A Proposed Strategy for Integrating Maintenance Considerations into the Design Phase of the Building An Egyptian Case Study

Laila Khodeir

Department of Architecture, Faculty of Engineering, Ain Shams University, Cairo, Egypt
archlailakhodeir@yahoo.com

Abstract: The processes of maintenance of buildings have a great impact on both their performance and their related systems. Whereas, building performance is valued and evaluated through the approach of building performance evaluation (BPE), which is based on the feedback and evaluation at every phase of the building delivery. However, the building maintenance industry in Egypt has long been an area of neglect, as most of buildings stakeholders restrict its role to the operation phase of the building. This attitude disregards the precautionary maintenance processes that could be achieved through the preliminary phases of the design of buildings. Thus, the main concern of this paper is setting a definite strategy that integrates maintenance considerations into the design process of buildings. The ultimate purpose is to achieve better performing buildings regarding maintenance aspects. The study sheds light on the major barriers of applying efficient maintenance, through the analysis of four chosen public buildings in Egypt. Emphasis is made on the role and impact of maintenance considerations in guiding the decision- making process, as well as the lack of integrating maintenance into the whole building design process. The paper suggests a precautionary strategy for integrating maintenance into the design process of buildings, through specific considerations that should be followed in order to achieve better performance of buildings.

[Laila Khodeir. **A Proposed Strategy for Integrating Maintenance Considerations into the Design Phase of the Building**: **An Egyptian Case Study.** *J Am Sci* 2012;8(12):890-898]. (ISSN: 1545-1003). http://www.americanscience.org. 124

Keywords: Maintenance; Building Performance Evaluation; Egypt

1. Introduction

The delivery of buildings comprises six major phases:

Planning, programming, design, construction, occupancy and adaptive reuse [1]. Planning is the first phase where a process of producing a strategic plan occurs. It also represents the starting point of the building delivery process [2]. The role of this phase is performing market-need analysis [3]. The Programming or Briefing phase begins as soon as the strategic planning ends. The program is considered vital when all details about the project, including needs, aims, resources as well as the context of the project, are documented [1]. The third phase is the design phase, where the design team develops two and three dimensional images that respond to the priorities established throughout the planning and functional programming processes [2]. The team produces ideas and the graphic representations to communicate them.

Afterwards, in the Construction phase, the construction documents are produced for the chosen design solution. Throughout this stage all relevant information is merged with the practical instructions and requirements needed to build the facility [1]. The Occupancy and Operation phase comes after the construction phase and is considered the longest of all phases as it might last for 30-50 years based upon the type of the building. During this phase, an adjustment of the building and its systems is done to fulfill the user's requirements [1]. The last phase in the design process is the Adaptive reuse of the building which is, like the planning phase, based on market and need- analysis [1].

The design phase, amongst all stages of the delivery of the building, has an immense impact on maintenance of the building afterwards. Vital decisions could be made at the preliminary design phases of the building delivery, which could make the application of different maintenance processes on both buildings systems and components easier. The value added is higher performance and lower operating costs of the buildings [4].

Maintenance industry has shown rapid growth awing to the increase in the number and variety of buildings that needed to be adequately maintained, the increase in complexities and advance in technology and the growing concern on the health, safety and environmental issues which, in turn, induce building owners to maintain their buildings to the required standards.[5] Nevertheless, building maintenance industry in Egypt has long been an area of neglect, as most of buildings stakeholders restrict its role to the operation phase of the building.

Besides Different barriers face the implementation of an effective maintenance process

on public buildings in Egypt. These barriers include the scarcity of some spare parts in local market, lack of qualified labor, inappropriate finishing relative to the nature of building type and the local site conditions, constrained budget for the maintenance of buildings vandalism and the inaccessibility of building spaces to apply the required maintenance work.

Thus, the main concern of this paper is setting a definite strategy that integrates maintenance considerations into the design process of buildings.

2- Design Phase vs. Effective Maintenance of Buildings

Generally speaking, the design phase includes three principal stages: schematic design, design development and construction documents [1].

