T.R.
MIMAR SINAN FINE ARTS UNIVERSITY
INSTITUTE OF SCIENCE AND TECHNOLOGY

IMPROVING THE ARCHITECTURAL DESIGN AND MAINTENANCE PROCESSES TO ENSURE BUILDING MAINTAINABILITY
A Model Proposal

Ph.D. THESIS

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Supervisor: Prof. Dr. Sema ERGÖNÜL

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MİMAR SİNAN GÜZEL SANATLAR ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ

BİNALARIN BAKIM-ONARIM KOLAYLIĞININ SAĞLANMASINA YÖNELİK OLARAK MİMARİ TASARIM VE BAKIM-ONARIM SÜREÇLERİNİN GELİŞTİRİLMESİ

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Nur ATAKUL tarafından hazırlanan IMPROVING THE ARCHITECTURAL DESIGN AND MAINTENANCE PROCESSES TO ENSURE BUILDING MAINTAINABILITY: A MODEL PROPOSAL adlı bu tezin Doktora tezi olarak uygun olduğunu onaylarım.

Prof. Dr. Sema ERGÖNÜL

Tez Yöneticisi

Bu çalışma, jürimiz tarafından Yapı Mühendisliği Anabilim Dalı'nda doktora tezi olarak kabul edilmiştir.

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Bu tez, Mimar Sinan Güzel Sanatlar Üniversitesi Fen Bilimleri Enstitüsü tez yazım kurallarına uygundur.

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ABSTRACT

Prolonging the useful life of existing building stocks has become even more important for national economies with rapid development of construction industry and increasing costs of new construction. Furthermore, continuous development of new construction technologies and building materials due to the rapid development of construction industry as well as growing demand for higher building standards cause an increase in the complexities of building systems thus maintainability problems and high maintenance costs during the operation phase. While considering that proper maintenance practices are also enable three pillars of sustainability – social, economic and environmental-; hence, the importance of effective building maintenance and thus building maintainability concept is being increasingly recognized throughout the world. It has been revealed from the literature that owners and facility managers have to deal with various maintainability problems as the consideration of future maintenance activities are mostly neglected and ignored by various groups of people involved in different phases of building life cycle. Detailed examination of the previous studies figured out that faulty decisions taken in design phase have the highest impact on building maintainability.

Accordingly, the main aims of the thesis are, to identify building maintainability factors that should be paid attention during architectural design and maintenance management processes, to understand the frequency of occurrence of the problems due to faulty decisions and the shortcomings of current practices in Turkey. Then the thesis aims to develop short-long term strategies for identified areas of concerns and further to propose a model peculiar to Turkey. In accordance with the aims of the thesis, a questionnaire has been conducted with maintenance managers of large scale buildings in Turkey and 42 acceptable responses have been obtained from approximately 150 managers reached out.

Considering the architectural areas of concerns appeared from the survey, the involvement of a maintenance expert in design phase is proposed to provide information regarding the points to be paid attention while selecting building materials, designing service areas and making provisions for ventilation requirements in indoor spaces. In order to deal with inadequate provisions for waterproofing as a most common problem; another new actor, supplier is proposed to be involved in design phase to provide designers information about the insulation performance of materials and proper detailing for such materials. In addition supplier could also provide adequate knowledge to maintenance expert and designers regarding the performance of the materials and their fitness for purpose.

Depending on the factors pertaining to maintenance process that come into forefront from the survey; development of user feedback system and user manuals, and providing regular trainings about technical and practical issues for maintenance staff

are proposed for the efficiency of management practices. Further, obtaining cost and performance data of materials and equipment is recommended as they are important determinants for maintenance planning and budgeting.

In terms of long-term strategies for the improvement of building maintainability; legal obligations are proposed for the involvement of a maintenance expert during design, for waterproofing provisions and for adding LCCA criterion in tendering phase. Moreover; establishment of material database and incentives for developing maintainability database by maintenance manager are supposed to be a nation-wide source for the building industry. Finally, modifications into the current education system are recommended in order to improve designers' knowledge regarding maintainability and to develop the facility management profession, hence introduce competent managers and experts for the industry.

Proposed strategies and the model assumed to enable maintainability problems, building defects and consequent maintenance costs be minimized and to ensure optimum performance of building along with its all components throughout the lifespan.

