Implementing Innovative Ideas in Structural Engineering and Project Management
Edited by Saha, S., Zhang, Y., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-1-7

DEVELOPMENT OF MAINTENANCE MANAGEMENT STANDARDS FOR FACILITIES OF LARGE PUBLIC ORGANIZATIONS

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Saudi Arabia is undergoing substantial growth in many sectors of the economy. This growth is evident mainly in the construction industry, through the development of several types of large facilities. Such facilities require comprehensive maintenance to keep them in operational condition, as originally designed. This study aims to develop maintenance management standards for facilities of large public organizations in Saudi Arabia. The methodology used to achieve the aim of this study involves two tasks. The first is to identify the quality criteria that could be included in the developed standards. This task entails a review of literature review and interviews with maintenance professionals. The second task comprises an assessment of the identified quality criteria by 40 maintenance professionals. Based on the results of the study, the standards have been developed, which include 20 measurable quality criteria, classified under four categories, namely technical, functional, behavioral and managerial.

Keywords: Saudi Arabia, Maintenance and management standards criteria, Assessment.

1 INTRODUCTION

Saudi Arabia is witnessing unprecedented development in many aspects. Most of which is realized in the construction industry, through the construction of several types of large facilities. These large facilities require extensive maintenance programs to preserve them in running conditions as were originally intended. This study seeks to develop maintenance management standards for facilities of large public organizations in Saudi Arabia. The methodology adopted in this research consists of two parts. The first employs the holistic system approach to maintenance to identify quality criteria for incorporation in the developed standards. This part uses ISO 9001:2000 standards, literature review, and a series of interviews with maintenance experts. The second part involves the assessment of the identified quality criteria through conducting a survey of experts in the maintenance of large public organizations. Based on the results obtained from the assessment, the standards have been developed. These standards can be applied to facilities of large public organizations in Saudi Arabia to assure their long-term protection and preservation, ensure a safe and healthy environment for users, mitigate the deterioration of existing and future public building facilities, and facilitate

the efficient use of government funds in support of facilities. The significance of this study stems from the non-availability of maintenance standards in Saudi Arabia, saving the value of the investment in public facilities, providing high level of user satisfaction for these facilities, and providing healthy and safe environment to improve productivity.

2 THE IDENTIFIED QUALITY CRITERIA

Twenty measurable quality criteria were identified based on literature review. These were classified into four major categories, namely technical, functional, behavioral and managerial, based on the common purpose among the criteria. Each of the 20 criteria has several elements (clauses). The total number of elements is 62. All these elements are potential clauses in the standards to be developed.

2.1 Technical Category

This category focuses on aspects dealing with the performance of the technical systems in the building (Preiser *et al.* 1988). There are nine criteria in this category:

- Thermal Comfort: "the state of mind that expresses satisfaction with the surrounding environment" (ASHRAE Standard - 55 2004). This criterion has two elements (clauses), namely:
    - Provision of comfortable temperatures during (i) summer, and (ii) winter, in all spaces.

Similarly, all other criteria have elements (clauses) that could not be presented due to limitation on the number of pages.

- Acoustical Comfort: "providing acoustic conditions in a building that facilitate clear communication of speech between the users of the building" (Steskens and Loomans 2010).
- Visual Comfort: "represents a positive or neutral user/occupant evaluation of the lighting conditions in a space" (ISDG 2009).
- Indoor Air Quality: "air in which there are no known contaminants at harmful concentrations" (ASHRAE Standard - 62.1 2007).
- Safety and Security: "the control of recognized hazards to achieve an acceptable level of risk" (ISECOM 2013).
- Cleanness: "both the abstract state of being clean and free from dirt, and the process of achieving and maintaining that state" (Cleanliness 2015).
- Maintaining Landscaping: "any activity that modifies the visible features of an area of land" (Landscaping 2015).
- Maintaining Structural Systems: "regular maintenance of the structure of building, including walls, floors, roofs, windows, doors, sanitary fittings and plumbing, drains, fire escapes, yard, roads and cleaning, and restoration of elevation" (Crips1984).

- Mechanical, Electrical and Plumbing Systems: maintenance activities that improve the operation of mechanical, electrical and plumbing systems.

2.2 Functional Category

This category deals with providing support for the activities conducted within the building. These criteria must be responsive to the specific requirements of the organization and the users, both quantitatively and qualitatively (Preiser *et al*. 1988). There are four criteria in this category:

- Human Factors: "factors concerned with the dimensions and configurations of the designed environment, often the near environment, to match building occupants' physiological needs and physical dimensions" (Preiser *et al*.1988).
- Storage: "the act of storing goods or the state of being stored'' (Storage 2015).
- Space layout and Furniture Quality: "the process of establishing, sizing, and locating the appropriate production and support activities within a new or existing structure" (Fink 1992).
- Accessibility and Parking Space: "ease with which a facility or location can be reached from other locations" (Accessibility 2015).