2.1 Stages of Design Phase

Schematic design is considered the initial stage in the design phase. The output of this stage is a group of alternatives that translate the program of the project into building solutions [1]. Design Development is the second stage in the building design. During this stage, one of the alternative solutions of the building is chosen and elaborated on in the next stage. The selected alternative should address the issues raised by the program in more in detail [1].

2.2 The Impact of Design Phase on Maintenance Process

Maintenance is defined as the combination of all technical and associated administrative actions intended to retain an items in, or restore it to a state in which it can be perform its required function. [6] [7] [8].

As the driving line between different building types is rapidly disappearing, the problem of building maintenance is universal and the consideration of the problem at the design stage is of vital importance. It is important, however, that the essential maintenance should be carried out easily, quickly and economically [4].

The choice of the materials and finishing of the building, which is involved in the design phase, is considered the first step for optimizing maintenance processes throughout the life cycle of the building. Additionally, the choice of suitable types of finishes for the walls, floors and ceilings greatly affects the extent and cost of maintenance, hence the frequency of any required replacements.

Amongst the barriers that are most frequently the result of inaccurate choice of building fixtures is vandalism, which is defined as “willful destruction”. Most vandalism is based on violence; in particular, violence external to buildings. Violence can ruin equipment or portable fixtures in order to use them as weapons [4].The physical environment of the building, including its design detailing and fittings may encourage vandalism. In return, the term “vandal- proof” stands for the prevention of this problem by the proper selection of fittings and lights in particular, which are most vulnerable to vandals, so that they are completely imbedded into the building fabric [4].

The design phase can also minimize a vital barrier to maintenance process, i.e. the accessibility for maintenance. This means that the place to be maintained should be easily reached or entered for maintenance to be carried out. The design phase should work on the design alternative that fulfills the requirements of access for maintenance for different parts of the building and through the suitable methods of access, whether temporary or permanent [4].

2.3 Requirements for Applying Efficient Maintenance of Buildings

The process of maintenance includes all services that are required to assure that the building will perform the functions for which it was designed and constructed. Maintenance typically includes the day-to-day activities necessary for the building and its systems and equipment to perform their intended function [9].

Maintenance process involves many different requirements, including maintainability, reliability, safety and manageability. Achieving the four requirements for the maintenance process aims at effectively and efficiently supporting the life cycle of the facility by eliminating unplanned work and realizing life-cycle cost savings [10].

2.3.1 Maintainability

Maintainability is that characteristic of design and installation which affects the amount of time and cost necessary to repair, test, calibrate, or adjust an item to a specified condition, when using defined procedures and resources [11].

The maintainability of the systems and components of a building includes achieving equipment access, built-in condition monitoring and other maintenance requirements. The Maintenance team should know ahead of time the types of controls, equipment and systems they will have to maintain once the facility is turned over to them [9].

The term maintainability also includes the accessibility, where the accesses for maintenance are places designed to allow the maintainer to perform maintenance actions on equipment or components including entrance doors, apertures, inspection windows and lubrication, pneumatic, and hydraulic servicing points [11].

The accessibility refers to the relative ease with which an assembly or component can be reached for repair, replacement, or servicing. An item is

considered accessible only when it can be operated, manipulated, removed or replaced by the suitably clothed and equipped user with applicable body dimensions. Applicable body dimensions are those dimensions which are design-critical to the operation, manipulation, removal or replacement task [11].

2.3.2 Reliability /Availability

Reliability is the probability that an item will survive a given operating period, under specified operating conditions [12]. For improving the reliability of building facilities, the most important issues requiring immediate attention are to grasp and remove the factors causing problems in all steps of the life cycle, such as building planning, design, construction and operation [13].

2.3.3 Safety

The design and construction of safe and secure buildings are one of the primary goals for building stakeholders. Security and safety measures, such as those for anti-vandalism, must be considered within a total project context, including impacts on occupants and on applying efficient maintenance processes. Human factors engineering/ergonomics in the performance of maintenance is a major factor in the design for safety of the operation.

Design should reflect the safety-related human factors engineering/ergonomics criteria below. The order of precedence for satisfying system safety requirements is as follows [11]:

a. Design for minimum risk;
b. Incorporate Safety devices;
c. Provide warning devices;
d. Provide procedures and training;
e. Provide Personnel Protective Equipment.