ÖZET

Binalar, yapımları tamamlandıkları andan itibaren iklimin, çevresel faktörlerin, kullanımın, yıpranma ve aşınmanın etkisiyle bozulmaya başlamakta; o andan itibaren binaların olumsuz süreçten en az derecede etkilenmesi için tüm bina bileşenlerinin *bakım-onarım ihtiyacı ortaya çıkmaktadır. İnşaat endüstrisinin hızlı gelişimi ile beraber inşaat maliyetlerinin giderek artmasıyla; mevcut bina stokunun faydalı ömrünün uzatılması ülke ekonomisine katkı sağlaması açısından giderek daha önemli hale gelmektedir. Bunun yanında; binanın yatırım değerinin korunması, işlevinin ve performansının sürdürülmesi, onarım ve yenileme maliyetlerinin azaltılması, sürdürülebilir kalkınmanın üç prensibinin –sosyal, çevresel ve ekonomik- sağlanması vb. katkılar sağlayacağı düşünüldüğünde binalarda bakım-onarım faaliyetlerinin etkin şekilde sürdürülmesinin önemi ve gerekliliği daha iyi anlaşılmaktadır. Ancak; tesis yöneticilerinin ve mal sahiplerinin karşı karşıya kaldığı yüksek bakım-onarım ve işletme maliyetleri, faaliyetlerin etkin bir şekilde sürdürülmesinin önünde problem olarak durmaktadır. Yapılan çalışmalarda işletme ve bakım-onarım maliyetlerinin bir binanın toplam yaşam boyu maliyetinin %50 ile %80'ini oluşturduğu tespit edilmiştir. En düşük ilk yatırım maliyetinin en ekonomik çözüm olmadığı yapılan birçok araştırma ve yaşam boyu maliyet analizleri ile belirlenmiş olmasına karşın; birçok işveren, yüklenici ve tasarımcı projenin ekonomik açıdan yapılabilirliğini ilk yatırım maliyetlerini esas alarak değerlendirmektedirler. Dolayısıyla binanın, kullanım aşamasında ortaya çıkabilecek maliyetlerinin büyüklüğü göz ardı edilmektedir.

İnşaat endüstrisindeki hızlı gelişmelere bağlı olarak yeni bina malzemelerinin ve inşaat teknolojilerinin ortaya çıkması, bunun yanında daha yüksek standardı karşılamak için tasarlanan modern binalar; bina sistemlerinde karmaşıklığın, bakım-onarım problemlerinin ve buna bağlı maliyetlerin giderek artmasına neden olmaktadır. Bu noktada, bakım-onarım faaliyetlerinin kolaylığını, ayrıca verimli ve etkin bir şekilde sürdürülmesini ifade eden "maintainability" kavramının önemi ortaya çıkmaktadır. Dünya genelinde bu konu ile ilgili farkındalığın artması ile birlikte bakım-onarım problemleri ve bu süreçte ortaya çıkan maliyetler bir çok çalışmanın odak noktasını oluşturmaya başlamıştır. Bu tez çalışması kapsamında yapılan literatür çalışmalarının sonucunda; bir projenin yaşam döngüsü boyunca farklı süreçlerde yer alan kişiler tarafından projenin gelecekteki bakım-onarım gereksinimlerinin dikkate alınmadığı ve ihmal edildiği ortaya çıkmıştır. Bunun en büyük nedeni; geleneksel uygulamada proje geliştirme aşamasında yer alan aktörlerin (tasarmcı, mühendis, yüklenici vb.) proje tamamlandıktan sonra herhangi bir sorumluluklarının kalmaması olabilir.

* Bu çalışmada kullanılan "bakım-onarım" terimi, yabancı literatürde "maintenance" olarak ifade edilen, bakım, onarım, yenileme, temizleme ve servis sağlama faaliyetlerinin tümünü kapsamaktadır.

