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Performance measurement indicators influential to the espousal of cyber-physical systems for facilities management – a Delphi approach

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Abstract

Purpose – The quest for improved facilities management (FM) delivery is receiving immense focus through the incorporation of innovative technologies such as cyber-physical systems (CPS). The system's high computational capabilities can aid in the abatement of some of the challenges plaguing FM functions. However, the requisite ingredients for the uptake of the system for FM have still not gained scholarly attention. Because performance measurement is a vital index in determining the outcome of FM methods, this study aims to investigate the influence of performance measurement indicators that are influential to the uptake of CPS for delivering FM functions.

Design/methodology/approach – A qualitative technique was adopted using the Delphi technique. The panel of experts for the study was selected through a well-defined process based on stipulated criteria. The experts gave their opinions in two rounds before consensus was attained on the identified performance measurement indicators, whereas methods of data analysis were measures of central tendency, inter-quartile deviation and Mann–Whitney U test.

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Findings – Results from this study showed that 11 of the performance indicators were of very high significance in the determination of the uptake of CPS for FM functions, whereas 5 of the indicators were proven to be of high significance. Furthermore, there was no statistical difference in the opinions of the experts based on their affiliation with academic institutions and professional practice.

Practical implications – The findings of this study contribute practically by aiding policymakers, facility managers and relevant stakeholders with the vital knowledge of delivery mandates for efficient FM services that can spur the uptake of digital technologies such as CPS.

Originality/value – This study contributes to the body of knowledge as it unveils a roadmap of the expected performance output and its accompanying evaluation that would drive the adoption of a promising technology such as CPS in the delivery of FM tasks.

Keywords Cyber-physical systems, Delphi technique, Digitalisation, Facilities management, Performance measurement

Paper type Research paper

Introduction

Facilities management (FM) is a process that delivers sustainable enterprise with respect to the overall management of the lifecycle of organisations in anticipation of efficient business support and productivity efficiency (Kamarazaly *et al.*, 2013; South African Facilities Management Association (SAFMA), 2012). It is also referred to as:

> A practice that ensures effective operational management of buildings, in both public and private organisations, comprising of a broad range of activities from strategic, operational planning to daily physical maintenance, cleaning and the management of environmental performance issues. (Facilities Management Association of Australia, 2019, p. 5).

FM is characterised by strategic placement with the aim of the attainment of a balance involving technical processes, service management and business concerns (Jawdeh, 2013). Hence, FM can be regarded as a coverage of a wide spectrum of service provisions spanning from productivity, maintenance, sustainability, accessibility, safety and hospitality (Kok *et al.*, 2011). Generally, the functions of FM in the lifecycle of any business concern are deemed significant because of the strategic values that are associated with its delivery, in combination with its roles in the evaluation of facility utilisation.

As a result of outdated methods and approaches, FM is significantly characterised by inadequacies and inefficiencies which make an influential impact on service delivery (Atkin and Bildsten, 2017; Aziz *et al.*, 2016; Hoxha *et al.*, 2021). These inherent challenges affecting the delivery of FM tasks ultimately snowball into hampering the actualisation of outlined objectives of organisations (Ikuabe *et al.*, 2022). Also, the delivery of FM tasks is significantly hindered resulting of the non-adherence to the uptake of digital and innovative technologies for service delivery (Ensafi and Thabet, 2021; Nidhi and Ali, 2020). Furthermore, Ikuabe *et al.* (2020a) observed that digital technologies are least applied in the operations/maintenance phase of building projects. This affirms that there is a low application of innovative technologies for the delivery of FM. Therefore, the attainment of optimum performance in service delivery is negatively impacted because of the non-alignment of FM mandates and technological innovations. However, digital technologies have been touted to be beneficial to core FM mandates as it seeks to seamlessly aid in the delivery of outlined tasks (Nidhi and Ali, 2020). In this regard, the building industry is mandated to make an introduction of the effective upkeep of service systems resulting from the development of innovative technologies with the prospect of attaining functional and operational longevity in buildings (Islam *et al.*, 2019; Marzouk and Zaher, 2020).