2.3.4 Manageability

Achieving Manageability means controlling and managing maintenance work, which is achieved through the existence of maintenance managers and setting a clear maintenance plan. The MP will identify the tasks required, their descriptions and schedules, troubleshooting, corrective maintenance (repair) task descriptions and spare parts identification and quantity, in addition to any unique storage requirements [10].

3 Approaches and Methodology

Four public buildings in Egypt were chosen for the case studies. The study involved the use of two major data collection techniques: focused interviews and observations. The interviews were conducted to the maintenance managers /general building manager of the chosen building.

The managers were asked about the background of the building, type of maintenance service provided, systems used, type of maintenance budget, as well as the barriers and problems that hinder them from applying maintenance work. The analyses of data extracted from both interviews and observations provided clear data from which the findings were extracted.

4 Analyses of Case Studies

The buildings under analysis were chosen from among diversified patterns of public buildings in Egypt: a museum, a hotel, a library, and a commercial and recreational center. This selection aims at objectively tackling the most important problems or obstructions which face the process of building maintenance as effectively and efficiently required.

This selection of the four patterns of buildings resulted in the researcher's ability to make clear inferences about the nature of such problems and obstructions in general, as a primary step towards achieving the main objective of the research, namely, "suggesting a precautionary strategy for integrating maintenance considerations into the primary phases of design", which has a great effect on relieving the effect of the obstructions which face the process of building maintenance.

4.1 Case (1) Museum Building: The Coptic Museum in Cairo

The Coptic Museum exists in a place called "civilizations center" in Cairo. The maintenance processes in this historical place depends on making contracts with specialized companies, only if any harm occurs in one of the different systems of the building. This is because there are no particular plans for the maintenance of the building or even for making daily cleaning processes, precautionary maintenance, renewal plans, or plans for replacing the current system, since the building lacks an administration that is responsible for the maintenance of the building.

The building has lately been subjected to a process of complete renewal of the systems of display and lighting. This process aimed at improving the performance of the building as a whole, along with providing a welcoming and motivating atmosphere for visitors. The process of improvement faced a number of problems and obstructions which strongly affected the performance of the required maintenance processes. These obstructions are represented in the following points:

After its renewal and opening, the museum depended on natural ventilation, which resulted in the continuous occurrence of collision between the open windows and the display glass cases, leading to the damage of some of them. It also resulted in the accumulation of large piles of dust inside and outside the glass cases.

This shows that the planning of the process of renewing the museum was poor and that the consequences of depending on natural ventilation in

such dusty atmosphere were not studied, especially with some display glass cases being placed beside open windows, resulting in their being subject to collision. Fig. (1a, 1b) show the glass cases which were used in the museum after the renewal processes and the glass windows from inside the museum.

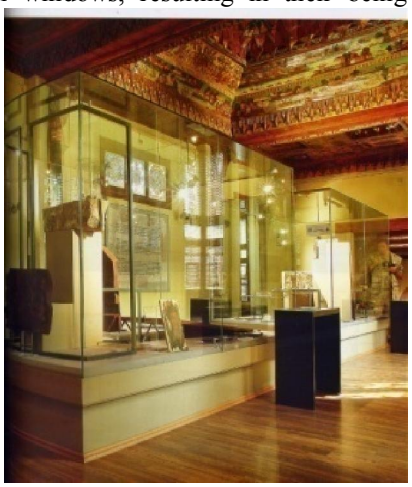

Fig (1a)The display glass cases at the Coptic museum facade

Fig (1b)Using natural ventilation at the Coptic museum

B- A large number of the lighting units were damaged after reopening of the museum. This damage occurred to nearly one third of the lighting units of the museum, which refers to the existence of a problem with the decision-making process regarding the systems used in the building and their efficiency.

The board of the building sought the assistance of a foreign company specialized in providing and setting glass cases. However, the technique used by this company in setting the glass cases, together with the policy of the company, do not allow anyone except the workers of the company to open the glass cases, and upon an advance request. This led to imposing new restrictions upon performing maintenance processes, whether the daily cleaning of glass cases from inside or the precautionary maintenance of lighting units or even replacing damaged ones.

