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Suggested Guidelines for Integrating Maintenance Considerations into the Life Cycle of the Building

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Abstract

Maintenance of buildings is a crucial process that has a great impact on both buildings' performance and the efficiency of their embedded systems. 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 buildings. The main concern of this paper is suggesting specific guidelines that enable the integration of maintenance considerations into the whole life cycle of the 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 results extracted from focused interviews that targeted a number of general and maintenance managers in a number of selected buildings. 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. This paper ends up with suggesting a framework that demonstrates the impact of integrating considerations of maintenance throughout the whole life cycle of the building.

الملخص:

تعد صيانة المباني من العمليات التى لها تاثير كبير على كل من اداء المبانى فاعلية الانظمة المتضمنه فيها.على الرغم من ذلك ففي مصر يقصر اغلب القائمين على تلك المباني والمنتفعين بها دور عمليات صيانة المباني على مرحلة تشغيل المبني فحسب. ترتب على ذلك الفهم القاصر لتلك العمليات اهمال الدور الوقائي الفعال الذي قد تقوم به ادارة الصيانة في المراحل الاولى لتصميم المبنى. تهدف هذه الورقة البحثية الى طرح عدد من الخطوط الارشادية التي من شأنها المساعدة على تحقيق التكامل بين اعتبارات الصياة ودورة حياة المباني. وذلك بهدف تحقيق مباني ذات اداءات اعلى لاسيما ما يرتبط باجراء عمليات الصيانة لها. يلقى البحث الضوء على اهم المعوقات التي تواجه اجراء صيانة فعالة للمباني وذلك من خلال تحليل النتائج المستخلصة من المقابلات المركزة مع عدد من مديري الصيانة ومديرى المشروعات في مجموعة من الامثلة المختارة من المباني العامة في مصر. تنتهي هذه الورقة البحثية بطرح مجموعة من الارشادات من خلال اطار عمل يتم من خلالها توضيح امكانية اجراء التكامل المنشود بين اعتبارات الصيانة ودرورة حياة المباني، الى جانب التنبيه للأثر الايجابي لتلك الارشادات واطار العمل المقترح في تقنين عمليات الصيانة لاحقا وتذليل المعوقات المرتبطة بها.

Index Terms*: Maintenance Considerations, Life Cycle , Building Performance Evaluation; Egypt*

1. INTRODUCTION

The life cycle of buildings comprises six major phases shown in figure (1). [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].

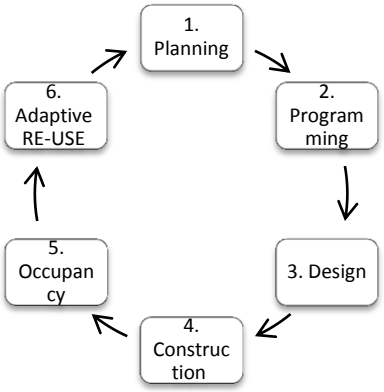


Figure (1): the six phases of the building life-cycle [1]

A number of factors induce building owners to maintain their buildings to the required standards, these factors include the increase in number and variety of buildings, the increase in complexities and advance in technology and the growing concern on the health, safety and environmental issues.[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 such as 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 ***suggesting specific guidelines that enable the integration of maintenance considerations into the whole life cycle of the buildings.***

I. THE ROLE OF DESIGN PHASE IN OPTIMIZING MAINTENANCE PROCESSES

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

A. 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. 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 details [1].

B. The Impact of Design Phase on Maintenance Process

The process of 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].

C. General 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 periodical 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].

C.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].

C.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].

C.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]:

- Design for minimum risk;
- Incorporate Safety devices;
- Provide warning devices;
- Provide procedures and training;
- Provide Personnel Protective Equipment.

C4. 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 Maintenance Plan 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].

II. METHODOLOGY

Four public buildings in Egypt were chosen for the case studies. The selection of the case studies was based upon a number of factors including:

- Public Buildings with relative significance.
- Large scale type of buildings.
- Varied years of operation.
- Varied types of buildings use.
- The existence/inexistence of a maintenance management department..
- Varied types of ownership (public/private).
- Varied locations (Cairo, Old Cairo, and Alexandria).

Selecting the case studies with varied nature, function, scale, years of operation, and type of ownership allowed the researcher to extract a framework that could be implemented on a wide range of similar types of projects.

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 managers that were involved in a number of selected case study buildings. The managers were asked about a number of basic issues as follows:

- The background of the buildings they worked in.
- Timing of involvement in the building.
- Types of maintenance service provided.
- Type of maintenance budget.
- The barriers and problems that hinder applying maintenance work.
- Root Causes of the barriers that hinders maintenance process.
- The impact of each specified barrier on the efficiency of applying maintenance.