The era of the fourth industrial revolution has unveiled the window of the application of a good number of digital technologies which is evident in various sectors of human activities (Hoosain *et al.*, 2020; Kayembe and Nel, 2019; Sima *et al.*, 2020). This has resulted in the increase in the uptake of digital technologies in sectors such as manufacturing, health care, banking, transportation and media (Ajibade and Mutula, 2020; Lee and Lim, 2017; Serumaga-Zake and van der Poll, 2021). Attributed as a dawdler in embracing digital transformation, the construction/FM industry is beginning to imbibe the principles to aid the drive for the espousal of digital technologies (Ikuabe *et al.*, 2020a). With the array of development challenges confronting humanity in the 21st century in conjunction with the desire to attain the stipulated Sustainable Development Goals, no people or profession can efficiently flourish without professional aspirations and strategies that are rooted in the technological realm of knowledge (Aghimien *et al.*, 2021; Ikuabe *et al.*, 2020b). There is a clear evidence of these innovative applications in several facets in the management of construction and built-up facilities (Rathore *et al.*, 2016; Rehman *et al.*, 2020; Saeed *et al.*, 2018). Hence, the uptake of digital technologies for the delivery of FM mandates would help to abate some of the inherent challenges plaguing its optimum service delivery. In recent times, one peculiar technology attributed with the formidability of delivering on this yearning is cyber-physical systems (CPS). This is a system characterised by computing networks operated on the premise of the integration of physical procedures and computational capabilities. CPS operates as the link between the physical and virtual space (Kim and Park, 2013; Alguliyev *et al.*, 2018; Ikuabe *et al.*, 2020c). In the fast-changing age of technology, CPS provides a formidable platform for resolving problems in real-time (Bhrugubanda, 2015; Taymanov *et al.*, 2017; Akanmu and Anumba, 2015). Also, the system enables the reduction of equipment downtime and improves operation efficiency (Banerjee and Nayaka, 2022; Hererich *et al.*, 2015). Therefore, the incorporation of CPS into FM delivery processes would help in delivering the objectives and mandates organisations.

According to McCarroll (2017), FM showcases the connection between management and the design of facilities through strategic execution in conforming to pre-established goals. Therefore, it becomes expedient to engage the assessment of the performance and the attendant deliverables of the adopted digital technology in relation to the set objectives of the organisation. Performance measurement enables the perceptive contributions for efficient control through the offering of discernments on the choice and needs of a range of control mechanisms (Fisher, 2021; Jonsson and Rudberg, 2017). Through the aid of measurement functions, a system of performance measurement contributes to achieving better objectives of an organisation. This provides an insight into the need for performance measurement by parties with a vested interest in the perspective of FM. Essentially, the delivery mandates of FM would be evaluated within the ambits of properly defined standards for performance within the spectrum of maintenance, economics or finance. Hence, the integration of CPS for FM tasks would be receiving a better acceptance if the measurement of the system's delivery is in tandem with optimised and enhanced productivity when compared with the traditional modes or systems. It is against this backdrop this study investigates the influence of performance measurement in the uptake of CPS in the delivery of FM duties. The distinction of this study lies in the notion that no research unravels the influential indicators of performance measurement in the quest for integrating innovative technologies such as CPS for FM. The findings of the study would make practical contributions by unveiling a roadmap that will serve as a guide for the adoption of innovative technologies for the efficient delivery of FM mandates.

Theoretical background

The performance of an organisation is highly reliant on its ability to garner and incorporate huge flows of information and the management framework put in place for the intelligent actions taken from the information. Performance is an action or a process to actualise or deliver on a task or function (Marques-Quinteiro *et al.*, 2013; Dubnick, 2005). Also, task performance is the ability to effectively indulge in the delivery of duties within the ambits of a stipulated job description and also with a recognition of being a portion of the job which calls for the capability of the use of a group of skills and knowledge (Wong and Snell, 2003). Furthermore, Armstrong and Murlis (2000, p. 240) stated that the completion of an obligation "with predetermined procedures" is the representation of performance, whereas Ismajli *et al.* (2015) opined that the intricate support of performance is an influential factor in knowledge, skills and motivation. The aspect of motivation in this context refers to the willingness to deliver on a given obligation, whereas skills refer to the ability in the conduct a function and knowledge refers to the ability of requisite details of knowing what to do. Generally, the overview of performance is a combination of the three stated factors (Dubnick, 2005).

The provision of insightful discernments on the alternatives given for the adoption of a control mechanism for the purpose of efficient management is a general overview of performance measurement. With aid of measurement functions, the performance measurement of a system makes contributions to the attainment of improved goals of the organisation. In a properly laid out context, the broad management's need for performance measurement can be interpreted from the perspective of FM (Amaratunga and Baldry, 2003; Amos *et al.*, 2019). The delivery of FM mandates would be assessed by the organisation's stakeholders within the ambits of a set of outline criteria for performance. These criteria would be given in a spectrum of constructs such as maintenance, economics and finance. According to Amos *et al.* (2019), there are different views on the contributions of FM to any organisation which is captured under resource control, change management, supply chain management, strategy, culture and service management. These are indicators of the effectiveness and the attendant contributions made by FM in any organisation and the evaluation of the different routes with which performance can be influenced. Medne and Lapina (2019) outlined the importance of the focus on performance measurement with respect to continuous improvement, whereas the provision of timely and accurate feedback on the effectiveness of operations is a deliberate mandate of an efficient system of performance measurement (Lampe and Hilgers, 2015). On this premise, the dimensions for assessment are resource allocation, change management, planning, control, motivation, measurement and improvement and communication (Koleoso *et al.*, 2017).

