Stakeholders' Participation in University Campus Facilities Maintenance: An e-Maintenance Approach

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Abstract

Maintenance of university campuses in Nigeria is paramount because of its present appalling state. But its complexity in infrastructures makes its maintenance cumbersome and challenging to the stakeholders. To support these functions, recent innovations in information and communication technologies is needed to ease the maintenance functions. This paper, which is a preliminary part of a PhD thesis proposal, proposes an e-maintenance conceptual framework for the participation of all stakeholders in university campus facilities maintenance management. The e-maintenance, integrates the facilities maintenance management functions with web-services and modern e-collaboration principles. The collaborative environment allows information exchange and knowledge and e-intelligence sharing. The collaborative environment facilitates real-time information in order to enhance the quality of maintenance decision. The paper review the concept of e-maintenance and ICT devices, their integration to formulate a component suited for electronic facilities maintenance management (eFMM).

Keywords: Collaboration, e-maintenance, facilities maintenance, stakeholder's, university campus

Introduction

Evidence from previous studies have shown that organizational activities such as operations, marketing, management and maintenance were not always integrated or solely customer focused. Maintenance operations were usually inadequately planned and tracked due to poor communication [1]. Different digital technologies have been employed in the diverse capacity to enhance maintenance efficiency and effectiveness. Most of these digital technologies are standalone devices and lack the ability to share or disseminate information and intelligence they gathered to other devices and /or stakeholders. These incapacity hinders an optimal maintenance decisions making within an organization. Maintenance issues and processes are complex in nature and require an effective communication network for the optimization of the management of maintenance data and information. In recent times, new technological innovation has been integrated to form a robust framework for optimal maintenance decision

making. Development in the field of information communication technology and maintenance management strategies has led to the emergence of a new era of electronic maintenance termed "e-Maintenance".

Most studies on e-Maintenance are geared towards the mechanical and electrical fields (especially in the manufacturing sector). Little or no research has been focused on how the concept of e-maintenance can assist the Facility Manager in the decision making process of managing buildings and its auxiliary facilities. The complexity of managing maintenance information, and the inflexibility and dwindling maintenance budget have led to the continuous deterioration of physical assets, and hence, there is a need to annex maintenance functions. Therefore, Facility management (FM) sector needs an integrated facilities maintenance platform to coordinate their daily activities to meet customers or users related needs. In an organization with disparate infrastructures such as the universities, in managing their campuses, it will do better to employ a technology that will integrate their maintenance endeavor than the traditional maintenance approach in use.

The university campuses comprise of various facilities that aid the operations (learning and research) of the academic environment. These facilities support the activities of the students, staffs and the public in the school domain. The university physical estate as a property investment is a huge sum of money. In the study of Kotze and Nkado, the estimated value of the physical properties held by higher institutions in South Africa is worth 24 billion Rand (i.e. 2.33 billion US Dollar) [2]. Therefore, management of these assets in order to retain its physical, economic and social values throughout its life-cycle is important. Schools physical environment, particularly classroom facilities affects learning performance/outcomes and attendance of the students [3]. The purpose of educational facilities is paramount and its condition must be able to enhance the learning process since there is a connection between the quality and performance of facility services on the outcome of the education, teaching and learning process [4]. The questions now are;

I. What is the level of performance of these facilities and their impact on the user's productivity?
II. Is there any way the users can express their satisfaction of our comfort-ability within the envelope of the school environment?
III. Are the users' views or perception considered during maintenance priority setting?
IV. How can the executive management of the university be educated on the activities of the Facility Management (FM) department?
V. Can the government/university owner's be incorporated on the university asset management stream?
VI. How can the contribution of the stakeholders makes a change in future development and improvement of the existing infrastructures?
VII. How can a feedback loop be created between stakeholders and the FM department in improving maintainability?
VIII. Can there be a platform for the interaction between all stakeholders in the life-cycle management of university(ies) campuses.

