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BUILDING DESIGNS AND PLUMBING FACILITIES: THE IMPLICATION FOR RISING MAINTENANCE COST

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ABSTRACT

The design of buildings plays a crucial role on how the structure/ facility would be utilized and maintained after completion of the project. The way the buildings are designed and maintained thereafter may determine the performance and fulfilment of client's objectives. However, there seems to be an inherent non-alignment between the building design and future maintenance of the building because design teams frequently neglect the consideration of maintenance aspects especially plumbing facilities. The study examined the influence of building design of plumbing facilities on rising maintenance cost. The questionnaire instrument data obtained were presented using stacked bar charts and Mann-Whitney U Test. The study revealed that the main cause of faulty designs of plumbing utilities in buildings was as a result of not involving plumbing engineers at the design stage. Non-consideration of maintenance of plumbing facilities at design stage pose high influence on design discrepancies resulting in rising maintenance cost. This can majorly be addressed by creating adequate and easy accessibility to plumbing facilities for maintenance purposes. It was noted that designers and maintenance experts are not in agreement on the causes of building design faults of plumbing utilities. It was recommended that proper attention be given to plumbing utilities that are designed for buildings through the integration of plumbing engineers at the design stage for plumbing services. Design agencies must ensure the use of experienced Designers whom should consider maintenance as a core activity at the design stage to actualize a more comprehensive design with contributions from other professionals in the built environment.

Keywords: Building Design, Building Life Cycle, Construction Industry, Maintenance Cost, Plumbing Facilities

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1. INTRODUCTION

Plumbing installations are generally concealed from view and run vertically within wall spaces and horizontally within floor and roof systems. They must therefore be carefully integrated within the building's form and physical elements to provide adequate accommodation for their components as well as visually coordinated outlets and points of access. Often, these systems will run parallel to one another in which case, close co-ordination between them becomes important. According to Ikpo (2009), the design and future repairs of mechanical and electrical fittings in buildings may ultimately determine how the building service systems perform. A well performing building is heavily dependent on the building services (Afolabi *et al.*, 2018). The users and occupants of the building use the building services on a daily basis, whereby, a breakdown of the services may hamper the worth of the structure. Tomasetti (2009) argued that the percentage allotted to building services is increasing compared to other structural and non-structural elements in the building. This cost is averaged at over one quarter of the final construction cost. This is evident in the increasing relevance placed on service facilities in terms of its cost price compared to the total cost plan in some specific buildings (COBRA, 2004). Any changes in the installation building services affects the scope of work and the overall final construction sum. In addition, COBRA (2004) noted that the quality of building services is affected when the periodic maintenance is neglected. According to Nwoye (1993), the efforts of the design and maintenance teams cannot be fully realized if the users of the equipment cannot effectively apply it, the part the users play should play includes maintaining conducive operational environment for the system, correct use of the control selection facilities on the equipment control centre and capability of offering valuable fault report. Ishak, Chohan and Ramly (2007) and Amusan *et al.* (2018) stated that when errors or omissions occur in building designs, it disrupts the follow of the spaces and can only be corrected by demolition. Chohan *et al.* (2011) argued that the percentage of maintenance can be greatly reduced when designs are properly carried out. In that these two (2) characters of building design and maintenance are negatively correlated whereby the more detailed a building design is, the lower the maintenance cost attached to the building and vice-versa. When building designs are poorly presented it can also affect the productivity of artisans such as plumbers, bricklayers, masons and so on (Fagbenle *et al.*, 2004; Fagbenle *et al.*, 2011). The Chartered Institute of Building (1982) stated the design stage can be used to positively influence the entire life cycle of the building including future maintenance. Hence, designers need to be aware and trained on the vast implication of their design decisions on the project lifecycle. Designers need to consider the safety of artisans that carry out maintenance works (Tunji-Olayeni *et al.*, 2018). For instance, services that are in enclosed spaces and at heights need to be given careful thought on the maintenance strategy to be carried out. Ishak *et al.* (2007) noted that in developing economies such as Nigeria, the subject of building maintenance is taking a central attention from researchers and practitioners. The issue is crucial for developing countries due to need to beef up the housing stock and therefore poor maintenance of existing structures can put more pressure on other future investment in the housing sector. Essentially, the study concentrated on plumbing facilities because of its strategic position in buildings. Some of the plumbing facilities are enclosed in walls, floors and other structural element. The relationship between plumbing works and water makes it a major concern in buildings. When there is any form of leakage in