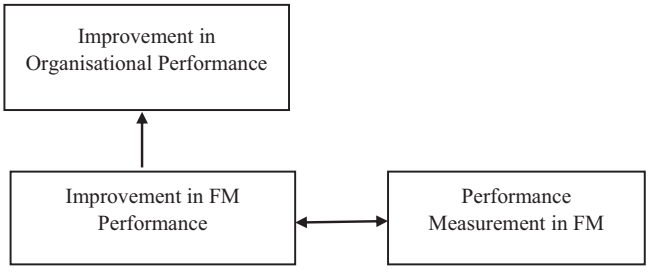
Generally, more volatility is encountered by professional services as well as an uncertain external environment in comparison to mass services which tend to require performance measurement systems that are interactive. As earlier established, performance measurement contributes to effective control by giving insights into the choice of control mechanism. However, the performance measurement process can serve other functions within the ambit of the control process. Katic and Bevanda (2019) stated that aside from the provision of insights, performance measurement might clarify the objectives of the organisation's management to the lower levels of the organisations. Looy and Shafagatova (2016) outlined the fundamentals of performance measurement as alignment of measures of performance with adopted strategies of the organisation; measures in sub-unit aggregating into wide measures of the organisation; measurement regime commitment; performance having effect from measurement; and reliability of measures. There has been the continuous recognition of FM as a change catalyst and also an enabler for the improvement of the

performance of organisations (Al-Tameemi *et al.*, 2018). The prominence of facilities managers is increasingly being hinged based on entrepreneurial skills coupled with knowledge of the organisation and having the abilities to pre-empt and translate the need for a change of the organisation into strategies that will serve as an underpinning of operational goals for the yielding of competitive advantage. Then and Akhlaghi (1992, p. 34) affirmed that "the focus of FM skills and techniques are in the area that contributes to the overall management of a business." Many organisations are having a transformation of their internal culture to serve as a channel with which performance can be improved. In enabling these transformations, FM has a prominent role to play by giving support to the organisation serving as a segment of the all-inclusive drive for change, paving the way for the emulation by others (Looy and Shafagatova, 2016). The concept outlined above is further clarified in Figure 1.

For organisations, exploitation is imbibed with efficiency through the enablement of activities, processes and functions to be duplicatable and predictable. In contrast, innovative ideas are naturally non-repetitive (Govindarajan and Trimble, 2010) and have some characteristics of a given degree of indistinctness and uncertainty (Sicotte and Langley, 2000). Hence, it is given that a differentiation is made between planning and organisation when innovations are being considered because of the inherent irreconcilability between efficiency and innovation (Govindarajan and Trimble, 2010). Furthermore, "while breaking all the rules is toxic as a leadership mantra, there is some truth in that notion because there are different rules for innovation" (Govindarajan and Trimble, 2010, p. 14). Also, the goal-setting theory stipulates that there is a general sanction for goal-setting with respect to challenging and specific goals. This results from the drive for the actualisation of improved job performance in comparison with placing a goal that may be vague, ambiguous, easy, and often connoted as "do your best goals" (Heslin *et al.*, 2008). Furthermore, in the act of putting into play the goal-setting strategy, a set of given criteria lay out the outcomes of the goals within the framework of its relevance, time frame, attainability and measurability (MacLeod, 2012). Table 1 presents a summary of the performance measurement indicators influential to the uptake of digital technologies for FM.

Research methodology

The study aims to evaluate the performance measurement indicators that are influential to the uptake of CPS for FM. A Delphi technique was adopted for the study because of the qualitative nature of the study, and the philosophical stance used is the constructive perspective. This method identifies the formation of distinct knowledge and understanding



Source: Looy and Shafagatova (2016)

Figure 1.
Relationship between FM and organisational performance

Indicators	Author(s)
Built-in capability of facility adaptation	Kamara *et al.* (2020)
Identification of problems in facilities	Abu Al-Aish and Love (2013), Martins (2000)
Improved customer satisfaction	Hernandez-Ortega *et al.* (2014) Phichitchaisopa and Naenna (2013)
Improvement in evaluation process through customers' involvement	Kim and Ammeter (2014)
Informed decision-making	Abu Al-Aish and Love (2013)
Significance of cost savings	Legris *et al.* (2003); Erdoğmuş and Esen (2011)
Significance of time savings	Legris *et al.* (2003); Erdoğmuş and Esen (2011)
Significance of quality assurance	Legris *et al.* (2003); Erdoğmuş and Esen (2011)
Attainment of customers' specific needs	Hernandez-Ortega *et al.* (2014) Phichitchaisopa and Naenna (2013)
Timely communication of policy changes	Kim and Ammeter (2014)
Stakeholders' perception of facilities performance	Rahmat and Nawawi (2020)
Improvement in facilities' standards	Stacey *et al.* (2021)
Economic utilisation of the facility	Aceves-Avila and Berger-Garcia (2019)
Evaluation of existing trends	Kaplan and Norton (1996)
Improvement of internal processes of the organisation	Kim and Ammeter (2014), Rahmat and Nawawi (2020)
Anticipation of the attainment of future needs of the organisation	Hernandez-Ortega *et al.* (2014), Abu Al-Aish and Love (2013)