Many questions bundle around the facilities maintenance management performance of institutional [5], [6], [7] and educational [8] buildings in Nigeria. The answers to these bothering questions require the application of an innovative technology that can marry all stakeholders' activities together in a collaborative environment. A collaborative environment that allows sharing, not only of data, but also of knowledge and e-intelligence, between all the stakeholders and throughout the product life cycle [1].

E-maintenance, what is it?

The basic debate on-going in the industry and academic fields about e-maintenance is its definition, concepts, framework and scope. Various researchers in the field considered "e-maintenance'' to a purpose which seems basically right. E-maintenance 'is defined as a subsystem of e-manufacturing or e-business in the form of an information network that integrates various concepts, applications, and tools' [1]. Also," e-maintenance is viewed as maintenance support which includes the resources, services and management necessary to enable proactive decision process execution. This support includes e-technologies (i.e. Information and Communication Technology (ICT), Web-based, tether-free, wireless, info-tronics technologies) and also, e-maintenance activities (operations or processes) such as e-monitoring, e-diagnosis, e-prognosis, and so on'' [9].

Further, "e-maintenance is defined as the part of maintenance support that ensures that the maintenance process is aligned with the operation and modification processes to obtain business objectives, through proper information logistics by information and communication technology (ICT) utilization and provision of information services. E-Maintenance might support different interconnected levels in an organization. One level might initiate the maintenance process to achieve a balance between operation and modification processes. Other levels might be support to the maintenance process and its actors and activities. Hence, its composition is highly dependent on, and is affected by, two major factors i) the view of the maintenance process and ii) the approach to ICT utilization" [10].

[11] defined e-maintenance in two abstraction levels. They describe "e-maintenance as maintenance managed and performed via computing in the first level". While "e-maintenance is defined as a multidisciplinary domain based on maintenance and information and communication technologies (ICT) ensuring that the e- maintenance services are aligned with the needs and business objectives of both customers and suppliers during the whole product lifecycle in the second level". Looking through all the e-maintenance definitions of this study, we propose a comprehensive definition for e- facilities maintenance management (eFMM): as an automated process of integrating the physical workplace or the environment with the people or users of that workplace / environment with its purpose and the facilities to enhance the productivity and comfortability of the people. eFMM can also be viewed as the integration of the principle of business administration, architecture, the behavioral and engineering sciences through e-technologies mean in an organization.

Previous developments and studies in e-maintenance domain

Various contributors in the domain of e-maintenance have proposed different frameworks for its applicability in industries most especially in the manufacturing sector that requires the optimal performance of machines and equipment to meet the business objectives. It is believed that production flow line must be sustained by avoiding the breakdown of machines and equipment. The e-maintenance approach is a proactive means to respond to maintenance necessity. A global architecture called ARIMA (Augmented Reality and Image processing in Maintenance Application) was developed in order to give solution to the technician during maintenance operations [12]. The ARIMA concept is based on the possibility to show the interactions that occur between different actors when Technicians intervene on the machine. Benbekacem, et al., Augmented Reality (AR) application allows the user to see computer generated virtual objects superimposed upon the real world through output devices. AR assist technician maintenance personnels to interact with the virtual world and may have access to extra information which might not be accessible directly from the work environment [12]. The idea is basically a relationship between the field men and the expert monitoring the maintenance tasks through instructions and intelligent transfer. The AR if applied to facilities repair, replacement and services will enhance the quality of maintenance output.

Another study proposed a novel e-maintenance framework, where existing maintenance knowhow is integrated with web-services and with the principles of enterprise collaboration for a small medium enterprise (SMEs) [13]. The e- maintenance system was also modeled as an intelligent system [14]. The proposed intelligent system framework merges computerized maintenance management system (CMMS) with the condition monitoring (CM) system. They agreed that an integrated arrangement is certainly more efficient and useful than one in which the various departments operate substantially independent information systems. They focused the research towards integration of diagnostic instrumentation to perform more effective and efficient maintenance. The framework enables the real time monitoring of equipment conditions and improves the quality of maintenance service provided by a specialized partner in the collaborative network [14].