Proje tamamlandıktan sonra sorumluluk tesis yöneticisi ve bakım-onarım yöneticisi olarak tabir edilen binanın işletilmesinden ve bakım-onarım faaliyetlerin yönetilmesinden yükümlü kişilere geçmektedir. Bu kişiler binayı teslim aldıktan sonra proje geliştirme aşamasında alınan hatalı kararların sonuçları ile karşı karşıya kalmakta ve bunların üzerinde kontrol sahibi olamamaktadırlar. Yapılan akademik çalışmalar incelendiğinde proje tasarımı aşamasında alınan kararların, bina kullanım aşamasında karşılaşılan bakım-onarım problemlerinin ve bina hasarlarının en büyük nedeni olduğu anlaşılmaktadır. Ayrıca; bu problemlerin ve hasarların yaklaşık olarak %40 ile %60 oranında doğru tasarım uygulamaları ile önlenebilir olduğu ortaya çıkmıştır. Çalışma kapsamında, halihazırda teknik müdür olarak görev yapmakta olan "Bina Tesis ve Enerji Yöneticileri Derneği (BITED)" ve "Uluslararası Tesis Teknik Müdürleri Derneği (UTTMD)" başkanları ile görüşmeler yapılmıştır. Bu görüşmelerde; tesisin işletme sürecinde karşılaşılan bakım-onarım problemlerin büyük çoğunluğunun mimari tasarım aşamasında alınan hatalı kararlardan kaynaklandığını belirtmişlerdir. Bakım-onarım faaliyetlerinin etkinliğinin önündeki bir diğer en büyük engelin ise; ülke genelinde tesis yönetimi disiplini ile ilgili farkındalığın oluşmamış olması ve ilgili eğitim eksikliği nedeni ile yöneticilerin yeterli yönetim yetkinliğine sahip olmamaları olarak belirtilmiştir. Türkiye genelinde yapılmış çalışmalar incelendiğinde bakım-onarım faaliyetlerinin kolaylığının sağlanmasına ve işletme maliyetlerinin azaltılmasına yönelik olarak yapılmış akademik çalışmalara rastlanmamaktadır. Bunlarla birlikte, Türkiye'de gerek hızlı nüfus artışı gerek ise inşaat sektörünün hızlı gelişimi ile birlikte sayısı giderek artan büyük ölçekli yatırımlar düşünüldüğünde; tüm bu eksiklikler büyük yatırımlar harcananarak yapılan tesislerin faaliyetlerini etkin şekilde sürdürebilmelerinin önünde problem olarak durmaktadır.

Bu çalışmanın amacı;

- tesislerin bakım-onarım kolaylığını etkileyen ve problemlerin oluşmasına neden olan, mimari tasarım ve bakım-onarım yönetimi faktörlerinin saptanması; ayrıca, bu faktörlerin karşılaşılma sıklığı ile beraber önem derecelerinin belirlenmesi,
- bakım-onarım kolaylığı açısından Türkiye'deki mevcut uygulamalardaki eksikliklerin saptanması,
- belirlenen problem alanlarına yönelik kısa ve uzun vadede stratejilerin geliştirilmesi,
- binalarda bakım-onarım faaliyetlerinin verimliliğinin ve tüm bina bileşenlerinin etkin kullanımının sağlanmasına yönelik olarak; mimari tasarım kararlarını ve yönetim sürecini etkileyen Türkiye'ye özgü bir modelin geliştirilmesidir.

Belirlenen amaç doğrultusunda; ülke genelinde tesis yöneticileri ile anket çalışması yapılmış ve toplamda 42 kullanılabilir yanıt elde edilmiştir.

Çalışma sonucunda ortaya çıkan mimari tasarım ile ilgili problem alanları dikkate alındığında; bir bakım-onarım uzmanının tasarım sürecine dahil olarak yapı malzemelerinin seçimi, servis alanlarının tasarımı ve iç mekanlardaki havalandırma gereksinimleri ile ilgili dikkate alınması gereken noktalar hakkında tasarımcılara bilgi sağlaması gerektiği önerilmiştir. Kullanım amacından bağımsız olarak tüm tesislerde en sık karşılaşılan problem olan su yalıtım problemlerinin oluşma sıklığını en aza indirmek için tedarikçinin de tasarım aşamasına dahil olması, malzemelerin yalıtım performansları ve doğru detaylandırma konusunda tasarımcılara bilgi sağlaması önerilmiştir. Bunun yanında tedarikçinin tasarım aşamasına dahil olması ile bakım-onarım uzmanına ve tasarımcıya gereken durumda yapı malzemelerinin performansı ve kullanım amacına uygunluğu ile ilgili bilgi sağlayabilecektir.