As an attempt from the administration of the museum to overcome the previous problems a central air-conditioning system was set up in the museum as a whole to prevent the collision of windows with the glass cases and to lessen the amount of dust inside them and, in turn, the rates of periodical maintenance and cleaning.

However, this solution led to the increase o the general budget of the renewal project, while, at the same time, leaving the problem of opening the cases for properly performing the maintenance processes unsolved.

4.2 Case (2): Hotel Building (Semiramis Intercontinental Hotel)

This hotel is on the Nile corniche in Cairo. The advantage of studying and analyzing this building is that it has already spent half of its age, since it had been opened since about twenty five years, which makes it a rich case for studying as it has been through many problems related to its maintenance processes throughout its lifetime.

The building had been subject to entire air-conditioning system replacement, in addition to undergoing renewal processes for all systems, as well as for the internal and external facades. These processes were followed up by a specialized maintenance administration which is inside the building. The most eminent problems which faced this building can be summed up as follows:

The project faced the problem of lack of some spare parts or high-quality materials; it also encountered the problem of lack of local trained workmen who are capable of dealing with modern techniques. Such problems clearly emerged when it was the time for making precautionary maintenance for the air-conditioning system of the building. The decision of replacing the whole air conditioning system was taken after studying the costs which were provided for treating and renewing the old system.

The decision of installing a new air conditioning system, which was made by the maintenance administration, led to lessening the burdens of maintaining the old system which needed many frequent maintenance cycles.

The building suffers from the incompatibility between the materials used for finishing and the dusty, polluted weather surrounding it as a result of its presence in a vital place in the middle of Cairo. This leads to many burdens on the performance of maintenance and cleaning processes, especially for entrances and glass facades for the purpose of keeping the appearance of the building good and attractive.

Some machines and accessories inside the building were subject to damage or vandalism from users, especially in public halls and lavatories.

There is great difficulty in performing maintenance processes and other relevant works (especially precautionary maintenance and fixing processes) in some of the hotel halls in which guests are present. This was the result of not putting the ergonomics of maintenance into consideration during designing the building.

This problem led to obligatory evacuation of the hotel during the required maintenance processes.

4.3 Case (3): Shopping and Recreational Building (City Stars Mall Building)

This huge project which is situated in Heliopolis, Cairo, includes an integrated management system, not only for the maintenance of the building, but also for facility management as a whole. This shows the integration between the maintenance administration and other administrations, since the maintenance administration depends on using computer techniques beside manual techniques in making maintenance schedules and issuing working order. The administration of the building started its job after the building was implemented and shortly before starting its work. The obstacles which encountered the maintenance of the project's halls comprised the following:

Despite using high-quality paintings in internal corridors and public halls, the selection of such kinds of paintings disregarded some hostile manners by some users who lean with their shoes on the walls, causing damage to these paintings and making their cleaning difficult, as well as leading to the need for repainting these walls more frequently than expected.

Decision makers disregarded a very important factor related to the choice of devices and accessories which are used in lavatories, namely subjection to vandalism. The system of selection of these devices depended on its efficiency and quality, regardless of safety measures against vandalism. This led to the subjection of most devices and accessories inside public lavatory halls to theft shortly after opening the project, which caused the administration to replace the devices with less efficient and safer ones (which cannot be removed).

The building was greatly affected by the lack of some locally modern techniques, as well as some materials with standard quality. This was clearly shown in implementing an external façade of the mall, which was planned to be made in the form of waterfalls. The administrators were forced during the implementation of the project to make use of limited local techniques to carry out the design by using pipes in hidden parts of the façade. This resulted in great problems represented in the leakage of water inside the mall because of lack of techniques and the bad implementation. Consequently, the maintenance administration resorted to periodical injection of leakage parts.

On the other hand, the effect of local water and the percentage of salt in it were not studied, resulting in the obvious accumulation of salt on the façade. This in turn resulted in using filters to purify water from salts, leading to the appearance of such relatively big filters on the external façade of the building, Fig. (2).