An e-maintenance framework based on the hybrid system approach was also proposed [1]. The framework was developed to coordinate maintenance and logistic data, shared between different stakeholders throughout the life cycle of the system. The architectural platform of the hybrid e-maintenance system is based on automated data collection, supportability analysis, concurrent engineering, electronic data interchange and interactive electronic technical manual. [15] Work on a systemic approach to integrated e-maintenance of Large Engineering Plants (LEPs), where the framework for the LEPs integrate the rates and modes of failure of the equipment to be maintenance and the appropriateness of the condition monitoring arrangement. It also integrates expert opinion, domain expertise, both local and remote, optimization and prioritization of maintenance objectives leading to optimal decisions. An intelligence based conceptual framework based on the CogAff architecture of intelligent agents for e-maintenance was proposed by [16].

[17] Proposed an e-maintenance system that is dependent upon coordination, cooperation and negotiation through the use of internet and tether-free (i.e. Wireless, web, and so on) communication technologies. The system consists of two subsystems: maintenance center and local maintenance. They supported that the system enables manufacturing operations to achieve near-zero-downtime performance on a sharable, quick and convenient platform through integrating the existent advanced technologies with distributed sources. [18] considered a conceptual framework for e-Maintenance with an illustration by e-Maintenance technologies and platforms.

From the studies, it is obvious that e- maintenance framework allows a collaborative environment where information and intelligence can be shared between all stakeholders. E-maintenance's incorporation in facility management (FM) functions, in particular to the built-environment may reduce the challenges confronting the facilities maintenance practitioners' in decision making.

E-technologies application in maintenance functions

Various applications of innovative technologies have been applied to the field of facilities maintenance management. These applications were implemented to ease maintenance decision making. In a study, mobile technology was used as a medium for effective communication with field crews as a support for facilities maintenance management functions [19]. Also, [20] studied the integration of radio frequency identification and building information modeling for decentralized information management to support the distribution of technical specifications and progress monitoring of maintenance activities such as ambient interaction of maintenance personnel with building components [20].

Further, Geographical Information System (GIS) was applied to building maintenance of the 13th Asian Games Athlete Village at Thammasat University, Rangsit campus in Thailand [21]. Integration of Building Management System (BMS) and Facilities Management System (FMS) on the internet/intranet was developed by [22]. An agent-based software term Virtual Administrator System (VAS) for the small-scale maintenance of school buildings was introduced [23]. A framework for a more decentralized, web-based asset management (AM) system built on the existing computer integrated facilities management (CIFM) system at the University of Sydney's, Australia was proposed in [24]. Sabol [25] believed that building information modeling should be integrated with facility management functions.

A service oriented architecture for developing an enterprise networking environment that is used for integrating facility management applications and Building Management System (BMS) with other operations enterprise functions for the purpose of information sharing, monitoring and controlling, and managing the enterprise environment using web enabled wireless sensor networks was exploited [26].

The proposed decision support system (DSS) and e-facilities maintenance management (eFFM)

The proposed facilities maintenance management decision support system (DSS) is a modification and improvement of the building maintenance DSS proposed [27] as shown in Figure 1. Figure 1, only represent the DSS components and not the generality of the e-facilities maintenance management system. The objective of the proposed facilities maintenance management decision support system is to integrate all the activities involved in facilities maintenance management process in an educational institution. The proposed DSS includes information and digital technologies to enhance, the final outcome which leads to the development of a proposed e-facilities maintenance management (eFMM) framework. The proposed DSS/eFMM will assist facility/maintenance personnels in weighting and prioritizing maintenance operations, predicting maintenance budget, predicting the rate of deterioration of the components, selecting procurement methods, evaluation of the facility's performance in relation to users' needs, assisting maintenance operatives with maintenance, repair and replacement instructions, training and to detect faulty components and their location.

