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Designing Buildings for Ease of Maintenance in the Caribbean

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Abstract: *Anecdotal evidence suggests that despite the fact that designing a building to make maintenance simpler can have a major impact on the building's life time and performance, there is still little attempt made to integrate maintainability into building design. As a result, this study was designed to test the hypothesis that maintenance is not considered during the design of large, multi-storey buildings in the Caribbean. To investigate this issue, a survey was conducted of 50 professionals involved on the design of such buildings. A questionnaire was designed to address various aspects of maintainability and design, including especially the areas in which the literature indicated that generated most maintenance related complaints from building owners and users. The findings reveal that the main areas where designers consider the impact of maintenance are in the specification of materials and of equipment selection and location. The findings were similar to those of a study conducted in the United States of America (USA) in 1999.*

Keywords: Design, maintenance, buildings, life-cycle costs, Caribbean

1. Introduction

The aim of this study was to determine whether maintenance is currently being considered at all during the design phase of large multi-storey buildings in the Caribbean and, if so by whom and when. It was also of interest to find out how designers account for future maintenance when they indicate that they do attempt to do so, to try to avoid 'false positives'. For example, an architect may choose a glass façade on a building rather than stone-work because it is easier to keep clean, but then not provide a gantry for the window cleaners' gondola. (Chew et al, 2004)

The study was based on a questionnaire that was administered to professionals and senior technical and administrative staff of architectural, M&E and structural engineering firms involved in the design, specifically, of multi-storey buildings in the Caribbean within the past five years. It was felt that these professionals were the ones with most input to building design, and so they were the ones, if any, who would be responsible for taking maintenance into account in the design. Although it would probably be good to take such issues into account at the Conceptual Design stage, the emphasis here is more on the Detailed Design stage as this is where it is felt that those involved can best understand the maintenance issues that may be arising, and take appropriate action. Because the study was concerned with current practices, the survey was limited to the experiences of the past five years. This was also felt to be the limit of reliability in the memory of those involved.

Some ten years ago a similar study was conducted in the USA as reported by Arditi and Nawakorawit (1999). The questionnaire used in this current study was derived from that one, because this meant that the results would be directly comparable, and would provide a baseline against which practices in the Caribbean could be measured. The attitude toward maintenance has traditionally been considered very lax in the Caribbean (Wall, 1993), and it was felt that this may have been reflected in design practices as well as in the conduct of the maintenance itself.

2. Background of the Study

The design life of a building ranges from 50 to 100 years depending on the structure's purpose (Dias, 2003). However, the building must be maintained properly to enjoy such a long effective life - and the easier it is to do the maintenance the more likely it is that it will be done. Building maintenance is defined as "work undertaken in order to keep, restore, or improve every part of the building, its services and surrounds, to currently accepted standards, and to sustain the utility and value of the building" (BSI, 1984).

Following from that, maintainability is "the relative ease and economy of time and resources with which an item can be retained in, or restored to, a specified condition when maintenance is performed by personnel

having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair" (DoD, 1997). In this context, it is a function of design. Thus, maintenance is, in theory, considered a characteristic of design which determines how easily and cheaply failures can be prevented or corrected (Al-Hammad and Assaf, 1997).

3. Building Maintenance

Maintenance is usually directed at features or systems within the building that enhance its aesthetic appeal or functionality. Because there are a large range of product alternatives for each, the designer is faced with a difficult choice on many different grounds, such as cost, durability, storage needs, maintenance requirements, appearance, availability and the contractor's familiarity with that product/material. Often a trade-off has to be made between the conflicting characteristics of different building elements or systems, and between initial capital cost and longer term operational costs (Wu et al., 2006). A building is a product, so to emphasise the message, "Minimising the cost to support a product and maximising the availability of that product are best done by designing the product to be reliable and maintainable" (DoD, 1997).

Schrag et al. (2007) suggested that the integration of maintenance in design requires: meaningful dialogue between the stakeholders, maintenance related training for designers, design review by the maintenance group, and input and review of design drawings and specifications by maintenance personnel. This is not easily achieved early in the design of a building, and helps explain why maintenance is not often factored into design. It also highlights the importance of training the designers so that they know how to take maintenance into account. This is a feature that is lacking from all of the undergraduate civil engineering and architecture programmes that have been checked, and it is not a common feature of postgraduate programmes. It is certainly missing from the programmes currently on offer in the Caribbean. In the circumstances it would seem appropriate for maintenance issues to be addressed by having the facilities manager involved in the design process by the time that detailed design is being undertaken, and that regular reviews should take place to ensure that design development has not resulted in compromises to maintenance related features that have already been specified and detailed.