This problem represents a clear example of what can be caused by not integrating the maintenance considerations during the first phases of design, because solving the problem after its occurrence led to adding more unexpected burdens to performing maintenance processes for the building.

Fig (2) Water falls on curtain wall at city stars mall

This project encountered another type of problems which represent an obstacle for building maintenance, which is the disability of reaching some systems, especially inside the shops that do not have an outer façade facing the street. This problem led to the occurrence of limited fires inside the mall, as well as the need for evacuating these shops during the maintenance process of the different control systems inside them.

4.4 Case (4): Library Building (Bibliotheca Alexandrina)

This building, which is considered a revival of the old Alexandrian library, is situated in Alexandria. The building has a complete administration which

covers all its fields. The administration started to perform its work after the implementation of the building and before its starting by the help of a foreign specialized management company. Then it sought the assistance of locally professional people after the foreign company had trained the local managers. The maintenance administration of the project depends on an improved administration system which is carried out by a specialized computer program which produces both precautionary and corrective maintenance schedules, in addition to managing human resources, materials, costs and issuing work orders. It also performs an effective role in following up the performance of employees and evaluating them at the end of each maintenance cycle (3 to 12 months).

Most of the problems and obstacles which confronted the implementation of maintenance processes for the building are represented in the following points:

A local specialized company was used to manufacture the internal partitions in the hall of the library with non-standard measures (as a kind of uniqueness for this building which has a symbolic importance). However, this resulted in a problem related to performing maintenance measures for these partitions and replacing damaged ones, since the manufacturing company cannot provide a small number of these partitions which were specially formed for the library building, which entails changing all the partitions at once after their hypothetical age.

This problem refers to the lack of effect of maintenance considerations on the phases of building design, as well as to the existence of a mistake in selecting materials and in the used systems, since the availability and costs of such materials and systems later in local markets were not studied.

The other challenge which encountered the maintenance of this building was the shape of the building itself, since the façade of the building is very sloping and made of glass (Fig. 3). This shape is incompatible with the climatic nature of Alexandria (the rainy, dusty weather), making the cleaning of the façade very difficult, especially with the lack of modern techniques and depending on manual workmanship. Moreover, the extremely sloping nature of the building makes it impossible to use cranes and imposes on workers to walk over the sloping top of the library to perform maintenance.

Using some materials which are not suitable for the climatic nature and the weather changes makes them subject to damage quickly, causing the distortion of the appearance of the building in the eyes of the guests. Fig. (4) Shows the cracks of the façade of the conference hall annexed to the library.

Fig (3)The inclined roof which forms a challenge for maintenance processes

Fig (4)Cracks in the facades of the conference hall - Bibliotheca Alexandrina

5. Findings of Case Studies

Through analyzing the previous case studies a group of findings were extracted and classified into a number of categories, as follows.

5.1 The Impact of the Existence of the Management Department

Case (1):

It has been shown that the lack of an administration that is specialized in the processes of building maintenance necessarily leads not only to the occurrence of problems which obstruct the processes of maintenance, but to a kind of randomness and hesitance in making decisions as well. Moreover, it adds new burdens especially on making the maintenance processes for the building with the required efficiency.

Case (2):

The existence of an administration that is specialized in managing the building has helped to a great extent in overcoming or lessening the effect of the problems that the building encounters, in addition to taking effective decisions regarding the maintenance of the systems of the building as a whole.

Case (3):

The existence of an integrated team for maintenance administration and building administration in this project guaranteed limiting the effect of different problems which encountered it and which affected the performance of maintenance of halls and different systems. Additionally, the integration between the maintenance administration and other administrations of the building also guaranteed the study of the effects of problems on all administrations and the equal distribution of resources, resulting in achieving efficiency in the performance of the whole building on the long run.

Case (4):

The presence of a specialized, professional administration led to lessening many problems which might obstruct the effective performance of maintenance processes, in addition to the advantage provided by the applied system which is represented in its ability to evaluate the performance of employees continuously to guarantee the efficiency of carrying out the maintenance processes for the building. However, most of the problems which face this building occurred because the maintenance administration had not interfered in decision-making since the primary stages of design.