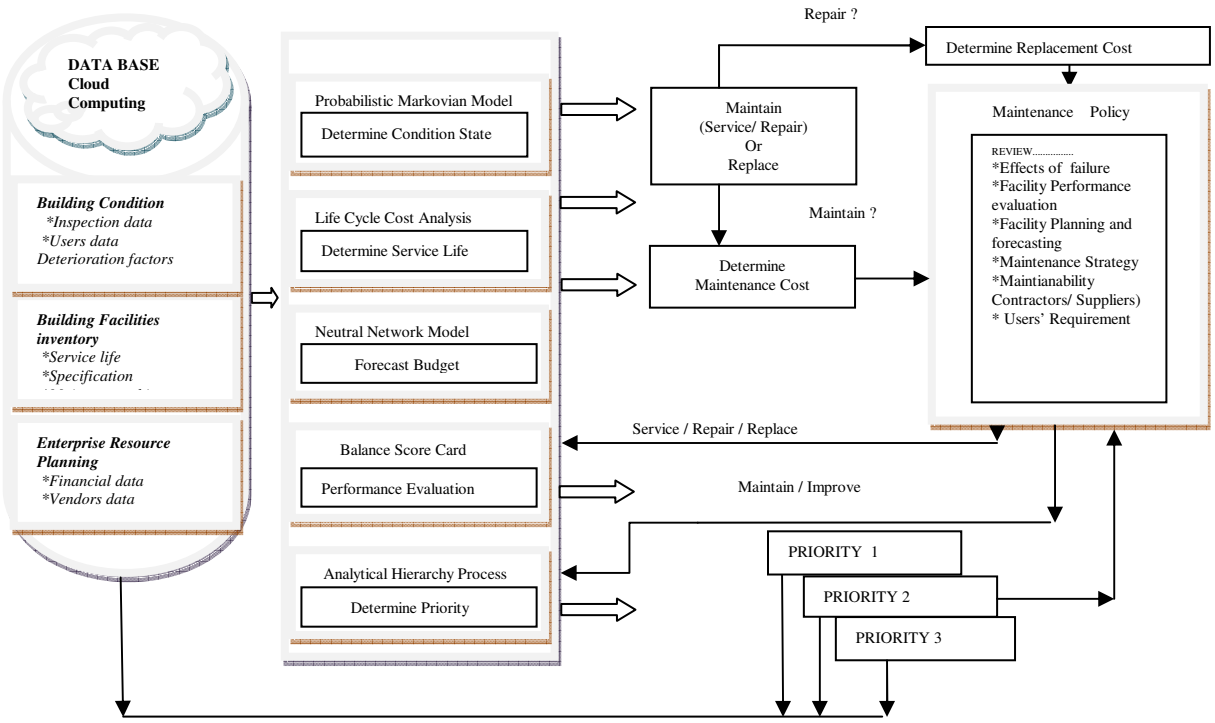

Figure 1: Conceptual framework of the proposed decision support system for facilities maintenance management

The eFMM must in all be able to create a collaborative network for all the stakeholders that share an interest in the facilities. The major stakeholders considered in the framework are the

varsity owners (major investor in the infrastructure), the institution management, the facility/maintenance department, the facility users (staffs and students), the maintenance contractors, suppliers/vendors, design and construction team and the public. The proposed framework can be implemented for improved facility performance in an educational institution, since it is believed that e-maintenance is an innovation that can be employed to improve support solutions in a global-support environment [28].

The conceptual design of the eFMM comprises the following:

I. A Decision Support System (DSS) module comprises a Probabilistic Markovian modelling to determine performance rates of a building component in different stages of its service life, a multi-criteria module that uses the analytical hierarchical process (AHP) method to determine the prioritization of maintenance operations and assess the relative importance of the maintenance budget for each facility under view and a Life Cycle Cost analysis module to determine the remaining service life of building component. In addition, a Neural Network module to predict maintenance budget estimation based on past maintenance historical data, expenditure, condition rating of facilities and service life data and also a Balance Score Card module use to evaluate the post-occupancy evaluation and facility performance of the building facilities based on user satisfaction survey is included.