Clearly, planned maintenance can be minimised and simplified if appropriate (durable) materials are selected during design, if the future use of the building is considered, if access is provided for maintenance and if the overall life-cycle costs are considered during design (Chudley, 1981). Each of these would normally be addressed independently by separate professionals, but rarely in a concerted, coordinated way, and as such may compromise one another.

In highlighting the importance of maintenance it is obviously recognised that this is only one factor that should be considered during design. The companion study by Arditi and Nawakorawit (1999) on which this one was based, considered a variety of factors that are important to design, which were grouped into five categories: Safety, Design Quality, Building User Comfort, Building Services as well as Maintenance (see Table 1). Because the other factors are known to be currently reasonably well addressed in the design process, whereas maintenance is less likely to be so, the focus here was confined to that.

Table 1. Building Design Factors

Category	*Design Factor*
1. Safety	• Fire protection • Structural constraints • Construction methods • Security
2. Design Quality	• Functional layout • Choice of equipment • Choice of materials
3. Maintenance	• Ease of cleaning • Ease of repair/replacement • Access to cleaning area
4. Building User Comfort	• Air circulation • Indoor air quality • Humidity control • Lighting • Heat loss/heat gain • Human traffic • Vertical transportation • Noise protection
5. Building Services	• Clean water supply • Wastewater disposal • Garbage disposal • Telecommunications

4. The Survey

The questionnaire used to conduct this research was based on the study in the USA by Arditi and Nawakorawit (1999). Because e-mailed questionnaires normally elicit a poor response rate, it was decided to email an advance copy of the questionnaire to the chosen participants, so that they would know what the survey was about and be prepared before following up with face-to-face interviews. The sample population for this research consisted of architects and structural engineers employed by established firms in Barbados and Trinidad. The number of questionnaires distributed and the response rates were as shown in Table 2.

Table 2. Response rate of questionnaires

Method	No. Distributed	No. of Responses	Response Rate
Face-to face	17	17	100%
Email	33	13	39%
Total	50	30	60%

The total number of usable responses was 30, which was the limit of acceptability based on the central limit theorem. This states that the sample size at which the sample mean becomes approximately normal depends on the size of the sample population, but that the mean is approximately normal once the sample size is above 30. Therefore, although the sample is small, it is sufficient to provide results that are statistically significant (Stephens, 2006).

Descriptive statistics were used to elaborate on the main features of the data and inferential statistics were used to draw conclusions beyond what the immediate data showed (Donnelly and Trochim, 2007). The one-sample *t*-test in the Statistical Package for the Social Sciences (SPSS) was used to compare the means of the different variables for this study with those of the research conducted in the USA (test value).

4.1 The results

All of the individuals involved in this survey work for firms that are considered 'small' in that they have less than 51 full-time members of staff - 20% have less than 10 full time employees and 80% have between 11 and 50. Half of these firms have been in existence for more than 40 years, while 20% have been in business for 20-40 years and 30% for less than 20 years. By comparison, almost all of the design firms in the study done in the USA (Arditi and Nawakorawit, 1999) were large and employed more than 100 full time employees, though the typical lifespan of a company was similar to the Caribbean sample.

The principal service offered by these firms covered a wide range of categories as shown in Table 3. The principal source of work was the private sector (i.e., 54%) with 28% of this from private owners, 24% from developers and 2% from architectural firms. The remaining 46% of the work comes from government organisations (including 2% from the military). The distribution of building types was as shown in Figure 1.