5.2 Barriers Facing Maintenance Processes

Table (1) shows the classification of different types of barriers that affected the efficiency of the maintenance process in the case study buildings. The barriers were classified in accordance to their impact on the different requirements for applying efficient maintenance of buildings.

Table (2) shows the degree of occurrence of these barriers in each of the four studied cases. The degree of occurrence is an indicator of the degree of impact of each barrier.

Table (3) shows the degree of impact of the barriers that occurred in the specified buildings on the efficiency of the maintenance process; this analysis was based on the interviews with the managers in the four case studies. The managers were asked to give a rank to the different barriers according to the severity of their impact on applying efficient maintenance in the case study buildings, from rank 1(most severe), to rank 5 (least severe).

Table (1): Common barriers affecting maintenance of buildings in the case studies:

Requirements for Applying Efficient Maintenance	Area of application	Types of barriers
Maintainability	Systems	A1 inaccessibility for maintenance
		A2 lack of qualified labor
	Materials	A3 lack of standard spare parts
Availability/Reliability	Materials	B1 Inaccurate choice
		B2 Lack of efficient materials
Safety		C1-Vandalism
D- Manageability		D1 Lack of maintenance management/management plan
		D2 Lack of integration between different management disciplines
		D3 late involvement of maintenance managers

Table (2): The degree of occurrence of barriers in the studied cases

Type of barrier	A1	A2	A3	B1	B2	C	D1	D2	D3
Case 1		=		=			=	=	=
Case 2	=			=	=	=		=	
Case 3	=			=	=	=			=
Case 4			=	=	=	=			=
Degree of occurrence in all case studies	**50%**	**25%**	**25%**	**100%**	**75%**	**75%**	**25%**	**50%**	**75%**

Table (3): The degree of impact of the barriers on the effectiveness of maintenance process (according to the manager's interview)

Rank	Maintenance barrier
1	**D1**
2	**D2- D3**
3	**A1**
4	**B1 C**
5	**A3 B1 B2**

Table (4) offers a more comprehensive ranking to the different barriers that affect the application of efficient maintenance in the studied cases, based on both factors: the degree of occurrence of each barrier and the severity of their impact on achieving efficient maintenance.

Thus the barriers that occurred in most of the case study buildings were: B1(Inaccurate choice of materials), C (Vandalism), D2 (Lack of integration between different management disciplines) and D3 (late involvement of maintenance managers), While

the barriers that have the most severe impact on achieving efficient maintenance of buildings were: D1(Lack of maintenance management/management plan), D2 and D3.

Table (4): Ranking maintenance barriers upon their degree of occurrence (table 2), and their impact on achieving efficient maintenance (based on the managers' interview, table 3)

Maintenance barriers	Rank according to the degree of occurrence	Rank according to their impact severity
D1	4	1
D2- D3	2	2
A1	3	3
B1 C	1	4
A3 B2	3	5

6. Proposed Strategy

The proposed strategy is based on performing a design review that involves evaluating the design of the building throughout all its stages, aiming at controlling and monitoring the most fatal barriers that face the maintenance of buildings. The review technique should be performed by the maintenance manager who is considered one of the stakeholders of the building.

6.1 Schematic Design Stage

Design alternatives should be reviewed by the maintenance manager to give them a primary evaluation, which might suggest rules for later maintenance processes of the building, which could impose additional burdens on maintenance.

Adopting such strategy at the schematic design stage would greatly affect the manageability of building maintenance and in turn decrease the impact of the three barriers related to it (D1,D2 and D3).

6.2 Design Development Stage

In this phase, the maintenance manager should make sure, and also monitor, that the design alternative that was selected had taken into consideration the three major factors needed for achieving effective building maintenance in the future. These factors include availability, maintainability and Reliability.

Availability

The maintenance manager should make sure of the availability of the finishing materials that are locally or universally selected. He is also responsible for clarifying to the team the importance of the availability of local, trained manpower, which is capable of performing maintenance processes for these materials and systems, in addition to the availability of standard spare parts for the chosen systems in the local market. The maintenance manager should also interfere in clarifying the requirements of the selected systems and materials for maintenance processes.