Source: Authors' compilation

Table 1. Summary of performance measurement indicators

of the world emanating from experiences and contemplation of these experiences (Adom *et al.*, 2016; Creswell, 2009; Mahamadu *et al.*, 2019). The Delphi method is a variant of the qualitative methodology applied in getting a consensus among a panel of experts on a subject matter (Chan *et al.*, 2001; Hallowell and Gambatese, 2010; Grisham, 2008). Also, the technique is recommended for the progression of concepts, models and frameworks of a study. Several studies conducted in the architecture, engineering, construction and FM domain have engaged the use of the Delphi method (Aghimien *et al.*, 2020; Ogunbayo *et al.*, 2022; Tengan and Aigbavboa, 2018). This study adopts the Delphi approach to seek the opinions of professionals with respect to performance measurement indicators that are influential to the espousal of CPS for FM mandates. This was accomplished through iterative rounds in anticipation of inundation in the given opinions of the group of experts, thereby presenting a convergence of views of the selected experts (Aigbavboa, 2013). For this study, this method of scale derivation aided in formulating experts' opinions (consensus) on the performance measurement attributes that would aid in the propagation of the infusion of CPS for FM task delivery. The research instrument deployed a Likert scale which presented the options for the experts to select the preferred option from a range of 1 to 10, outlining the significance of the performance indicator from very low significance to very high significance (VHS). Figure 2 shows the framework of the Delphi process conducted for this study.

Selection of Delphi experts

After the establishment of the objectives of the study, the selection of panel experts is next for the Delphi study. Hasson *et al.* (2000) and Rowe and Wright (1999) opined that one of the foremost areas of unclarity in the process of a Delphi technique is the panel expert selection. For this study, the selection of the experts making up the panel of the