Yönetim faaliyetlerinin etkinliğinin sağlanması için bakım-onarım planlamasının doğru şekilde yapılması büyük önem taşımaktadır. Bunun yanı sıra çalışma sonucunda bakım-onarım süreci ile ilgili ön plana çıkan problem faktörlerine bakıldığında; kullanıcı geri bildirim ve kullanım sonrası değerlendirme (POE) sistemlerinin geliştirilmesi, kullanım kılavuzunun sağlanması ve bakım-onarım personeline teknik konularda ve uygulamaya yönelik düzenli eğitimlerin sağlanması önerilmiştir. Bakım-onarım planlamasının ve bütçelemenin doğru şekilde yapılabilmesi için malzemelerin ve ekipmanların maliyet ve performans verilerinin temin edilmesi gerekmektedir. İhale aşamasında işveren tarafından yüklenicilere yaşam boyu maliyet analizi yapmaları şart koşulmalı ve tüm veriler ihale dokümanlarına eklenmelidir. Böylelikle tüm malzemelerin kullanım aşamasındaki performansları ve tesisin işletme maliyetleri dikkate alınmış olacaktır. Elde edilen bu veriler daha sonra ilgili tesisin yöneticisi ve/veya bakım-onarım yöneticisi ile paylaşılmalıdır.

Tesislerde bakım-onarım kolaylığının sağlanmasına yönelik olarak uzun vadeli stratejilerin de geliştirilmesi gerekmektedir. Öncelikle bir bakım-onarım uzmanının tasarım aşamasına dahil olması, su yalıtım gereksinimlerinin sağlanması ve yaşam boyu maliyet analizlerinin ihale sürecinde şart koşulması ile ilgili yasal zorunlulukların sağlanması gerekmektedir. Ayrıca; yapı malzemelerinin performanslarına yönelik bir veri tabanın oluşturulması ve tesis yöneticileri tarafından kullanım sonrası değerlendirme sonuçlarından (POE) ve karşılaştıkları problemlerden faydalanarak bir bakım-onarım veri tabanının oluşturulmasına yönelik teşviklerin sağlanması, yapım endüstrisi için önemli başvuru kaynaklarının oluşmasını sağlayacaktır. Kullanım aşamasındaki bakım-onarım faaliyetlerinin kolaylığının sağlanması ve yapı bileşenlerinin performansının etkin şekilde sürdürülebilmesi ile ilgili tasarımcılara bilgi ve farkındalık sağlanması, dolayısıyla mevcut mimarlık eğitiminde bir takım değişikliklerin yapılması gerektiği ortaya çıkmıştır. Bununla birlikte; tesis yönetimi konusunda uzmanlığın geliştirilmesi için üniversiteler tarafından eğitim programlarının oluşturulması; yetkin yöneticilerin ve uzmanların yetiştirilmesi açısından büyük önem taşımaktadır.

Çalışma kapsamında geliştirilen model, aynı zamanda özel bir sağlık kurumunun tesis müdürü olarak görev yapmakta olan UTTMD Başkanı’na tanıtılmıştır. Yapılan görüşme sonucunda önerilen modelin yararlılığı, etkinliği ve uygulanabilirliği teyit edilmiştir.

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June, 2016 **Nur Atakul**

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1 INTRODUCTION

1.1 PROBLEM STATEMENT

With rapid development of construction industry and increasing costs of new construction, prolonging the useful life of existing building stocks has become even more important for national economies. All building structures, materials, finishes and services start to deteriorate from the moment they are completed through the adverse effects of climatic and environmental conditions, usage and wear and tear. Henceforward, the need for maintenance of all building assets begins in order to minimize these negative effects.

The importance of effective building maintenance and assessing the total costs which occur during the life span of the building is being increasingly recognized throughout the world, as owners and facility managers encounter high maintenance costs. However many clients, contractors and designers are still considering the economic feasibility of projects based on initial investment costs although research studies and life-cycle cost analyses reveal that the alternative with lowest initial investment cost may not always be the most economical option as cheaper materials often require more frequent maintenance. Previous studies have shown that the maintenance and operation costs account for 50% to 80% of the total life cycle cost (Flanagan et al., 1989; Griffin, 1993; Kirk and Dell'Isola, 1995). As a result of the increasing awareness on the aforementioned high ratio, efficiency of the building maintenance in order to decrease the cost of maintenance during the operation has become even more important.