plumbing facilities, prolonged water exposure to the building is detrimental to the structure which leads to defects in the building. For plumbing utilities that requires the passage of water through inlets and outlets, any fault in such amenities when not quickly attended to, can be damaging to the integrity of the structure. The designer needs to consider the consequences the choice of materials chosen, thermal movement, inadequate detailing and inadequate access to maintenance space can impose on their designs. In studying the influence of building design on maintenance cost of plumbing utilities, attempts will be made to clarify the following research questions:

- What are the causes of faulty designs of plumbing utilities in Buildings?
- What aspects of the design of plumbing utilities impact building maintenance cost?
- How can building designs of plumbing utilities be used to reduce building maintenance cost?

2. RESEARCH METHODS

This section outlines the procedure for conducting the inquiries into the study. The main instrument employed was a questionnaire which was administered to construction professionals. The research instrument was prepared and administered to professionals in different levels within design firms, facilities and maintenance management organizations with cognate knowledge on building design faults and maintenance cost of plumbing utilities. The structured questionnaires instruments were developed to collect data from the targeted group. The target respondents included Architects, Builders, Engineers, Estate valuers and Facility managers that are involved in the design and maintenance activities both in design and maintenance sections of their organizations. These people were selected purposively based on their knowledge of maintenance works and specifically towards plumbing utilities. Quota-purposive sampling method was used to select the sample size from the list of design firms and facility management agencies. For the research, a total sample of forty three (43) was drawn from these collections of design firms and facility management agencies of various categories in Lagos. The sample size was considered adequate for this research because the minimum number of respondents used for an unknown population for a study is thirty (30). The designed survey instrument consists of four (4) sections. Section ‘A’ sought background information on the personal characteristics of the construction professionals and including their industry experience. Section ‘B – D’ examined the objectives of the study. Questionnaires were distributed by hand to construction professionals involved in their various organizations. Personal visits and phone calls for proper follow up were made to their offices to deliver and also retrieve the questionnaires. The retrieved data was presented using mean scores which were transformed into stacked bars. The inferential statistic was measured using Mann Whitney U-test.

3. RESULT AND DISCUSSION OF FINDINGS

This section contained the analysis and findings of the objectives and the hypothesis tested. From the forty-three (43) questionnaires administered to the respondents, thirty-seven (37) was returned and thirty-five (35) was used for the analysis.

3.1. Characteristics of respondents

This section examined the respondent’s characteristics such as their professional background and working experience of the respondents. Figure 1 presented a summary of the respondent’s characteristics. Figure 1 showed that response was gotten from all the professionals involved in building design and hence their opinion would be useful on assessing the effect of building

design on maintenance cost of plumbing utilities. The breakdown of the construction professionals showed that 12 (34.3%) were estate surveyors, 11 (31.4%) accounts for architects, 6 (17.1%) were structural engineers, 3 (8.6%) were electrical engineers, 2 (5.7%) were builders and 1 (2.9%) of the sample were mechanical engineers. On working experience in the construction industry, 17 (48.6%) have within 1-10 years industry experience, 8 (22.9%) have 11-20 years industry experience, 6 (17.1%) with a working experience of 21-30 years while an equal proportion of 2 (5.7%) have an industry experience of 31-40 years and 41-50 years respectively. A cumulative of 71.5% of the construction professionals had an industry working experience of 1-20 years which suggest that they are qualified on examining the implication of rising maintenance cost from building designs and plumbing facilities.