II. A Computerized Maintenance Management system (CMMS) to automate the logistical functions performed by maintenance staff and management. A typical CMMS functions include: work order generation, prioritization, and tracking by equipment/component, historical tracking of all works generated which become sorted by equipment, date, person responding and so on, tracking of scheduled and unscheduled maintenance activities, storing of all technical documentation and maintenance procedures, complete parts and materials inventory control with automated reorder capability, real-time reports of ongoing work activity and so on.

III. A Condition Monitoring System (CM) accurately monitor real-time equipment performance and alert the maintenance professional to any changes in performance trends. The CM package might be able to track, including vibration, oil condition, temperature and humidity, luminaries, window blinds through sensor devices.

IV. A Building Management system (BMS) is an isolated computer system that can calculate the pre-set requirements of the building and control the connected plant to meet those needs. Its functions with connected sensors for input and output such as on/off signal connected into outstations around the building. The information is derived based on the outstation programmed mode, which determines the level of applied control. All the outstations are linked together for easy flow of information between the outstations. Also a modem is connected to the system to allow for remote access.

V. A Geographic Information System (GIS) is a system that is designed to capture, store, analysis, manipulate, edits, shares, integrate and displays geographic information for decision making in an organization. It is important because it able

to integrate disparate information from multiple sources. GIS application systems enable users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all the operations. GIS is applied in Facilities Management for locating underground pipes and cables, tracking energy use, planning facility maintenance, balancing loads in electrical installation networks, tracking water supply and distribution and so on.

VI. An Augmented Reality (AR) software architecture and Virtual Reality module to assist the stakeholders to share a real image in real time in a virtual environment;

VII. A Building Information Modelling (BIM) module that will assist in the virtual display of the building envelope environment.

VIII. Other digital technologies that are incorporated in the proposed framework are radio frequency identification (RFID), wireless and sensor devices, worldwide web and closed circuit television (CCTV) and so on. Robotics and intelligent schedulers have also been identified as monitoring devices.

Lung et al., [18], identifies various innovative technologies (hardware and /or software) needed to support e-Maintenance capacities as follows;

I. New sensors such as smart sensors like wireless sensors, sensor networks, memory cells, and so on.

II. Radio Frequency Identification (RFID) tag (passive and active; Radio Frequency Identification Device)

III. Global Positioning System (GPS) it is used to complement the purpose of RFID for locating the position of maintenance personnel, operators or maintenance tools.

IV. Wireless technologies employ for saving networking cost and flexibility that cannot be achieved in wired systems. Examples of wireless technologies are Wireless Personal Area Network, such as 802.11, 802.15.4 ZigBee, 802.15.1. Bluetooth; Wireless Local Area Network, such as WiFi, Worldwide Interoperability for Microwaves Access (WiMax); Global System for Mobile Communication (GSM) and Universal Mobile Telecommunications system (UMTS) for long distance.

V. Innovative communication equipment (virtual reality) for supporting man/machine or man/man exchanges (to speak, hear, see, touch, and feel).

VI. Tools for diagnostics and prognostics which allows developing an intelligent support to maintenance decision-making.

VII. Personal Digital Assistant (PDA), Smartphone's, Graphic tablets, harden laptops, and so on. The devices are equipped with WiFi, Bluetooth, RFID Reader, and Windows Mobile to develop more functions to aid operator on site.

VIII. Web services (for monitoring, diagnosis, prognosis, scheduling) are based on a set of protocols and technical standards (Internet-based technologies) used for exchanging data between applications within heterogeneous environments: SOAP (Simple Object Access Protocol) for message exchanging; WSDL (Web Service Description Language); Universal Description Discovery and Integration (UDDI) for referencing the web services, and so on

IX. Full Web-Computerized Maintenance Management System (e-CMMS) is a CMMS that is able to monitor and manage the preventive maintenance activities of the enterprise, but by offering new functionalities such as ASP (Application Service

Provider/Providing); links with mobile technologies for retrieving data, loading maintenance action; workflow module, and so on.

