to operational and organizational performance", *Journal of Operations Management*, Vol. 27 No. 3, pp. 247-264.

Gertler, M.S. (2003), "Tacit knowledge and the economic geography of context, the undefinable tacitness of being (there)", *Journal of Economic Geography*, Vol. 3, pp. 75-99.

Graham, B., Gahan, D. and Thomas, K. (2007), *The Application of Knowledge Management Practices in the Procurement and Construction of Clean Room Projects*, Waterford Institute of Technology, University of Southampton, pp. 545-554.

Griffith, R.J. (2012), *Knowledge Flow: Exploring the Links between Knowledge Resources, Organizational Actions, and Performance*, The University of TX at San Antonio.

Hair, J.F. Jr, William, B.C., Barry, B.J. and Rolph, A.E. (2010), *Multivariate Data Analysis*, Pearson Education International, Upper saddle River, New Jersey.

Håkansson, H. and Waluszewski, A. (2014), *Knowledge and Innovation in Business and Industry: The Importance of Using Others*, Routledge.

Hashim, N.I., Chileshe, N. and Baroudi, B. (2013), "Management challenges within multiple project environments: lessons for developing countries", *Australasian Journal of Construction Economics and Building – Conference Series*, Vol. 1 No. 2, pp. 21-31.

Heijstek, W. (2012), *Architecture Design in Global and Model-centric Software Development*, Leiden Institute of Advanced Computer Sciences (LIACS), Faculty of Science, Leiden University.

Hendriks, P. (1999), "Why share knowledge? The influence of ICT on the motivation for knowledge sharing", *Knowledge and Process Management*, Vol. 6 No. 2, pp. 91-100.

Jahan, A., Edwards, K.L. and Bahraminasab, M. (2016), *5 – Multi-Attribute Decision-Making for Ranking of Candidate Materials Multi-Criteria Decision Analysis for Supporting the Selection of Engineering Materials in Product Design*, 2nd ed., Butterworth-Heinemann, pp. 81-126, available at: http://dx.doi.org/10.1016/B978-0-08-100536-1.00005-9

Karana, E., Hekkert, P. and Kandachar, P. (2008), "Material considerations in product design: a survey on crucial material aspects used by product designers", *Materials and Design*, Vol. 29 No. 6, pp. 1081-1089.

Kaur, K. (2014), "Knowledge management and firm performance: a descriptive study", *International Journal*, Vol. 2 No. 4.

Khuzaimah, K.H.M. and Hassan, F. (2012), "Uncovering tacit knowledge in construction industry: Communities of practice approach", *Procedia-Social and Behavioral Sciences*, Vol. 50, pp. 343-349.

Kogut, B. and Zander, U. (1993), "Knowledge of the firm and the evolutionary theory of the multinational corporation", *Journal of International Business Studies*, pp. 625-645.

Koops, L., Bosch-Rekveldt, M., Bakker, H. and Hertogh, M. (2017), "Exploring the influence of external actors on the cooperation in public–private project organizations for constructing infrastructure", *International Journal of Project Management*, Vol. 35 No. 4, pp. 618-632.

Malhotra, Y. (2000), "Knowledge management and new organization forms: a framework for business model innovation", *Knowledge Management and Virtual Organizations*, Vol. 2 No. 19.

Pallant, J. (2005), *SPSS Survival Manual: A Step by Step Guide to Data Analysis using SPSS for Windows (Version 12)*, Open University Press, Berkshitre.

Paulin, D. and Suneson, K. (2015), "Knowledge transfer, knowledge sharing and knowledge barriers–three blurry terms in KM", *Leading Issues in Knowledge Management*, Vol. 2 No. 2, p. 73.

Pedgley, O. (2014), "Chapter 24 – materials Selection for product experience: new thinking, new tools A2 – Rognoli", *Elvin KaranaOwain PedgleyValentina Materials Experience*, Butterworth-Heinemann, Boston, pp. 337-349, available at: http://dx.doi.org/10.1016/B978-0-08-099359-1.00024-2

Pemsel, S. and Wiewiora, A. (2013), "Project management office a knowledge broker in project-based organisations", *International Journal of Project Management*, Vol. 31 No. 1, pp. 31-42.

Reagans, R. and McEvily, B. (2003), "Network structure and knowledge transfer: the effects of cohesion and range", *Administrative Science Quarterly*, Vol. 48 No. 2, pp. 240-267.

Sajeva, S. and Jucevicius, R. (2010), "Determination of essential knowledge management system components and their parameters", *Social Sciences/Socialiniai Mokslai*, Vol. 1 No. 67, pp. 80-90.

Tabachnick, B.G and Fidell, L.S. (2007), *Using Multivariate Statistics*, 5th ed., Pearson Education, Boston.

Todorović, M.L., Petrović, D.Č., Mihić, M.M., Obradović, V.L. and Bushuyev, S.D. (2015), "Project success analysis framework: a knowledge-based approach in project management", *International Journal of Project Management*, Vol. 33 No. 4, pp. 772-783.

Tong, C., Tak, W.I.W. and Wong, A. (2015), "The impact of knowledge sharing on the relationship between organizational culture and job satisfaction: the perception of information communication and technology (ICT) practitioners in Hong Kong", *International Journal of Human Resource Studies*, Vol. 5 No. 1, pp. 19-47. Pages

Tyagi, S., Cai, X., Yang, K. and Chambers, T. (2015), "Lean tools and methods to support efficient knowledge creation", *International Journal of Information Management*, Vol. 35 No. 2, pp. 204-214.

Valmohammadi, C., Ahmadi, M., Irani, Z. and Irani, Z. (2015), "The impact of knowledge management practices on organizational performance: a balanced scorecard approach", *Journal of Enterprise Information Management*, Vol. 28 No. 1.

Wastiels, L. and Wouters, I. (2012), "Architects' considerations while selecting materials", *Materials and Design*, Vol. 34, pp. 584-593.

Yeung, C.L., Cheung, C.F., Wang, W.M., Tsui, E., Lee, W. and Chase, R. (2016), "Managing knowledge in the construction industry through computational generation of semi-fiction narratives", *Journal of Knowledge Management*, Vol. 20 No. 2.

Further reading

Ahern, T., Leavy, B. and Byrne, P. (2014), "Knowledge formation and learning in the management of projects: a problem solving perspective", *International Journal of Project Management*, Vol. 32 No. 8, pp. 1423-1431.

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