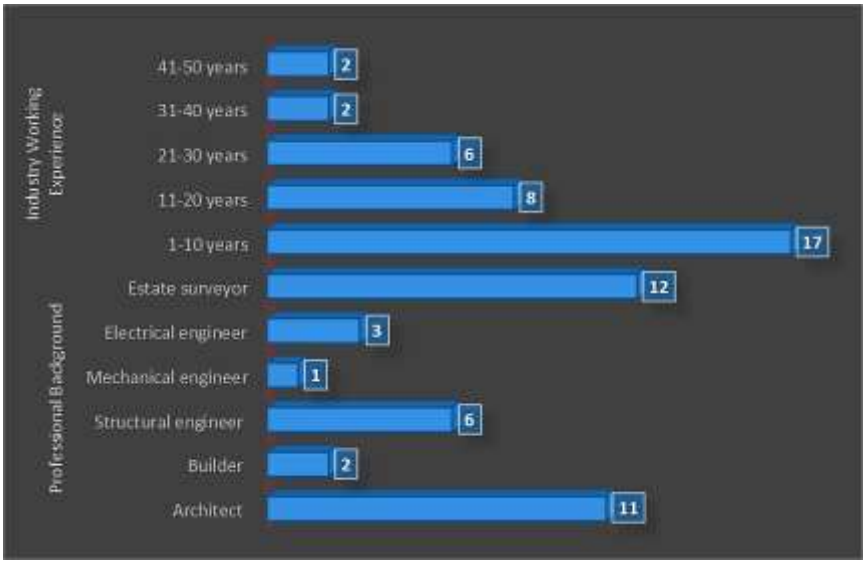

Figure 1 Respondents' Characteristics

3.2. Causes of faulty building designs of plumbing utilities

The construction professionals highlighted the causes of faulty building design of plumbing utilities and their response is presented in Figure 2. Figure 2 showed that the most significant cause of faulty building design of plumbing utilities are non-involvement of plumbing engineers at design stage (MS = 4.26), carelessness (MS = 4.14), non-consideration of build ability analysis (MS = 4.00), underestimating design load (MS = 3.97), inexperience of designer in plumbing details (MS = 3.89), lack of standardization (MS = 3.86) and incorrect selection of plumbing materials (MS = 3.80). While unsatisfactory detailing (MS = 3.74), communication gap among professionals (MS = 3.71), limited choice of materials (MS = 3.71), errors and omission (MS = 3.69), poor joint design (MS = 3.67), use of new materials which have not been tested (MS = 3.66) and failure of designer to appreciate how the structure is been used and maintained (MS = 3.63) are of moderate significance.