The analyses of data extracted from both open interviews with CEO (Chief Executive Officer), Maintenance Managers, Deputy Project Manager and data extracted through observations provided clear data from which the findings were extracted.

III. SELECTION AND ANALYSES OF CASE STUDIES

The buildings under analysis were selected from among diversified patterns of public buildings in Egypt: a museum, a hotel, a library, and a commercial /recreational center. This selection aims at objectively tackling the most important problems or obstructions which face the process of public 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 specific guidelines that enable the integration of maintenance considerations into the whole life cycle of the buildings.*", which has a great effect on relieving the effect of the obstructions which face the process of building maintenance.

A. Case (1) Museum Building

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 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:[14]

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. Figure (1a, 1b) shows 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 façade

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

Source: Researcher

- 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 of 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.

B. Case (2) Hotel Building

The Semiramis Intercontinental hotel overlooks River Nile 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 about twenty five years ago. This makes it a rich case for studying as it has encountered varied maintenance -related problems throughout its lifetime.

The building had been subjected 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 stationed inside the building. The most eminent problems which faced this building can be summed up as follows: [15]

- The project faced the problem of lack of some spare parts of 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 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 good and attractive appearance of the building.Figure (2) shows the structure of the maintenance management department in the case study building.
- Some machines and accessories inside the building were subjected 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 neglecting the accessibility for maintenance during the design of the building spaces. This problem led to obligatory evacuation of the hotel during the required maintenance processes.

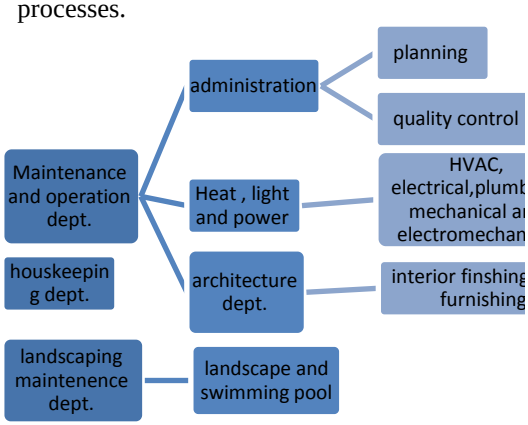


Figure (2): the structure of the maintenance management department in the case study(2) building.[15]

C. Case (3) Shopping Mall and Recreational Building

The City Stars project 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. Figure (3) illustrates the structure of the maintenance management departments in the building. 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.

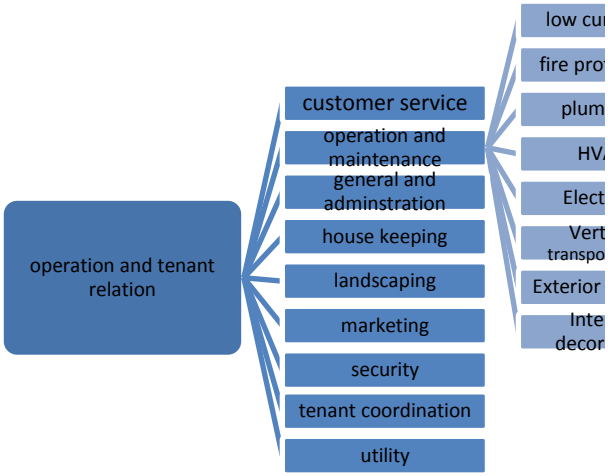


Figure (3): the structure of the maintenance management departments in the case study (3)[16]

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:[16]

- 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 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, figure (4). 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 (4) Water falls on curtain wall at city stars mall Source: Researcher

- This project encountered another type of problems which represent an obstacle for building maintenance, which is the inability to reach 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.

D. Case (4) Library Building

The Bibliotheca Alexandrina library building is considered a revival of the old Alexandrian library and is situated in Alexandria, Egypt. The building has a complete administration which covers all its fields. Figure (5) shows the structure of the management department. The administration started to perform its work after the implementation of the building and before its beginning 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.