X. Specific standards for ensuring Integration and Interoperation issues between all the IT components to develop e-Maintenance solutions

The inclusion of the digital technologies in the proposed conceptual framework aids the DSS to function as an e-maintenance system that incorporates organizational management and the stakeholders together in a collaborative environment

DSS/eFFM implementation and integration

The DSS/eFFM development and implementation is vital to the FM sector, especially those in the university system. The DSS/eFMM at least must have required data in response to the maintenance activities / tasks such as building defects, vandalism, faults components, replacement and repairs, user's requisition, maintenance history and all the parameters such as contractor selection. Further, the system has the capability to show the appropriate maintenance strategies and maintenance decision, maintenance budget, maintenance cost and priority setting, contractor selection, user satisfaction evaluation base on data inputted.

The program is run with web server software such as Apache and windows server, and must have a continuous connection to the internet as shown in Fig. 2. Hypertext Preprocessor (PHP) and MySQL database is installed so that the program will be able to run effectively and all data can be uploaded in the database server. The site must be accessible from the world wide web at the domain address that it is being hosted from any location.

The framework considered the feedback from the stakeholders (especially the direct users) as input (stakeholder's requirement) to the organization to enhance decision making. The stakeholders can assess the performance and the condition of the facilities by direct observation or impact of the facilities on their performance and explore the available e-technologies like mobile phone, personal digital assistants (PDAs), internet and so on to send information to the platform networks of the CMMS which is linked with the DSS. The BMS, CM and the CMMS platform are interconnected to monitor building systems such as lighting, heating, ventilation and air conditioning systems (HVAC), plumbing, fire and security and so on, their information output is fed into the DSS for the use of the decision maker (DM).

The DSS aids the decision making of the facility manager. The maintenance personnel (technicians, field men, site crews) can also navigate the network systems. They collect, retrieve, share and receive information through the CM, RFID, sensor networks, GPS, PDA, virtual reality, e-CMMS and the DSS (see Figure 2). The DSS and the CMMS are the major platforms for the facility/maintenance management department and the vendors. The platform can coordinate contractor selection, tendering, project scheduling, feedback loop and so on.

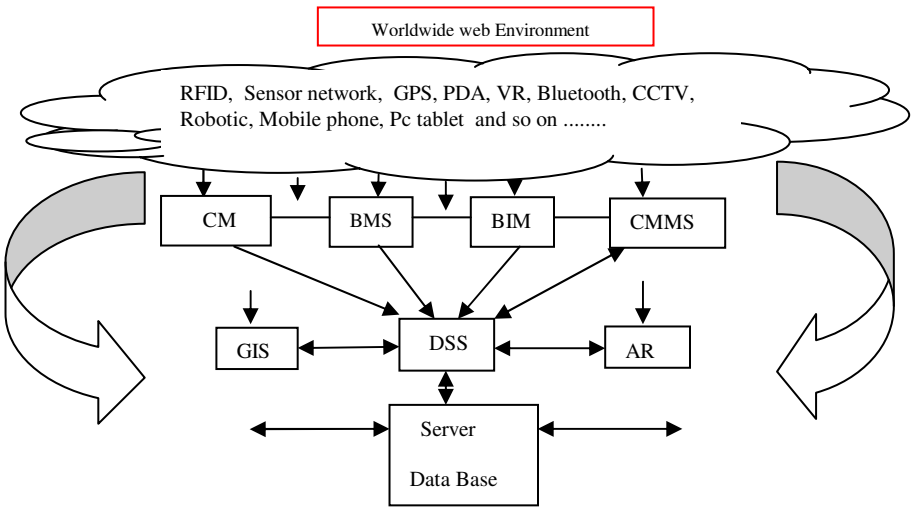

Figure 2: The proposed e-facilities maintenance management, web based interconnectivity

The other stakeholders can also connect to the web platform for the required information and intelligence sharing. Government or university owner can access the necessary platform for information, though caution in terms of security code will be required to limit unauthorized accessibility to a confidential site within the domains.