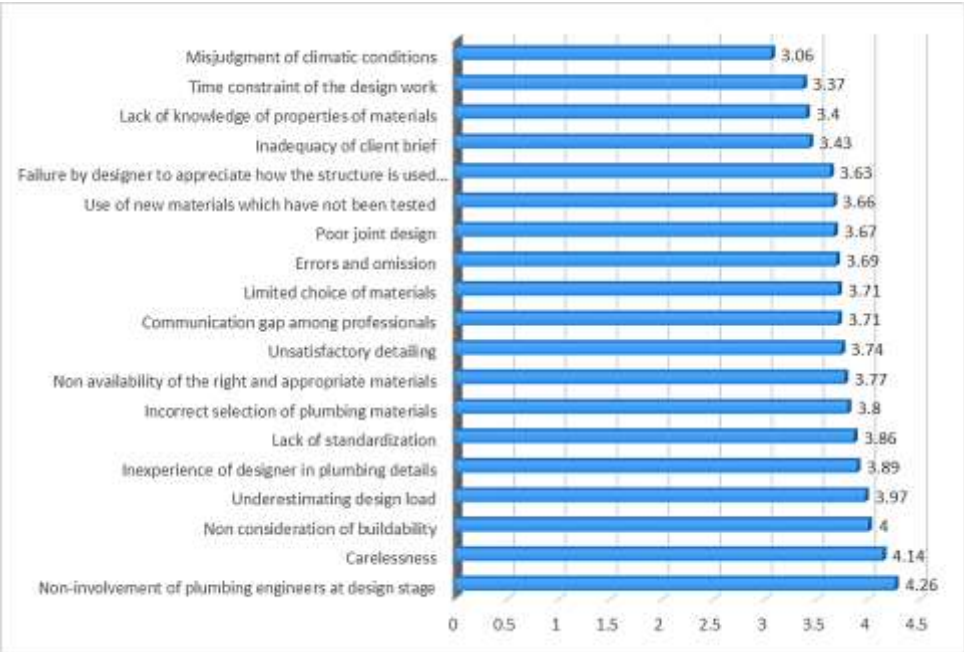

Figure 2 Causes of faulty building design of plumbing utilities

Lack of knowledge of properties of materials, time constraint of the design work and misjudgement of climatic conditions were ranked to have little significant effect of faulty design on plumbing utilities. It can be deduced from the outcome that causes of faulty building plumbing design is associated with the engineers or professional responsible for the design and not affected by external factors like client briefs, time constraints and weather conditions, which further suggest that the faults can be reduced and easily controlled as this can be termed human factors. Mohammed and Hassanain (2010) stated that the plumbing engineers with the plumbing utility information are meant to work in collaboration with the building designers. These plumbing engineers would be able to input their knowledge and industry experience in the design details. But, this has not been the case. There are less plumbing engineers in the construction industry. Most plumbing specialist available in Nigeria are artisans and do not have an educational background to understand the concept of design. Also, where there are plumbing engineers, designers fails to call for their contributions to reduce the maintenance cost that may arise from a defective installation.

3.3. Design discrepancies in plumbing facilities that influence rising maintenance cost

Apart from the human factors identified in the previous section as the main cause of faulty design in plumbing works, this section highlighted the nature of design discrepancies in plumbing facilities. Figure 3 presented the design discrepancies in plumbing facilities that influence rising maintenance cost. In Figure 3, non-consideration of maintenance at design stage (MS = 4.20) pose high influence on design discrepancies resulting in rising maintenance cost, followed by complexity of design (MS = 3.94), lack of work space for carrying out maintenance (MS = 3.91), inaccessibility to some elements and components for maintenance work (MS = 3.85), poor drainage layout (MS = 3.83), designing of permanent fixation of elements which needs continuous maintenance (MS = 3.80) and unrealistic design, frequent replacement and insufficient detailing (MS = 3.74). While poor design control, lack of personnel to carry out maintenance works (MS = 3.60), disruption of maintenance in building to carry out maintenance (MS = 3.54), inadequacy of technological knowhow to remedy defect and non-availability or scarcity of components to replace part (MS = 3.43) are rated by

the respondents to pose moderate influence on design discrepancies resulting in rising maintenance cost. The aspect of the design of plumbing utilities that influence rising maintenance cost most was assessed as non-consideration of maintenance at design stage. Iyagba (2005) stated that in the building lifecycle, the design stage and subsequent maintenance activities are essential to determining the efficiency and effectiveness the building facility. But, the findings in this study suggest that there is a neglect of maintenance procedures in the final design plan prepared by designers. Amairilla *et al.* (2002) explained that in the field of architecture, its primary function focuses more on the creation of new and inter-relationship of spaces without consideration for maintenance of the facilities created. There are cases where services have been placed at height or in enclosed spaces where it becomes difficult to access them. Some designers have ensured to provide grill spaces for the enclosure of plumbing services outside of the building facility.