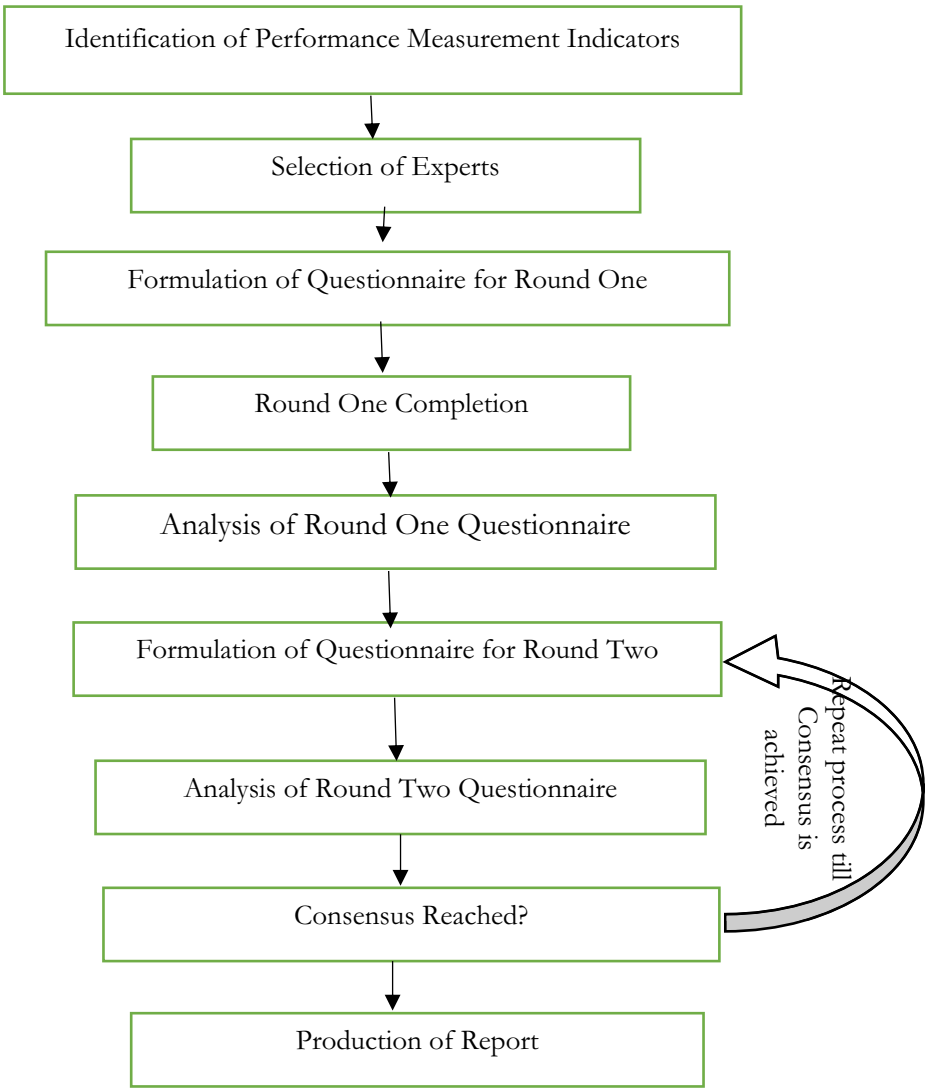


Figure 2.
Framework for the Delphi study

Source: Aigbavboa (2013)

Delphi process was actualised by properly defining the requisite criteria needed for choosing the panel experts. Previous studies aligned with a thorough process for the selection of panel experts for a Delphi study (Chan *et al.*, 2001; Armstrong *et al.*, 2005), whereas others have adopted a flexible selection process that should be hinged on appropriate requirements for the Delphi study (Hallowell and Gambatese, 2010; Somiah *et al.*, 2020). The approach deployed for the current study evaluates the outlined criteria for the study in conjunction with the profile of the prospective experts while affirming

selection if 50% criteria are met. This approach is in line with studies by Ogunbayo *et al.* (2022) and Aghimien *et al.* (2020). The set criteria for this study are an academic qualification of a minimum bachelor's degree in the subject of construction, FM, architecture and engineering (Giel and Issa, 2016; Evans and Farrell, 2021); a minimum of five years of professional working experience (Chan *et al.*, 2001; Aghimien *et al.*, 2020); profound knowledge in information and communication technology as a construction or facility management professional (Somiah *et al.*, 2020); and a current employee of construction or FM establishment or organisation or a faculty member in a university (Ogunbayo *et al.*, 2022; Chan *et al.*, 2001).

It has long been established from previous literature that there is no general agreement on the sample size for Delphi studies (Howell and Kemp, 2005; Ameyaw *et al.*, 2016). On this notion, the current study engaged in the selection process of the Delphi panel experts by sending out an invitation to 32 identified experts through email. This entailed a comprehensive elucidation of the entire concept of the Delphi process and the detailed breakdown of the processes involved therein. Out of the 32 experts initially reached out to, a total of 18 panellists signified interest to partake in the study. This led to sending out the questionnaire for the Delphi study to the 18 panellists. Of the 18 panellists reached out, only 11 returned their filled questionnaires within the stipulated time frame provided by the study. These 11 panellists were involved in the entirety of the Delphi process from start to completion. Table 2 presents the demographic representation of the experts making up the Delphi panel.

Demographic designation	No. of experts	%
Academic qualification		
Bachelor's degree	4	36.36
Master's degree	3	27.28
Doctor of philosophy	4	36.36
Total	11	100.00
Area of specialisation		
Facilities management	4	36.36
Construction management	4	36.36
Building construction	2	18.19
Information technology	1	9.09
Total	11	100.00
Years of experience		
1–5 years	1	9.09
6–10 years	3	27.28
11–15 years	5	45.45
16–20 years	1	9.09
Over 20 years	1	9.09
Total	11	100.00
Employment agency		
Consultancy	3	27.27
Contractor	3	27.27
Government	5	45.46
Total	11	100.00

Source: Authors' compilation

Table 2. Background information of experts

Delphi iterations

According to Aigbavboa (2013), there is no consensus on the number of rounds required for the conduct of a Delphi study. However, for most studies in the architecture, engineering, construction and FM space, a consensus is usually attained within two or three rounds (Ameyaw *et al.*, 2016). In this study, a consensus was achieved after two iterations of the Delphi process. Each round was completed within an average time frame of one month, with the panellists being given sufficient time for the input of quality contributions. The questionnaire for the first round of the Delphi process was exclusively based on the findings from the review of literature, whereas the second round questionnaire was based on the feedback gotten from the experts in the first round. Hence, the second round of the Delphi study was the outcome of the brainstorming engagement by the experts from the first round. The questionnaire for the first round of the Delphi study was characterised by closed- and open-ended questions, which enabled the panellists to offer new suggestions. Therefore, this culminated into the formation of the questionnaire for the second round. At the individual rounds, the responses gotten from the experts were analysed to evaluate the extent of consensus for the opinions provided by the experts. In the second round of the study, a closed-ended questionnaire was used in eliciting the responses of the experts based on their agreement with the outcome of the first round. Subsequently, the responses gotten from the second round were subjected to analysis to assess the attainment of consensus of the provided opinions.