Maintainability

The maintenance manager should offer a primary evaluation for the extent to which the selected materials and systems are suitable for undergoing maintenance processes, and the appropriate rate of performing cleaning processes and periodic maintenance for them. In addition the manager should investigate the role of weather conditions in affecting both the type and frequency of maintaining the selected materials and systems of the building.

The maintenance manager also revises all the used systems of the building with respect to their accessibility for the purpose of daily maintenance and cleaning of its different parts. Accordingly, it is his responsibility to inspect the areas, service passages and the availability of entrances for the different parts of the building.

Reliability

The maintenance manager is responsible of checking that the systems and materials used in the building (especially in the public halls) are vandal- and theft-proof, and are highly efficient at the same time.

Adopting such strategy at the stage of design development would greatly affect both the maintainability of maintenance (A1, A2, A3),and the availability (B1, B2) .

Construction Documents Stage

At this crucial stage, the building manual, which comprises all the building maintenance considerations and the rates of their applicability, should be attached to implementation documents. Also the maintenance manager should work on integrating maintenance data with all technical information about the building materials, equipment furnishings and systems. This stage should also include the process of designing the details necessary for protecting the systems and finishing from robbery and vandalism.

Adopting such strategy at the stage of setting construction documents would greatly affect the manageability especially regarding the lack of integration between different management disciplines (D2) and achieving safety(C).

References

[1] Wolfgang F.E. and Jacqueline C. (2005). Assessing Building Performance. Elsevier publisher, pages (15-19).

[2] Preiser, W.F.E. and Schramm, U. (1997). Building performance evaluation. In Time Saver Standards for Architectural Design Data (D. Watson et al., eds), McGraw-Hill. Pages (231-238)

[3] Petronis, J.P. (1993). Strategic Asset Management: An Expanded Role for Facility Programmers. In Professional Practice in Facility Programming (W. F. E. Prieser, ed.). McGraw-Hill

[4] Mills E., Building Maintenance and Preservation. (1996). A Guide to Design and Management. Reed Publisher, 2nd ed. Page (77).

[5] Chau C.K., Sing W.L., Leung T.M.. (Sep.2002). An analysis on the HVAC maintenance contractors selection process-Elsevier, p.583

[6] Wood, B., (2005), "Towards Innovative Building Maintenance," Structural Survey, Vol. 23 No. 4, pp. 291- 297

[7] Lam, E.W.M, Chan, A.P.C, and Chan, D.W.M, "Benchmarking success of building maintenance projects" Facilities, Vol. 28, No. 5/6, 2010, pp. 290-305

[8] British Standard Institution: BS 3811:1984 British Standard Glossary of Maintenance Management terms in terotechnology, United Kingdom.

[9] Don Sapp -Facilities Operations & Maintenance Updated by the Facilities O&M Committee - Last updated: 11-09-2011- http://www.wbdg.org/resources/rcm.php?r=env_sustainability#intro- whole building design guide- a program of the nati9onal institute of building sciences. (Last accessed 10-10-2012)

[10] Glenn Hunt, Peripheral Systems, Inc.- **Comprehensive Facility Operation & Maintenance Manual-** Last updated: 11-09-2011- http://www.wbdg.org/resources/rcm.php?r=env_sustainability#intro- whole building design guide- a program of the nati9onal institute of building sciences. (Last accessed 10-10-2012)

[11]Doe Handbook - Human Factors/Ergonomics Handbook for the Design for Ease of Maintenance- U.S. Department of Energy - AREA HFAC Washington, D.C. 20585-2001. Pages (111, 115)

[12] Alan Pride -Reliability-Centered Maintenance (RCM) - Last updated: 06-17-2010- http://www.wbdg.org/resources/rcm.php?r=env_sustainability#intro- whole building design guide- a program of the nati9onal institute of building sciences (Last accessed 10-9-2012).

[13] Ro-Yeul Kwaka, Akira Takakusagib, Jang-Yeul Sohna, Shuji Fujiic, Byung-Yoon Parkd Development of an optimal preventive maintenance model based on the reliability assessment for air-conditioning facilities in office buildings – Elsevier- January 2004- p1.

11/2/2012