Table 3. Services offered by designers' firms

Services	Percentage of designers
Engineering design	28%
Architectural design	20%
Interior design	16%
Urban design	12%
Project Management	12%
Landscape	6%
Building equipment design	2%
Town Planning	1%
Geotechnical engineering	1%
Condition surveys	1%
Consultancy	1%

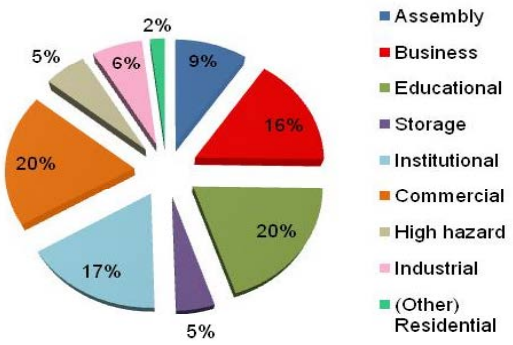

Figure 1. Major building types designed in the Caribbean within the past 5 years

4.2 Selecting building materials and equipment

43% of the designers believe that maintenance should be considered in the conceptual design stage, 30% during schematic design, 20% during preliminary design, and 7% believe it can be left until the final design stage. The USA study showed that designers believe that maintenance can be considered one stage later than those in the Caribbean - the schematic as opposed to conceptual stage - but both groups agree that maintenance input is most valuable early in the design process.

Designers in the Caribbean considered cost to be the most important criterion when selecting building materials and equipment followed by maintenance, availability and then aesthetics. The results were not statistically different from those reported for firms in the USA except that availability and aesthetics were transposed. This was probably due to the fact that in a large economy like the USA, availability is normally not an issue, whilst it would be much more important in a small island developing country where shipping and importation can be major drawbacks. The results are illustrated in Figure 2.

When asked to rank the factors that were considered most important in building design the Caribbean designers were rather more different from their US counterparts (see Figure 3). Perhaps the biggest difference was the emphasis placed on "Functional Layout" as the number one factor in the USA with "Fire Protection" second while "Fire Protection" was number one in the Caribbean and "Functional Layout" was fifth. The difference in ranking of importance may have a cultural explanation.

There is a long history of major fires in the capitals of the Caribbean islands, and there is an instinctive aversion to it happening again. In addition, it is suggested that their relative lack of concern for the functionality of the layout may be due to the fact that the building owners often do not have a clear idea of how the building will be used. It is not very unusual to find that a large, multi-storey building in a prime area of downtown Port of Spain may remain without partitions,

furniture or fittings for six months or more after structural completion. By the same token, in this study, "Wastewater disposal" and a "Clean water supply" came in third and fourth in importance – reflecting concern over the inefficiencies of the water supply and disposal infrastructure, and an attempt to take account of this in new buildings. In the USA, the relative comfort over the availability of these services resulted in designers putting them down in 14th and 13th positions respectively. In the USA study, 10 out of the 22 factors were considered "very important", whilst in the Caribbean 15 factors were rated "very important". In neither case, however, did the designers choose factors described as being maintenance-related (e.g. 'ease of cleaning') as being "very important".

Given that future maintenance will usually be done by a facility manager it is probably unfortunate that only 38% of the designers indicated that they "always" receive input from the future managers of the buildings they design. A further 35% "often" received input, 24% "sometimes" and 3% "seldom".

Figure 2. Criteria used by Caribbean designers when selecting materials and equipment