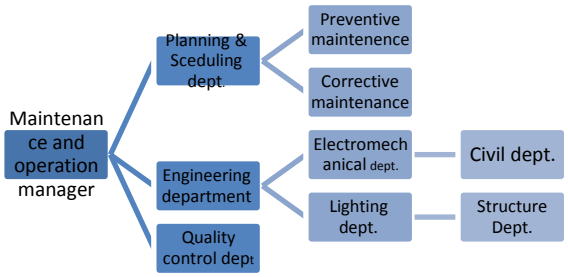


figure (5): the structure of the management department in case study (4) [17]

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:[17]

- 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 extremely sloped and made of glass. 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, figure (6). Moreover, the extremely sloping nature of the building makes it impossible to use cranes and imposes on workers the need 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. (7) Shows the cracks of the façade of the conference hall annexed to the library.

Fig (6) The inclined roof which forms a challenge for maintenance processes
Source: Researcher

Fig (7) Cracks in the facades of the conference hall - Bibliotheca Alexandrina
Source: Researcher

IV. 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.

A. The Impact of the Existence of the Management Department

This part of the findings was mainly based on both observations detected in each of the case studies and open interviews with managers.

- **Case (1):** It has been shown that the lack of an administration specialized in the processes of building maintenance leads

necessarily not only to the occurrence of problems which obstruct the processes of maintenance, but to a kind of randomness and hesitance in making decisions. Moreover, it adds new burdens especially on making the maintenance processes of 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 building systems 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 that affected the performance of halls and different systems maintenance. Additionally, the integration between the maintenance administration and other administrations of the building also guaranteed the study of the effects of the problems on all administrations and the equal distribution of resources, resulting, in turn, 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.

B. Barriers Facing Maintenance Processes

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

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

requirements for efficient maintenance	*area of pplication*	*type of barrier*
A. Maintainability	systems	A1 inaccessibility for maintenance
	systems	A2 lack of qualified labor
	materials	A3 lack of standard spare parts
B.Availability /Reliability	materials	B1 Inaccurate choice
	materials	B2 Lack of efficient materials
C.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) 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 (2): The degree of occurrence of different maintenance barriers in studied cases.

barrier	*A 1*	*A 2*	*A 3*	*B 1*	*B 2*	*C 1*	*D 1*	*D 2*	*D 3*
case1		√		√			√	√	√
case 2	√			√	√	√		√	
case 3	√			√	√	√			√
case 4			√	√	√	√			√

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 (3): The degree of impact of different barriers on the effectiveness of maintenance process (According to the interview with the managers)

Rank	*Maintenance Barrier*
1	D1
2	D2,D3
3	A1
4	B1,C1
5	A3,B1,B2

V. SUGGESTED INTEGRATION GUIDELINES

The suggested guidelines is based on performing a design review that involves evaluating the design of the building throughout all its life cycle, 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.

A. 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 guidelines 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).

B. 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.

B1. 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.

B2. 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.

B3. 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 guidelines at the stage of design development would greatly affect both the maintainability of maintenance (A1, A2, A3), and the availability (B1, B2) .

C. 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 guidelines 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).

The framework in figure (8) shows the suggested guidelines integrated with, the phases of building life cycle, the suggested role of maintenance manager in each phase is highlighted, also the updated output of each phase is described after integrating the consideration of maintenance The expected impact of such integration in either mitigating or eliminating different maintenance barriers is also highlighted on the framework.

According to this framework the maintenance manager team work in parallel with the design team to ensure that the decisions taken tackles the architecture design objectives, meanwhile have minimum negative impact on the application of maintenance processes later on . The suggested role of the maintenance manager starts with setting up a strategic maintenance plan that is based on examining the needs for maintenance of the building, either regarding the systems, the envelope, the facilities and infrastructure.

During Programming phase the maintenance management team should check the integration of maintenance needs with the design program; this includes offering enough spaces for applying maintenance requirements on each building component or system.
Afterwards, during the establishment of design priorities the maintenance management team could interfere in producing modified drawings that achieves accessibility for maintenance and start working on the detailed maintenance plan for each system or component of the designed building. The role of the maintenance management through the construction of the building is limited to the Preparation of maintenance manuals, preventive and corrective maintenance plans.
During the operation of the building, the maintenance management should focus on both roles; applying different maintenance plans and monitoring the performance of the building through building performance evaluation techniques. Finally at the end of the expected building life time, maintenance management should work on extracting lessons learned and best maintenance management practices and on applying them either on , refurbished existing buildings or on new implemented buildings.