Management of any organization would depend on the consideration of the requirements of the stakeholders to enhance their performance and leverages and their activities in a competitive environment. This notion led to the proposed performance prism that adopts a stakeholder centric view of performance measurement [29]. The five facets of the performance prism are:

I. Stakeholder satisfaction: who are our key stakeholders and what do they want and need?
II. Strategics: what strategies do we have to put in place to satisfy the wants and needs of these key stakeholders?
III. Processes: what critical processes do we need to operate and enhance these processes?
IV. Capabilities: what capabilities do we need to operate and enhance these processes?
V. Stakeholder contribution: what contributions do we require from our stakeholders if we are to maintain and develop these capabilities.

Feedback and the consideration of the stakeholders' requirement creates a platform for capacity building within the organization [29]. These make the organization to be customer driven focus and increase the effectiveness and efficiency of the performance of their facilities. This study proposed a conceptual framework that comprises the university organizational culture, change management, stakeholder management, facility and maintenance management concept and strategies and e-technologies (see Figure 3)

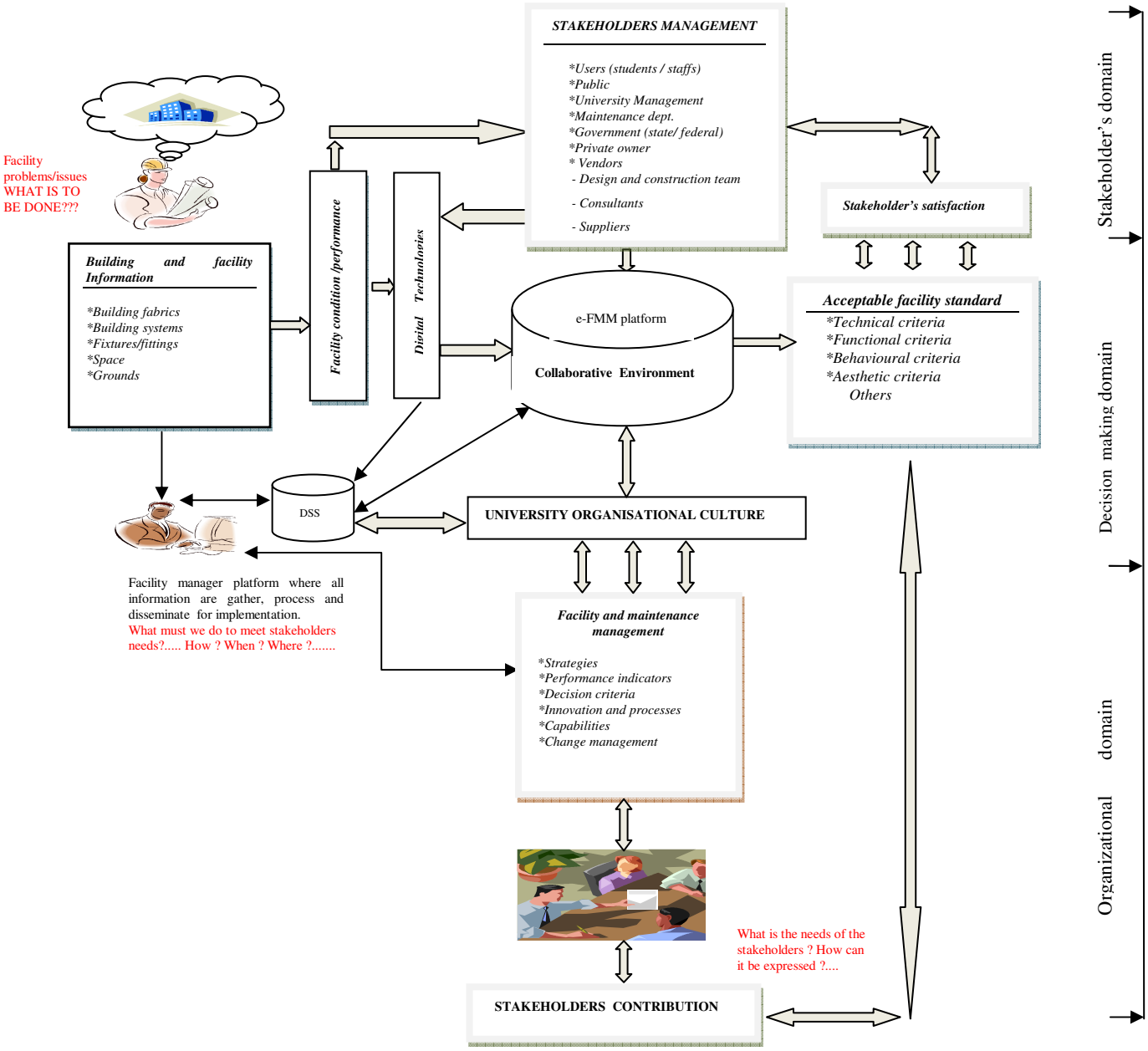

Figure 3: The proposed conceptual framework for stakeholder participation in University campus e- Facilities Maintenance Management.

The stakeholders' contribution is the driver of the framework. Organizational culture has a great influence on the activities and performance of any organization, it determines the process of achieving the vision, mission and objectives set by such organization. Stakeholder involvement in the decision process can shape organizational culture towards customer focus and driven orientation. In a competitive world an organization can only strive based on

customer recommendation. A functional school facility enhances the path of learning among the teachers and the students, and gives a competitive edge for university with adequate and functional facilities, and makes it the student's choice.

The e-facilities maintenance management domains

The proposed framework in Figure 3, is targeted to achieve organizational improvement through stakeholder's contribution. The framework is subdivided into three domains, the stakeholders, organizations and the decision domains. The organizational domain comprises the facility maintenance management functions of the organization. This domain is the central processing unit which composed of the three functional levels of the organization the strategic, tactical and operational levels of all the internal activities and the e maintenance processes within the system [16]. [16] The strategic level duty is to monitor, evaluate, and control other components of the architecture. Further, this level coordinates other modules to ensure the effective and efficient performance of the whole system. Also the level is saddled with the