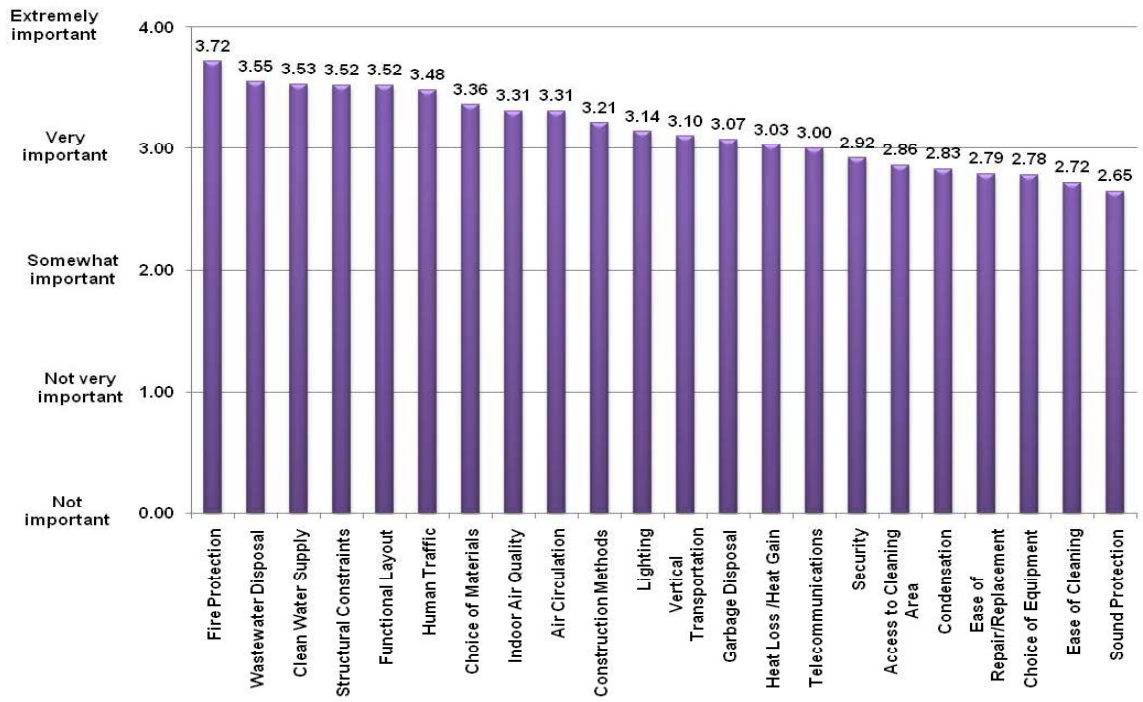

Figure 3. Factors considered by designers in designing buildings in order of importance

On the other hand, it is reassuring that 70% of these designers consider maintenance during the design stage of all projects, while 27% consider it on "some" projects and only 3% never consider maintenance. These figures are surprisingly high given the traditional lack of attention to maintenance in the region, but it is possibly in response to that very expectation - that there would be a lack of maintenance - that architects and engineers take it into account in their designs, and try to minimise the need.

An open ended question on what designers do to ease maintenance in buildings brought a wide variety of responses including such things as:

- Selecting low maintenance/durable materials and equipment (41%);
- Ensuring that access is provided to building components (16%);
- Ensuring skilled maintenance personnel are available (14%);
- Carefully laying out building components (14%);
- Accounting for present and future use of the building (5%);
- Ensuring replacement parts are available (4%);
- Basing design on life-cycle costing (4%);
- Using modular designs (2%)

When asked about the most difficult building components to clean, inspect, repair and replace, the Caribbean responses were similar to those received in the US study, with only minor differences. The findings are presented in Figure 4, and summarised in Table 3. The roof is an area of particular concern in the Caribbean despite the fact that there is never a need to worry about winter weather and snow loads, but it may be a sensitive issue because of the large number of buildings that have a flat concrete roof that leaks, or that is very noisy during tropical storms or allows significant heat gain in direct sunshine (see also Wall (1993)).