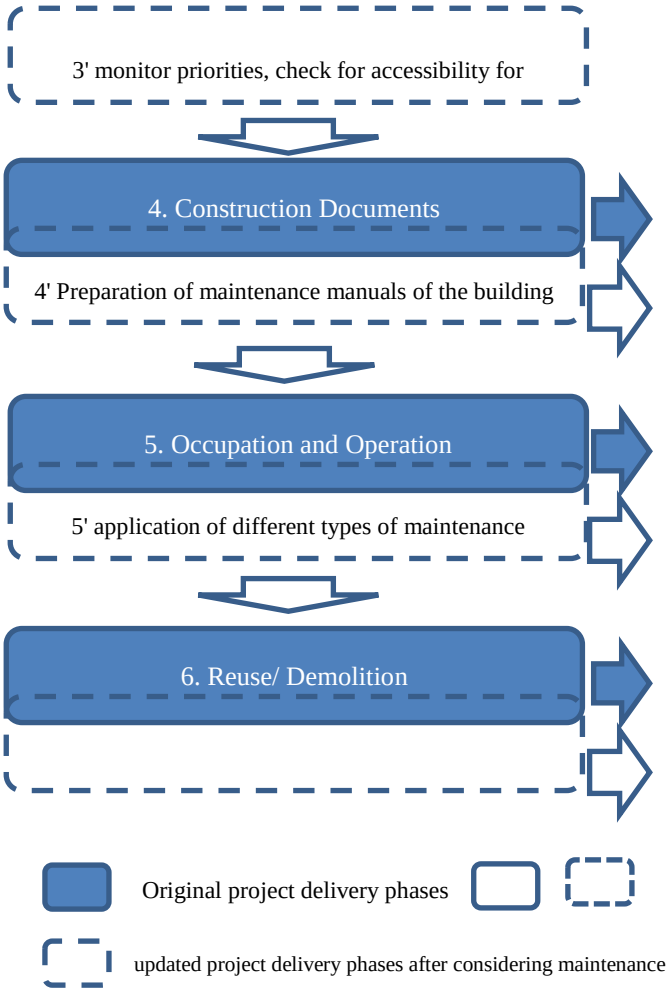
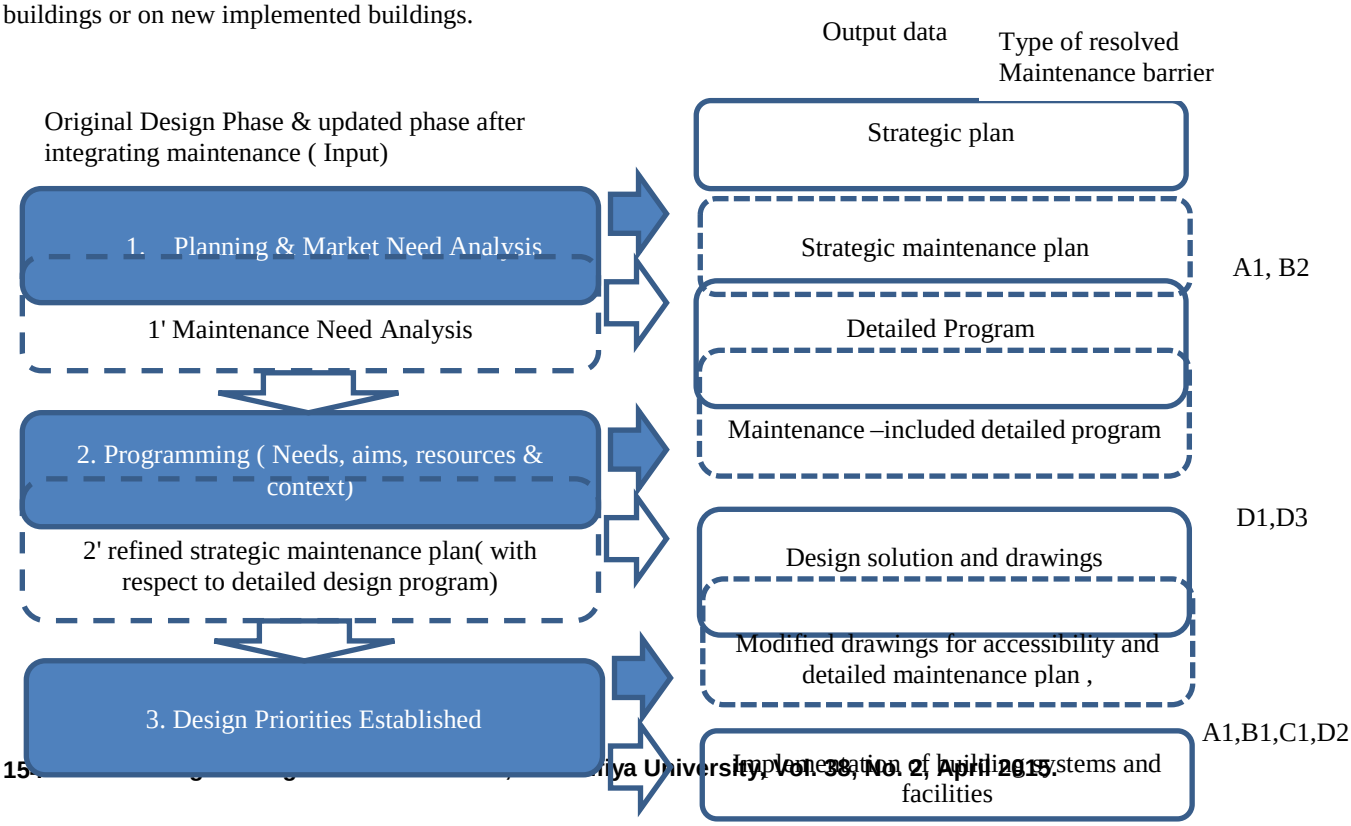