2.3 Behavioral Category

This category focuses on criteria that "deal with the perceptions and psychological needs of the building users and how they interact with the facility image and environmental perception" (Preiser *et al*. 1988). This category includes one criterion:

- Image and Environmental Perception: "the significant effect of the building design on their occupants or visitors perception" (Preiser *et al*. 1988).

2.4 Managerial Category

This category focuses on the administrative actions for the execution of maintenance work (BS 3811:1993). There are six criteria in this category:

- Maintenance Strategy: "a long-term plan, covering all aspects of maintenance management which sets the direction for maintenance management, and contains firm action plans for achieving a desired future state for the maintenance function" (Maintenance Strategy 2015).
- Management Responsibilities: "different task of top management that provide evidence of its commitment to the development and implementation of the QMS and continually improving its effectiveness" (ISO 9001 2008).
- Resource Management: "the process of using a company's resources in the most efficient way possible. These resources can include tangible resources such as goods and equipment, financial resources, and labor resources such as employees" (http://www.businessdictionary).

- Service Realizations: "plan and develop the processes needed for service realization" (ISO 9001 2008).
- Measurement, Analysis and Improvement: "plan and implement the monitoring, measurement, analysis and improvement processes needed" (ISO 9001 2008).
- Maintenance Financing: "the variable sum based on the costs of some primary activity or replacement value, or taken from fixed sum based on historic costs or an analysis of anticipated benefits" (Lee 1991).

3 METHODOLOGY OF THE STUDY

Upon developing the identified quality criteria, a questionnaire survey was developed to assess their importance. The survey was filled out by a randomly selected sample of 40 professionals (11.7% as maintenance managers, 16.5% as facilities managers, and 71.8% as architects/engineers). The respondents' experience ranged from 5-20 years in the relevant domains. Respondents were asked to mark their perceived relative degree of importance for each of the identified quality criteria through selecting one of five evaluation terms. Based on the response to the survey, importance indices were calculated to reflect the level of importance of these quality criteria. The importance index was calculated as follows (Dominowski, 1980):

$$\text{Importance Index (I)} = [\ \sum (a_i)(x_i) / 5\sum x_i\ ] \times 100\% \quad (1)$$

where: i = Response category index where i= 1, 2, 3, 4, 5; a_i = Wight given to i response where i= 1, 2, 3, 4, 5; and X_i = variable expressing the frequency of i as illustrated in the following: X_1 = frequency of "Extremely Important" response corresponding to $a_0 = 5$; X_2 = frequency of "Very Important" response corresponding to $a_1 = 4$; X_3 = frequency of "Important" response corresponding to $a_2 = 3$; X_4 = frequency of "Somewhat Important" response corresponding to $a_3 = 2$; X_5 = frequency of "Not Important" response corresponding to $a_4 = 1$.

To reflect the scale of the respondents' answers to the questionnaire, the importance index is classified as follows: 0 <12.5% is categorized as ''Extremely Not Important'' (ENI); 12.5 –<37.5% is categorized as ''Not Important'' (NI); 37.5 –<62.5% is categorized as ''Moderately Important'' (MI); 62.5 –<87.5% is categorized as ''Important'' (I); and 87.5 –100% is categorized as ''Extremely Important'' (EI).

4 ASSESSMENT OF THE IDENTIFIED CRITERIA

Tables 1-4 present the results of the assessment of the quality criteria. Table 1 shows that the overall scores for the criteria in the technical category range from 78% (I) for the landscaping criterion to 90% (EI) for the mechanical, electrical and plumbing systems criterion. Therefore, all the criteria in this category will be included in the developed standards.

Table 2 shows that the overall scores for the criteria in the functional category range from 78% (I) for the accessibility and parking space criterion to 86% (I) for the human factors criterion. Therefore, all the criteria in this category will be included in the developed standards.

Table 1. Overall average scores for the technical category.

No.	Technical Category	E(X)	Importance Index (%)	MR
1.	Thermal Comfort	4.4	88.0	EI
2.	Acoustical Comfort	4.0	80.0	I
3.	Visual Comfort	4.2	84.0	I
4.	Indoor Air Quality	4.2	84.0	I
5.	Safety and Security	4.3	86.0	I
6.	Cleanness	4.3	86.0	I
7.	Landscaping	3.9	78.0	I
8.	Structural Systems	4.4	88.0	EI
9.	Mechanical, Electrical and Plumbing Systems	4.5	90.0	EI

Table 2. Overall average scores for the functional category.