Apart from reducing maintenance costs, efficient building maintenance further aims to:

- prolong the useful life of the building,
- maintain the function and building performance,
- maintain the image of the building,

- maintain the value of investment,
- ensure the safety and comfort,
- attract and retain satisfied users,
- maintain the historical and/or architectural value of the building (Seeley, 1987; Arditi and Nawakorawit, 1999b; Ramly et al., 2006; Moller and McCartney, 2007).

Maintenance related problems and associated costs that occur during the useful life of a building and factors affecting the ease of maintenance have become one of the major concerns in many countries (Arditi and Nawakorawit, 1999a; Building Construction Authority (BCA), 2000; Building Maintenance Information (BMI), 2000; Lam, 2000; Boussabaine and Kirkham, 2004; Chong and Low, 2006; Ramly et al. 2006; Hassanain et al., 2013). In recent years, the construction industry has been experiencing an increase in higher building standard demands besides the development and use of new building materials and construction technologies. This has led to an increase in complexities of building systems, as well as maintainability problems and additional costs.

A survey conducted by Lam (2000) in Hong Kong has found that up to 40% of maintenance faults were related to design, up to 30% were related to construction or installation and up to 30% were related to maintenance management. Another survey in Malaysia showed that about 47% of defects in public housing were caused by design-related negligence, 18% from misuses of facilities, 17% from materials, 15% from construction, 15% from poor maintenance, and 5% from vandalism (Ramly et al., 2006). The Building Research Establishment in England conducted a survey of building failure patterns and their implications and found that 58% of defects were caused by faulty design (Seeley, 1987).

As a result of above mentioned and similar studies, it can be understood that the consideration of future maintenance activities are mostly neglected and ignored through the building life cycle by various groups of people involved in different phases of the building production (Seeley, 1987; Al-Hammad et al., 1997; Lam, 2000; Chew et al., 2004a; Chong and Low, 2006; Ramly et al., 2006). The reasons behind the lack of knowledge or ignorance of maintainability considerations are several. Generally in traditional practice, both designers and other professionals involved in building production phases are not responsible for the building once the building is completed and this may be one of the major reasons behind the ignorance of maintainability considerations. After completion, the responsibility is taken over by facility manager who is responsible for the maintenance management activities throughout the operational lifespan of the building. As a result of faulty decisions made in project development phases, managers are faced with a multitude of frequent and costly building performance problems during the occupation phase and have very little control to minimize maintainability problems and defects. Based on the literature and the current practices in Turkey, it is clear that the contribution of a maintenance expert in early phases of building development process is not taken into consideration and there is a lack of communication with maintenance experts to seek advice about the decisions based on their practical exposure to maintainability problems that are faced during the occupancy. These deficiencies are the main cause of the lack of knowledge about maintainability considerations in the early phase of building development and may be due to unfamiliarity of facility management profession in the local industry in Turkey. With increasing investments in our country such as residences, shopping malls, multi-storey buildings due to either rapid growth of population or of construction industry, awareness about 'facility management' concept of which building maintenance management is one of the major field of activity has begun to emerge.

Field surveys which identify the factors that affect the ease of maintenance and/or cause defects during the occupancy reveal that design decisions have the highest percent and have a significant impact on the future performance of the building. Condition survey by Low and Chong (2004) showed that proper design could have prevented at least 66% of latent defects had been found during the occupancy. Faulty design decisions place a heavy burden on the building for its operational life and there is no compensation for it. According to the general way of thinking that maintenance and design are two activities which are not connected, designers are not fully aware of the impact of their decisions on the post occupation phase.

Poor consideration of maintainability problems which may occur during the useful life of the building and/or not taking decisions for the efficient use of all building components in design process may cause deterioration and damage of the building components, failure of managing these problems, user discomfort and increased related costs. Therefore, it is crucial that future maintainability issues need to be taken into consideration at the design stage. Dunston and Williamson (1999) have defined effective design as the design characteristic which incorporates function, accessibility, reliability and ease of servicing and repair into all active and passive system components that minimizes costs and maximizes benefits of the expected life cycle value of a facility.