Achieving consensus

Establishing consensus among a set of opinions is a tedious task. For a Delphi study, there is no commonly recognized rule stipulating how consensus ought to be obtained. Because consensus is synonymous with an agreement, it can be achieved through the collective projection of judgements, whose pitch is in tandem with a subjective notion of central tendency, or affirmation of the view stability with constant views in the ensuing rounds of the process (Holey *et al.*, 2007; Chan *et al.*, 2001). Past studies have deployed several statistical techniques in ascertaining consensus for a Delphi process. McKenna (1994) used frequency distribution for affirmation of consensus with an outlined criterion of 51%, whereas Rayens and Hahn (2000) used means and standard deviation which stipulated that a decrease in standard deviation in the progressive rounds portrays a high tendency of consensus. Also, some studies have deployed the use of inter-quartile deviation (IQD) in determining consensus (Aigbavboa, 2013; Ogunbayo *et al.*, 2022; Somiah *et al.*, 2020). The current study employed the mean, median and IQD was used in determining the fulfilment of consensus. The IQD involves achieving an absolute difference between 75th and 25th percentiles. A percentile is the representation of values of tests that are non-referenced. Within a spectrum of the entirety of the aggregate formation, there are Q1, Q2 and Q3; these are connoted with 25th, 50th (median) and 75th percentiles, respectively. IQD is determined by establishing the difference between the 75th and 25th percentiles. A small value of IQD depicts a high degree of consensus or agreement, whereas a high value of IQD depicts a low degree of consensus or agreement (Aigbavboa, 2013). Table 3 presents the scales for the determination of consensus by the current study. Accordingly, in achieving a strong consensus, the median should have a value ranging from 9 to 10, the value of the mean should be within the range of 8–10 and the IQD should be ≤ 1.

Determining reliability and validity of the Delphi process

Accounting for a dependable result from the Delphi process can be conducted by ascertaining the reliability and viability of the data set used for the study. Although the

determination of the reliability and viability of the Delphi process is a considerable challenge for the Delphi study (Ameyaw *et al.*, 2016), Els and Delarey (2006, p. 52) noted that "reliability is the extent to which a procedure produces similar results under constant conditions at all times." Considering that a Delphi study is categorised as a qualitative research method, it is thus characterised with its own challenges in determining statistical reliability (Creswell, 2009). However, this can be abated by a careful and thorough explanation of the process to the prospective experts while also ensuring a simple interpretation of the intent of the process (Yousuf, 2007). Therefore, the current study made sure that a clear detailing of the objective of the study was communicated to the experts of the panel for the Delphi study. This was conducted by providing a clear explanation of the identified performance measurement indicators that are influential to the espousal digital technology (CPS) for FM. Furthermore, clear instruction was provided to the experts on how the survey should be filled. Because expert selection for a Delphi study serves as a valid basis for the process (Aigbavboa, 2013), robust and all-encompassing efforts were invested in the expert selection process for the study, while ensuring the fit for purpose of the study.

Findings

Background information of experts

The demographic information of the experts making up the panel of the Delphi study indicates that four experts have a doctorate degree as the highest educational qualification, which makes up 36.36% of the total experts. Also, those with a master's and bachelor's degree are three and four experts, respectively. For the area of specialisation, both FM and construction management have four experts, whereas building and construction and information technology both have two and one experts, respectively. With respect to years of professional experience, five experts have 11–15 years, three have 6–10 years, whereas for over 20 years, 16–20 years and 1–5 years all have one expert each. On the basis of the experts' employment designation, five are affiliated with government agencies making up 45.46% of the total number of experts, whereas there are three experts each for both consultancy and contracting establishments, having 27.27% of the total number of experts.

Delphi round one result

In the initial round of the Delphi process, responses were gotten from the panel experts based on performance measurement indicators that are influential to the uptake of CPS for the delivery of FM tasks. In this round, the survey made the provision of the avenue for the experts to include indicators that they consider would be significant but not captured in the study. The survey used a 10-point scale given in a spectrum of very low significance to VHS. Table 4 shows the result of the first round of the Delphi study which entails the group median, mean, standard deviation, IQD and Mann–Whitney U test. In trying to inquire if there is a difference in the opinion of experts based on the categorisation of academic and professional affiliation, Mann–Whitney U test was deployed. In establishing this, an indicator with a p-value ≤ 0.05 is

Status of consensus	Median	Mean	Interquartile deviation (IQD)
Weak consensus	≤6.99	≤5.99	≥2.1 ≤ 3 and ≤59% (5.99)
Good consensus	7–8.99	6–7.99	≥1.1 ≤ 2 and ≥60% ≤ 79% (6–7.99)
Strong consensus	9–10	8–10	≤1 and ≥80% (8–10)