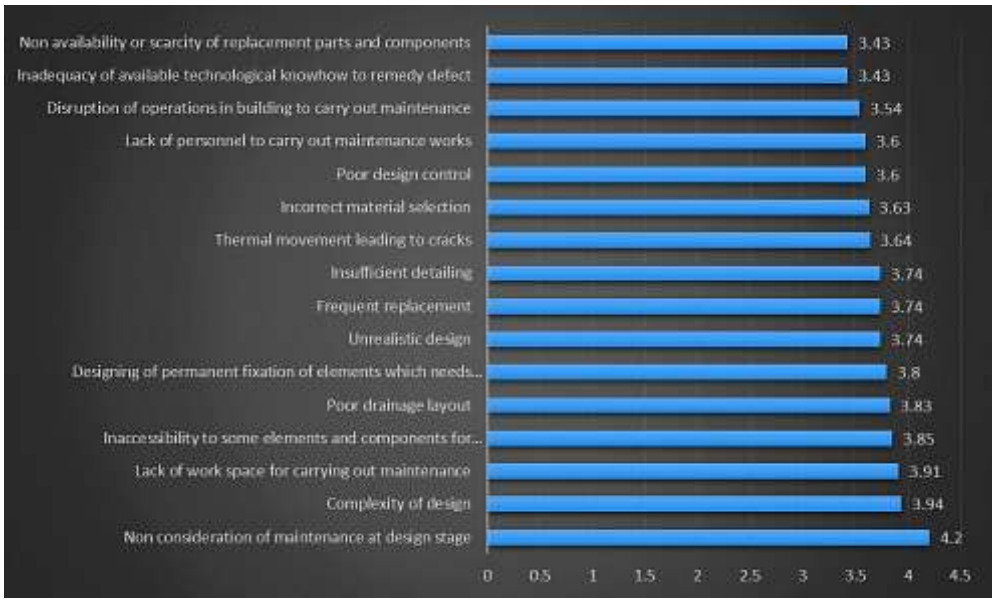

Figure 3 Design discrepancies in plumbing facilities that influence rising maintenance cost

3.4. Measures to minimize rising maintenance cost through building designs

Figure 4 showed minimization measures that can be achieved through building design of plumbing works in order to curtail rising maintenance cost. In Figure 4, seven factors were ranked as significant for minimizing building maintenance cost which are creating easy accessibility to plumbing utilities (MS = 4.37), good understanding of the construction management process, use of experienced and knowledgeable senior designers (MS = 4.34), prescribing acceptable standard materials (MS = 4.26), adequate drainage system layout design stage (MS = 4.23) and specifying readily available materials in plumbing design layout (MS = 4.00). In this study creating easy accessibility to plumbing facilities is the most important measure by which building designs of plumbing utilities can be used to reduce building maintenance cost. This is supported by Al-Arjani (1995), in that the plumbing services becomes hard to reach, thereby causing delay in carrying out the maintenance activity required. This in turn will lead to delay in the maintenance scope for the plumbing facility. The delay would result in a rise in the maintenance cost allocated for the maintenance of the plumbing facility (Ishak *et al.*, 2007). In addition, maintenance cost is affected where new access has to be created to carry out maintenance works such as breaking block walls, floors and other structural elements. Designers that are able to incorporate adequate access to plumbing services are such that have considered future maintenance in their design. Designers can also work in conjunction with professionals Builders who can prepare a buildability and

maintainability analysis of projects. Professional Builders are able to identify the flaws in designs and the maintenance prospect of such services before they are installed (Afolabi and Oyeyipo, 2017).