No.	Functional Category	E(X)	Importance Index (%)	MR
1.	Human Factors	4.3	86.0	I
2.	Storage	4.0	80.0	I
3.	Space Layout and Furniture Quality	4.1	82.0	I
4.	Accessibility and Parking Space	3.9	78.0	I

Table 3 shows that the overall score for the only criterion in the behavioral category is 80% (I) for the image and environmental perception criterion. Therefore, this criterion will be included in the developed standards.

Table 3. Overall average score for the behavioral category.

No.	Behavioral Category	E(X)	Importance Index (%)	MR
1.	Image and Environmental Perception	4.0	80.0	I

Table 4 shows that the overall scores for the criteria in the managerial category range from 80% (I) for the service realization criterion to 86% (I) for both the resource management and the maintenance financing criterion. Therefore, all the criteria in this category will be included in the developed standards.

Since all of the identified twenty quality criteria were found to be either “Extremely Important” or “Important”, they were all included in the standards.

Table 4. Overall average score for the managerial category.

No.	Managerial Category	E(X)	Importance Index (%)	MR
1.	Maintenance Strategy	4.1	82.0	I
2.	Management Responsibilities	4.2	84.0	I
3.	Resource Management	4.3	86.0	I
4.	Service Realizations	4.0	80.0	I
5.	Measurement, Analysis and Improvement	4.1	82.0	I
6.	Maintenance Financing	4.3	86.0	I

5 CONCLUSIONS

This study presented the development of maintenance management standards for facilities of large public organizations in Saudi Arabia. Based on a review of literature, twenty measurable quality criteria were identified. Each of the twenty criteria has several elements (clauses). The total number of elements is sixty-two elements. These criteria were classified in four major categories, namely technical, functional, behavioral and managerial. A questionnaire survey was developed to assess the importance of the identified quality criteria. The survey was filled out by a randomly selected sample of 40 maintenance professionals. Data analysis indicted that the highest importance index value was 90% (Extremely Important) for the quality criteria of "Mechanical, Electrical and Plumbing Systems" in the technical category, while the lowest importance index value was 78% (Important) for the quality criteria "landscaping" in the technical category, and the quality criteria "Accessibility and Parking Space" in the functional category.

Acknowledgments

The authors thank King Fahd University of Petroleum and Minerals for the support and facilities that made this research possible. The authors also acknowledge the financial support for this research through KFUPM Internal research grant No. RG1206-1 & RG1206-2.

References

Accessibility, 2015. Retrieved from http://www.businessdictionary.com/ on Mar. 14, 2015.

ASHRAE Standard 55, *Thermal Environmental Conditions for Human Occupancy*, ASHRAE, GA, 2004.

ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*, ASHRAE, GA, 2007.

British Standards Institute (BS 3811), *Glossary of Maintenance Management Terms in Terotechnology*, HMSO, London, 1993.

Cleanliness, 2015. Retrieved from http://www.answers.com on Mar. 14, 2015.

Crips, D. J., *Building Maintenance, A Client's Viewpoint, Managing building maintenance*, London, 1984.

Dominowski, R., *Research Methods*, Prentice Hall, N.J., 1980.

Fink, P., *An Intelligent Facility Planning Adviser*, Isa Trans. 31, 77–95, 1992.

Indiana School Design Guidelines (ISDG), *Indoor Environmental Quality*, Centre for School Innovation Ball State University, 2009.

ISO 9001, *Quality Management Systems – Requirements*, Geneva, Switzerland, 2008.

Landscaping, 2015. Retrieved from http://en.wikipedia.org/wiki/Landscaping on Mar. 14, 2015.

Lee, R., *Building Maintenance Management*, Wiley-Blackwell, London, 1991.

Maintenance Strategy, 2015. Retrieved from http://www.kwaliteg.co.za/ on Mar. 14, 2015.

Preiser, W., Rabinowitz, H., and White, E., *Post-occupancy Evaluation*, Van Nostrand Reinhold, NY, 1988.

Resource Management, 2015. Retrieved from http://www.businessdictionary.com/ on Mar. 14, 2015.

Steskens, P., and Loomans, M., *T1.3 Performance Indicators for Health and Comfort*, PERFECTION – Performance Indicators for Health, Comfort and Safety of the Indoor Environment, The Netherlands, 2010.

Storage, 2015. Retrieved from http://www.thefreedictionary.com/storage on Mar. 14, 2015.

The Institute for Security and Open Methodologies (ISECOM), *The Institute for Security and Open Methodologies (ISECOM)*, Spain, 2013.