Source: Authors' compilation

Table 3. Scale for consensus categorisation

Indicators	Median	Mean	SD	IQD	Mann–Whitney Z	Mann–Whitney p-value
Built-in capability of facility adaptation	6	8.13	0.73	1.50	−1.674	0.331
Identification of problems in facilities	7	7.05	0.89	1.50	−0.239	0.127
Improved customer satisfaction	7	8.32	1.04	2.00	−1.725	0.183
Customers' involvement in improving evaluation process	8	7.94	0.79	1.50	−0.224	0.482
Informed decision-making	7	7.48	0.66	1.00	−1.637	0.296
Significance of cost savings	6	8.46	1.51	1.50	−0.318	0.092
Significance of time savings	7	7.73	1.06	1.50	−1.005	0.146
Significance of quality assurance	6	8.26	0.84	1.50	−0.227	0.394
Attainment of customers' specific needs	7	7.36	0.97	1.50	−1.026	0.641
Timely communication of policy changes	8	7.26	1.18	0.50	−1.311	0.552
Stakeholders' perception of facilities performance	7	8.16	0.83	1.00	−0.824	0.295
Improvement in facilities' standards	7	8.28	1.02	1.00	−1.594	0.384
Economic utilisation of the facility	8	7.73	0.65	1.00	−0.661	0.136
Evaluation of existing trends	6	8.57	0.93	1.50	−1.428	0.117
Organisation's internal process improvement	7	8.31	1.16	1.50	−0.445	0.326
Attainment of future needs of the organisation	8	7.96	0.77	0.50	0.926	0.274
Cronbach's alpha				0.786		

Table 4.
Delphi round 1 results

Source: Authors' compilation

considered to have a disparity in the views of the group of respondents, whereas an indicator with a p-value > 0.05 is considered not to have a difference in the views of the group of respondents (Pallant, 2005). The results gotten in this round show that all the indicators have a p-value > 0.05, thus indicating that there is no significant difference in the opinions of the two groups of experts. Also, with the aid of Cronbach's alpha test, the validity and reliability of the survey instrument were evaluated. The test gave a value of 0.786 which indicates good reliability because the value is closer to 1 (Tavakol and Dennick, 2011). Using the scale of categorisation for the attainment of consensus as shown in Table 3, it is revealed that the first round of the Delphi study indicates that there was no consensus met among the performance measurement indicators as opined by the panel of experts.

Delphi round two result

Table 5 shows the result of the second round of the Delphi study. It is portrayed from the result of the Mann–Whitney U test conducted that there is no significant statistical difference in the opinions given by experts whose affiliation is with professional practice and those affiliated with academic establishments. It is given that 11 of the performance measurement indicators are of VHS (9.00–10.00) as opined by the panel of experts for the Delphi study for determining the uptake of CPS for FM. These are built-in capability of facility adaptation (mean = 8.55; IQD = 0.00); identification of problems in facilities (mean = 7.92; IQD = 0.50); improved customer satisfaction (mean = 8.62; IQD = 0.50); customers' involvement in improving evaluation process (mean = 8.37; IQD = 0.00); significance of time savings (mean = 8.21; IQD = 0.00); attainment of customers' specific needs (mean = 8.05; IQD = 0.50); timely communication of policy changes (mean = 7.89; IQD = 0.00); improvement in facilities' standards (mean = 8.75; IQD = 0.00); economic utilisation of the facility (mean = 7.94; IQD = 0.00); evaluation of existing trends (mean = 8.75; IQD = 0.50); and attainment of future needs of the organisation (mean = 8.39; IQD = 0.00). Also, the result shows that five performance indicators are of high significance (HS: 7.99–8.00). These are informed decision-making (mean = 7.91; IQD = 0.00);

Indicators	Median	Mean	SD	IQD	Mann–Whitney Z	Mann–Whitney p-value
Built-in capability of facility adaptation	9	8.55	0.34	0.00	−1.724	0.521
Identification of problems in facilities	9	7.92	1.28	0.50	−0.837	0.072
Improved customer satisfaction	9	8.62	0.52	0.50	−1.226	0.175
Customers' involvement in improving evaluation process	9	8.37	0.66	0.00	−0.839	0.336
Informed decision-making	8	7.91	0.94	0.00	−1.413	0.914
Significance of cost savings	8	8.84	1.37	0.50	−0.747	0.225
Significance of time savings	9	8.21	0.46	0.00	−1.125	0.937
Significance of quality assurance	8	8.63	0.81	0.50	−1.047	0.914
Attainment of customers' specific needs	9	8.05	0.33	0.50	−1.285	0.773
Timely communication of policy changes	9	7.89	1.05	0.00	−1.483	0.893
Stakeholders' perception of facilities performance	8	8.85	1.26	0.50	−0.893	0.736
Improvement in facilities' standards	9	8.75	1.09	0.00	−1.396	0.913
Economic utilisation of the facility	9	7.94	0.05	0.00	−0.667	0.224
Evaluation of existing trends	9	8.75	0.64	0.50	−1.381	0.091
Organisation's internal process improvement	8	8.92	1.07	0.50	−0.489	0.413
Attainment of future needs of the organisation	9	8.39	1.64	0.00	−0.735	0.925
Cronbach's alpha				0.817		