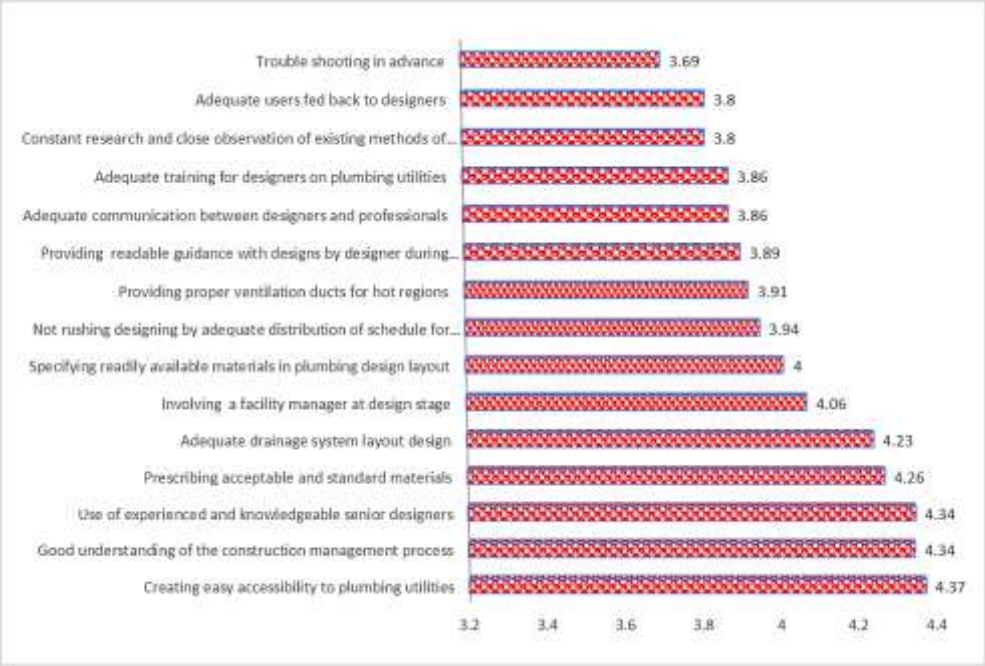

Figure 4 Measures to minimize rising maintenance cost through building designs

While constant research and close observation of existing methods of design, adequate users feedback to designers (MS = 3.80) and trouble shooting in advance (MS = 3.69) were rated has moderately significant.

Furthermore, the study tested a hypothesis to determine the significant difference among the groups on the causes of building design faults in plumbing works installations. H_0 represents the null hypothesis while H_1 represents the alternate hypothesis.

H_0: Construction professionals do not differ on the causes of building design faults in plumbing work installations.

H_1: Construction professionals differ on the causes of building design faults in plumbing work installations.

For this hypothesis, the construction professionals (grouping of designers and non-designers) were tested on the causes of building design faults in plumbing work installations. The analysis deployed the use of Mann-Whitney U test to carry out inferential investigation on difference among groups. The result of the analysis is presented as follows;

Table 1 Mann-Whitney U Test on building design faults in plumbing facilities

	Building design faults
Mann-Whitney U	78.700
Wilcoxon W	120.300
Z	-0.462
Asymp. Sig. (2-tailed)	0.618
Remark	Not Sig.

The outcome was achieved by computing the entire building design fault in the research instrument into a dummy variable as building design faults against the opinion of the construction professionals. Table 1 showed that there is significant difference among construction professionals on building design fault ($p > 0.05$ at 0.618; $Z = -0.462$). Hence, the

alternate hypothesis is accepted. The group tested consists of designers and those responsible for facilities management of the plumbing works. The study revealed that they had differing perception on the causes of building design faults in plumbing works. It is pertinent that designers ensure maintainability analysis in their designs so as to forestall the rising maintenance cost associated with plumbing works. Most building designs are created without considerations given to how the plumbing utility would be fixed when faulty. This has been found to increase the maintenance cost has in some cases there may be need to hack through structural elements to fix the defects in plumbing utilities. Some defective plumbing utilities have also been abandoned due to inaccessibility while new ones where created. It is therefore pertinent; to create easy accessibility to plumbing utility through innovative designs that would not reduce the aesthetics of the building. These innovative designs of plumbing utilities may still be concealed but must be easily accessible.

4. CONCLUSION AND RECOMMENDATION

The study examined the influence of building design on the rising maintenance cost of plumbing utilities. The study revealed that non-involvement of plumbing engineers at design stage was identified as the main cause of faulty designs of plumbing utilities in Buildings. The major aspect of the design of plumbing utilities that influence the rising maintenance cost was assessed as non-consideration of maintenance at design stage. It was identified that creating easy accessibility to plumbing utility is the most important measure by which building designs of plumbing utilities can be used to reduce the rising maintenance cost. Furthermore, the study showed that construction professionals differ on the causes of building design faults of plumbing utilities. It is recommended that proper attention needs to be given to plumbing utilities that are designed for buildings. There is need for framework to capture the plumbing engineers as a professional in the design team from inception. The plumbing engineer would be able to indicate maintenance solutions for designed plumbing services. Design agencies must ensure the use of experienced Designers to actualize a more comprehensive design which relates to other professionals even at the design stage. The use of young and inexperienced designers should be strongly controlled. There is need to consider buildability and maintainability analysis which requires a feasibility study carried out by the professional Builder to trouble shoot the design in such a way that it becomes clearer and workable. Finally, there is need for proper retraining of designers to understand the importance of considering maintenance from the inception of design. Designers need to be taught on issues of maintenance and incorporated in the curriculum of young designers from their tertiary institutions.

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