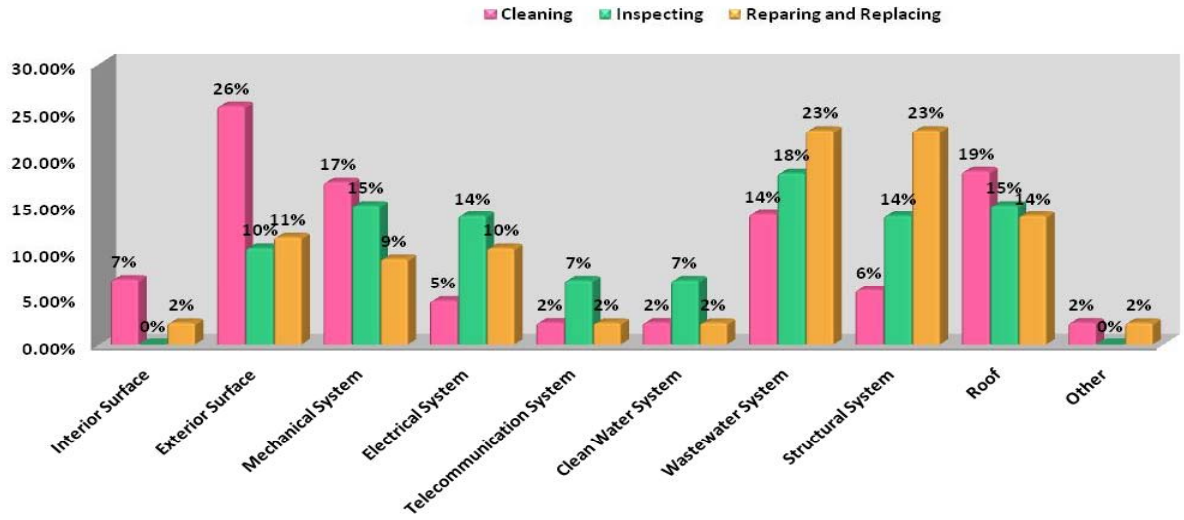

Figure 4. Difficulty of cleaning, inspecting, and repairing and replacing building components

Table 3. Most difficult building components to clean, inspect, repair and replace

Clean	Inspect	Repair and Replace
1. Exterior Surface	1. Mechanical System	1. Wastewater System
2. Mechanical System	2. Wastewater System	2. Structural System
3. Roof	3. Roof	3. Roof

Figure 5 shows the ranking of factors which were felt to affect the ease of maintenance of a building. These would be the areas that the designers would focus on when looking to improve or ease maintainability.

Despite the high nominal importance placed on maintenance, however, only 10% of the designers "often" attended related training, 63% "sometimes" and 27% "rarely" attended training. This may help to explain why there is "a dearth of knowledge of the specific impact of upstream design and construction decisions and choices on the downstream preservation, operation, and maintenance of building structures and fabrics" (Ilozor, 2008)

Figure 6 shows the frequency of complaints received from building users that were related to maintenance issues. Only 4% of the architects and engineers indicated that they "never" got complaints. When asked specifically about complaints relating to buildings they had designed, 7% said "some" of the buildings had had complaints, 56% said a "few" of their

buildings and 37% said that "none" of their buildings had had complaints. The US professionals reported similarly.

The full results of the survey have not been included here, nor the details of all of the various statistical tests carried out, these have only been mentioned where it was deemed relevant.

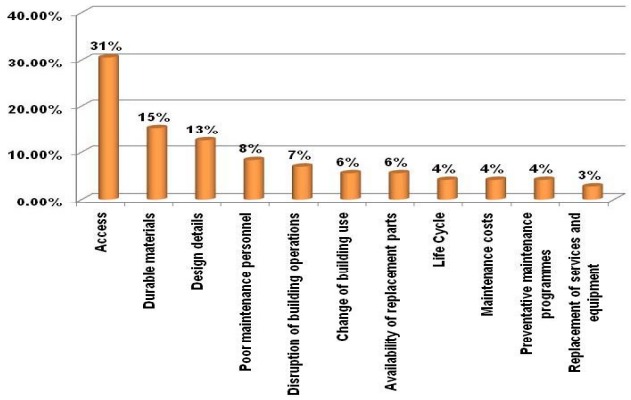

Figure 5. Factors which affect ease of building maintenance

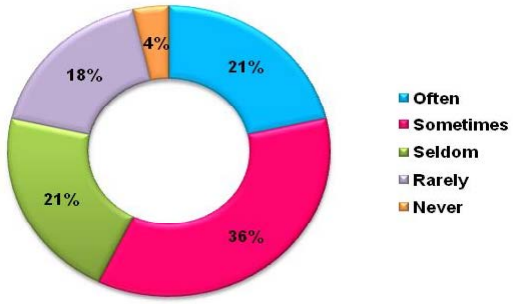

Figure 6. Frequency of maintenance related complaints received by designers

5. Conclusion

Despite the feeling that cultural and climatic differences would have a significant impact on the maintenance issues, this was not really the case. The results of this limited survey of two Caribbean islands compared quite closely with the US survey. A statistical analysis of the similarity of the results was not included. Although most of the professionals indicated that they do consider maintenance at the design stage, they subsequently give a low rank to such maintenance factors as; ease of repair and replacement, access to cleaning area and ease of cleaning. This may be influenced by the fact that maintenance related training is not seen as a priority by firms when training designers. The results of this survey suggest that there is a need to get more detailed information on how professionals design for improved maintainability, and also suggested that there is a need for supplemental maintenance related training for design professionals. Improving maintainability through design could have major benefits for the Caribbean.

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