responsibility to assist the maintenance strategic managers. Its responsibilities span to maintenance contribution and interactive search for appropriate strategic goals and plans to maintenance activities within changing internal and external University environment Since the maintenance strategic managers function under risk and uncertainty that affect greatly maintenance decision the DSS assist the managers in making effective decisions. The tactical level relies solely on the assistance of a decision support system (DSS) for high performance and real time decision making for planning, reasoning, learning and problem solving [16]. The DSS is to address different issues such as resource control, scheduling, maintenance polices, knowledge management, change management, facilities evaluation and so on. The level is basic responsible for the interactive decision support towards tactical maintenance managers [16].

The stakeholders domain (internal and external environment) is the platform for all those with interest in the university campus and its environment in relation to maintenance. This involves the students, management, executive, functional and technical staff, human experts, vendors (contractors and consultants organization and suppliers), university operatives (public or private), and so on. An interactive environment is created among the stakeholders for a collaborative information sharing on the e maintenance platform using the various digital e-technologies devices. The environment enables the stakeholders to complete their tasks as an individual or as a team.

While the decision domain is the realm where all information and intelligence within the framework is shared and processed.This platform is responsible for providing the central processing unit with information based on data received from different environment sources [16] In the domain, data are to be processed in priority and categorized into segments to allow the central unit to assess the state of the environment and to make appropriate decision [16]. All the domains have its particular strength and limitation which is not considered yet in the study.

Conclusion

The proposed framework for e-maintenance is a collaborative network aimed at integrating stakeholders' participation in facilities maintenance management process. Improving facility's performance as indicated earlier can be achieved by optimizing the process. This optimization will be achieved through the contributions of the stakeholders to the maintenance decision making process of the university. As a result, university(ies) tend to imbibe a customer-driven culture that will change the maintenance strategies of educational organization and improve the quality of maintenance service provided which will give functional value to the stakeholders. Though the framework has not been validated but its employment in the university system in Nigeria is paramount, so as to minimize or eliminate the maintenance challenges faced daily in the facility management department.

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Biographies

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