Based on a literature review and interviews with the facility managers it is realized that the most common and frequent faults faced during the occupancy arises due to architectural design decisions. However, until recently, the early consideration of maintainability issues in architectural design was not considered as a common practice for the building industry in Turkey. Besides, it is understood that facility managers' / maintenance staffs’ decisions and management plans during the post-occupancy also have a high impact on the efficiency of maintenance activities. Especially in Turkey along with unfamiliarity of facility management discipline, there is also a lack of educational background of facility managers. This profession is practiced by people from various fields of education (e.g. mechanical engineer, electrical engineer, high school graduate etc.) Therefore, there is a need to identify and assess the maintainability factors that should be paid attention during architectural design and maintenance management processes. In this context, even though there are several studies conducted in different countries in order to identify faulty design decisions, there have been limited studies that have examined the factors pertaining to architectural decisions and maintenance process, and also when considering our country, there hasn't been any academic study about these issues. These circumstances constitute an obstacle to the buildings’, which require sizable investment, carrying on their activities effectively.

1.2 RESEARCH AIMS

The main aims of this research are to:

- identify the factors that affect the ease of maintenance and cause maintainability problems during the occupation phase pertaining to architectural design and maintenance management process as well as their importance and frequency,

- find out the shortcomings of current practices in Turkey regarding building maintainability,
- develop short and long-term strategies for main areas of concerns,
- develop a model peculiar to Turkey that would affect the architectural design decisions and maintenance management process in order to ensure effectiveness of maintenance operations and efficient use of all building components.

1.3 SIGNIFICANCE OF THE RESEARCH

It is revealed from the survey of literature and the interviews with facility managers that managerial and architectural design decisions have significant impact on occupation phase and maintenance activities. Therefore, identifying maintainability factors that affect ease of maintenance and cause problems during the occupational phase pertaining to architectural design and managerial decisions, developing strategies and proposing a model are of paramount importance to provide knowledge and awareness about maintainability considerations to architectural design team members and facility managers/maintenance team. Moreover, through overcoming the shortcomings in current practices in Turkey, building industry would also be benefited from these strategies.

1.4 ASSUMPTIONS

Providing knowledge and awareness about maintainability considerations to architectural design team members and facility managers / maintenance team and further introducing new regulations in the building industry, it is assumed that probability of occurrence and negative effect of maintenance related problems and maintenance requirements will be minimized during the occupation phase. It is crucial not only to ensure the ease and effectiveness of maintenance operations and to minimize related costs but also for the sake of national economy. Hence; all of the building components can be easily maintained with less expense, less time and less effort and the optimum performance of building can be ensured throughout its useful life.

1.5 SCOPE OF THE RESEARCH

The present study has several limitations. First, only the perspectives of facility managers are evaluated as they are the responsible parties for dealing with maintainability problems. Another limitation of this study is that only the decisions made in architectural design phase and maintenance activities in occupation phase of building life cycle are assessed. Evaluation of the decisions made in other phases e.g. engineering design and execution phase etc. are excluded from the study. This study is irrespective of location as well as the type of building.

1.6 THESIS ORGANIZATION

The thesis consists of six chapters. As an introductory part, Chapter 1 firstly defines the identification process of the research problem through general review of literature and interviews carried out by the author of this thesis. Thereafter; main aim and significance of the research as well as assumptions, scope and methodology of the research is mentioned respectively.

In Chapter 2; building maintenance concept is introduced through the provision of its history and definition and the importance of building maintenance in terms of economic, social, physical and legal aspects. Then, building maintenance management system and processes are explained, types of maintenance strategies and factors enhancing management activities are highlighted. Maintainability term and its importance due to ever increasing maintainability problems and maintenance cost are discussed, furthermore; importance of taking into account maintainability considerations during the whole building life cycle is emphasized. In the last part; previous field studies are discussed in detail which have been carried out to identify factors affecting maintainability and attributed building life cycle phases. Thereafter; research undertaken regarding decisions taken during the design phase are further examined and problem factors that should be assessed within the scope of this thesis are identified.

Chapter 3 focuses on building life cycle phases which have been determined as a result of the examinations carried out in previous chapter. Therefore; maintainability factors pertaining to architectural design process and maintenance management process are considered to provide a basis for the survey to be conducted. Factors are discussed in detail by gathering under two groups - as architectural design factors and factors pertaining to management process-; further, factors are classified by the author in order to provide a better understanding.

The first part of Chapter 4 provides information regarding the survey carried out within the scope of the thesis. First, various data collection methods are examined in order to determine the appropriate data collection method for the survey. Then, the structure of the survey, which has been developed according to determined data collection method, is described; thereafter the survey implementation process is explained. Second part of the chapter consists of the analysis results of the survey carried out. Analyses are demonstrated for demographic profile of the respondents, current maintenance practices, importance of the maintainability factors and occurrence frequency of maintainability problems respectively. Finally, survey findings are discussed along with the comments of the respondents.