Source: Authors' compilation

Table 5.
Delphi round 2 results

significance of cost savings (mean = 8.84; IQD = 0.50); significance of quality assurance (mean = 8.63; IQD = 0.50); stakeholders' perception of facilities performance (mean = 8.85; IQD = 0.50); and organisation's internal process improvement (mean = 8.92; IQD = 0.50). Conversely, none of the performance measurement indicators was given to be of no significance in the determination of the espousal of CPS for FM activities. Moreover, all the performance measurement indicators attained consensus using the scale provided in Table 3. Furthermore, it is shown that the survey instrument for the Delphi process achieved high reliability with a Cronbach's alpha value of 0.817.

Discussion

The study assessed the influence of performance measurement indicators on the drive for the uptake of CPS in the delivery of FM tasks. Using the opinions given by a panel of experts for a Delphi study, it is shown that 11 of the identified indicators were proven to be of VHS, whereas 5 were shown to be of HS. Also, results indicate that consensus was achieved for all the identified performance indicators. The findings of this study is in tandem with the goal-setting theory which stipulates that organisations whose mandates are clearly outlined, exhaustive and realistic tend to deliver better in comparison with those whose objectives are easy, not specified and with no properly outlined goals (Young and Smith, 2013; Grünig and Kühn, 2015; Dubrin, 2012). Also, organisations must be attributed with the requisite capability, projection of specific goals and setting up the right framework for performance assessment (Latham, 2003). The determination of the measurement scales of the deliverables from the utilisation of innovative technologies is portrayed as a driver for the espousal of the system. In the delivery of FM mandates, the measurement of the performance from the used system is an important yardstick. This is affirmed by Hernandez-Ortega *et al.* (2014) and Phichitchaisopa and Naenna (2013) who noted that the measurement of the delivery mandates of a system would serve as a propelling factor for the use of the system. The incorporation of CPS for FM tasks is clearly proven to be upscale in the operations and services rendered in delivering FM mandates in

comparison to the traditional and conventional methods, thereby encouraging the adoption of the technological system. Moreover, the evaluation of the improvement of the deliveries of services would aid the drive for the espousal if the innovative technology. Similarly, the upgrade in a facility's standard because of the application of technological innovation poses viable grounds to push for its use. Because of the complex nature attributed to FM, approaches and methods that seek to proffer efficient and effective delivery in stipulated tasks would always be preferred. Hence, innovative systems such as CPS whose use offers better offerings because of its high computational capabilities would ultimately aid in achieving better service delivery in significant terms. Consequently, giving credence to the uptake of the system for FM functions and services. Legris *et al.* (2003) affirmed that the reduction in time on task delivery is a significant indicator in the assessment of the performance of a system. This is reflected in the outcome of this study which shows that significance in time savings resulting from the use of CPS for FM is very significant in the pursuit of its adoption. Generally, the pursuit of the uptake of digital technologies such as CPS for FM mandates is significantly influenced by the assessment of the performance to be accrued for the use of the system.

Conclusion

The study explored the influence of the performance measurement indicators that are influential to the uptake of CPS for FM using a Delphi approach. The review of extant literature unveiled 16 indicators which were presented to the panel of selected experts of the study for their opinions. The Delphi process entailed two iterations, while consensus was achieved in the second round on all the identified indicators. The result of the Delphi study portrayed that the indicators that were of VHS are built-in capability of facility adaptation, improved customer satisfaction, customers' involvement in improving the evaluation process, the significance of time savings, attainment of customers' specific needs, timely communication of policy changes, improvement in facilities' standards, economic utilisation of the facility, evaluation of existing trends and attainment of future needs of the organisation. Therefore, it is pertinent to note that the drive for inculcating digital technologies such as CPS for FM is significantly impacted by the assessment of the deliverables accruing from the use of the system. The findings from the study present a roadmap of the expected performance output and its accompanying evaluation that would drive the adoption of promising technologies such as CPS in the delivery of FM tasks. The study contributes practically by aiding policymakers, facility managers and relevant stakeholders with the vital knowledge of delivery mandates for efficient FM services that can spur the uptake of digital technologies such as CPS. Also, the study contributes immensely theoretically to the conversation on the use of technological systems for improved construction delivery and built asset management. Its findings can serve as a solid theoretical base for future studies on the improvement of FM with the use of innovative technologies. It is pertinent to note that a limitation of the study as with most Delphi studies is the participation of experts. Not all invited experts signified interest in the participation of the study. Maybe if all invited experts partook in the study, a different outcome would have been gotten. Also, future studies can engage in the validation of the findings of the current studies using other methodologies such as quantitative and mixed methods.

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