Figure (8) a framework that shows the suggested guidelines for integrating maintenance considerations with the phases of building life cycle



VI. CONCLUSIONS

The top barriers that occurred in most of the case study buildings were in order as follows:

- B1(Inaccurate choice of materials),
- C (Vandalism),
- D2 (Lack of integration between different management disciplines)
- D3(late involvement of maintenance managers),

Meanwhile, the barriers that have the most severe impacts on achieving efficient maintenance of buildings were found to be: D1(Lack of maintenance management/management plan), D2 (Lack of integration between different management disciplines and D3(late involvement of maintenance managers).

- The paper finally introduced suggested guidelines, in the form of a framework, that aim at integrating the considerations of maintenance into the whole design process. The suggested guidelines could be implemented throughout the whole building life cycle and ensures the achievement of efficient maintenance through minimizing the key major barriers that might face the maintenance processes.
- A couple of limitations could face the application of the suggested framework on different buildings as follows:
  - The standardization of the framework might not be applicable on building types other than public buildings, where the type of ownership, the scale, the context and the surrounding services could all form variables that need to be furtherly studied.
  - Although the framework would resolve all the top key barriers that hinder the achievement of efficient maintenance process, or at least mitigate their negative impact, some barriers couldn't be resolved through this framework. The unresolved barriers include the lack of qualified labor and the lack of spare parts, which are both considered as external type of barriers that could hardly be controlled or mitigated.
- Finally, since the research focused on integrating maintenance considerations with the delivery phases of different public buildings, it is believed that applying this framework on other types of buildings, for example residential buildings, would imply for further investigation and modifications of the suggested framework.

REFERENCES

[1] Wolfgang F.E. and Jacqueline C., **"Assessing Building Performance",** Elsevier publisher, pp. 15-19, 2005.

[2] Preiser, W.F.E. and Schramm, U., **"Building performance evaluation,"** Time Saver Standards for Architectural Design Data,McGraw-Hill, pp. 231-238, 1997.

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

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

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

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

[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, pp. 290-305, 2010.

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

[9] Don Sapp -**Facilities Operations & Maintenance Updated by the Facilities O&M Committee** - Last updated: 11-09-2014- http://www.wbdg.org/resources/rcm, whole building design guide- a program of the national institute of building sciences (Last accessed 10-9-2014).

[10] Glenn Hunt, Peripheral Systems, Inc.- **Comprehensive Facility Operation & Maintenance Manual-** Last updated: 11-09-2014- http://www.wbdg.org/resources/rcm, whole building design guide- a program of the national institute of building sciences (Last accessed 10-9-2014).

[11]Doe Handbook - **Human Factors/Ergonomics Handbook for the Design for Ease of Maintenance-** U.S. Department of Energy - AREA HFAC Washington, pp. 111- 115, 2001.

[12] Alan Pride **-Reliability-Centered Maintenance(RCM)** - Last updated: 17-6-2014- http://www.wbdg.org/resources/rcm., whole building design guide- a program of the national institute of building sciences (Last accessed 10-9-2014).

[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.
[14] CEO (chief executive officer) -**Open Interview**, Coptic Museum – Old Cairo, April 2012
[15] Head of Maintenance Management Department -**Open Interview**, Semeramis Intercontinental Hotel, Tahrir, Cairo, January 2011
[16] PMO and Deputy Project Manager-**Open Interview**, City Stars – Heliopolis, Cairo, May 2012
[17] Head of Preventive Maintenance Management Department-**Open Interview**, Bibliotequa Alexandrina – Alexandria, July 2010