Chapter 5 introduces a model within the scope of the thesis. The chapter consists of indication of the shortcomings in traditional practice, demonstration and explanation of the flowchart diagram created for the building life cycle and strategies developed against the shortcomings of current practices in Turkey in order to improve maintainability of buildings. At the end of the chapter, verification of the proposed model is presented.

1.7 METHODOLOGY

The methodology of this research consists of seven phases. The purpose, activities undertaken and the outputs of each phase are summarized in Figure 1.1.

Identification of the Problem Area

In order to have an idea about the problems encountered during the occupation process regarding building maintainability, following activities were undertaken;

- General literature review on building maintenance. Research studies made to identify areas of concern and also theses, books and articles that have been published to develop solutions are examined. Gap analysis is made to identify the areas that should be further studied.

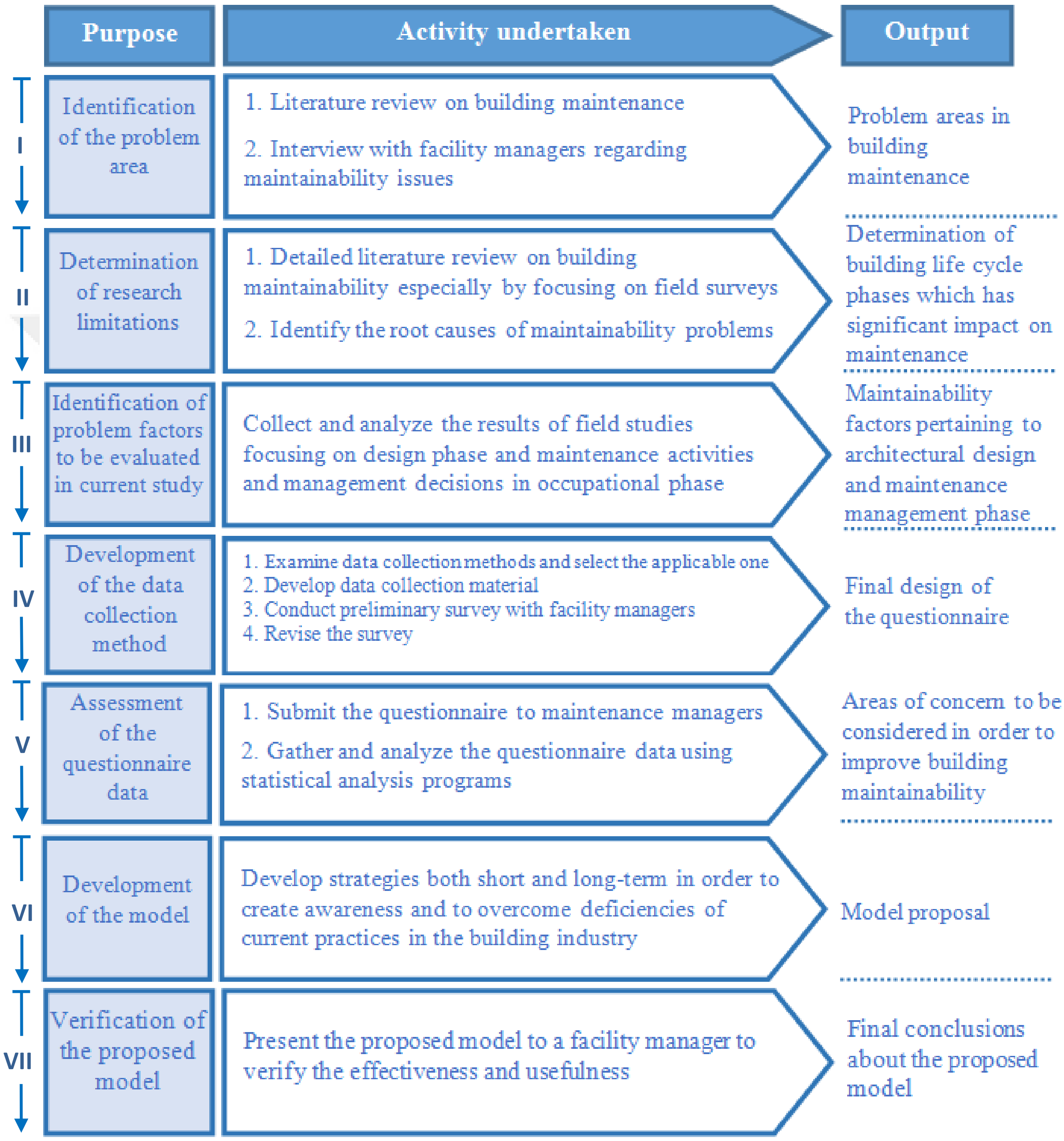

Figure 1.1. The methodology of the research; purposes, activities and outputs

- Interview with facility managers regarding maintainability issues: Through the interviews with facility managers, one of whom is the Head of International Association of Facilities Technical Managers (UTTMD), general information regarding maintenance are obtained. In addition, difficulties encountered and their underlying causes are identified and besides, information obtained are examined to find out whether it is compatible with literature or not.

As a result of these activities, areas of concern that require more attention and will provide an insight into this research are provided.

Determination of Research Limitations

After identifying the research area that will be focused, further examinations are carried out to determine the research limitations. These examinations include;

- Detailed literature review on building maintainability especially by focusing on previous field surveys. Previous field surveys which have been conducted in various countries and for various kinds of buildings are examined and then collected. The aim is to identify maintainability problems and building defects that are attributed to decisions taken and activities performed during the whole building life cycle phases.
- Identify the root causes of building maintainability problems. Previously selected field surveys and their findings shed light on determining the limitations. Detailed analyses are made with regard to the root causes of maintainability problems and building defects in order to figure out which building life cycle phases that they are attributed to.

Through the research activities undertaken; the building life cycle phase, in which decisions taken has the most significant impacts on further maintenance activities is identified. Thus the limitation and the area of concern of this research are determined for further studies to be conducted within the scope of the thesis.

Identification of Problem Factors to be Evaluated in Current Study

In this phase it is aimed to form a basis for the evaluation of the current situation and practices regarding building maintainability in Turkey. In accordance with this purpose, research activities are undertaken by focusing on architectural design and occupation phase of building life cycle. Field studies that have been carried out to identify factors affecting maintainability with regard to;

- decisions taken during architectural design phase and
- maintenance activities performed and decisions taken during the building occupation phase are examined.

Analyses are made without making discrimination on the type of the building to identify common maintainability problems and their causes. Further examinations are carried out in order to assess the compatibility of these factors with the current industry conditions of the country and besides, the evaluability of these factors by the persons in manager positions are taken into account. Therefore; factors that will be evaluated within the scope of this thesis are determined.

Development of the Data Collection Method

In order to develop the data collection method to be carried out within the scope of the thesis, following activities are performed respectively;

- Examine data collection methods and select the most appropriate method. As the method of data collection depends on a number of parameters, various methods have been developed. In this phase; positive and negative sides of these methods –e.g. descriptive and analytical surveys, experiments, case studies - are examined. Thereafter, depending on the respondents' profile, their availability and reachability and also the available resources; web-based and self-administered questionnaire survey is considered to be the most suitable and effective method for this research. Google forms tool is selected to convert the questionnaire into web-based form.
- Develop data collection material. Selected survey method is organized into four sections. In the first two sections, it is aimed to find out demographic profiles of the respondents, characteristics and maintenance practices of the buildings which they are currently managing respectively. Third section is developed for the evaluation of each identified maintainability factor in terms of level of importance, while in the fourth section maintainability problems are required to be evaluated with regard to frequency of occurrence. Both third and fourth section requires responses on a 5-point Likert scale.

- Conduct preliminary survey with facility managers. In order to assess the validity and acceptability of the developed questionnaire preliminary survey was conducted with two maintenance managers.

- Revise the survey. According to facility managers remarks, revisions were made on identified maintainability factors and related problems. Thereafter; the questionnaire was checked over by a Professor of Statistic in Mimar Sinan Fine Arts University, to ensure accurate assessment of the survey results by organizing the survey in a proper way.

As a result of all of these activities undertaken, final questionnaire is provided for delivering.

Assessment of the Questionnaire Data

In order to obtain and analyze the result of the survey and assessments of maintenance managers, following activities are carried out;

- Submit the questionnaire to maintenance managers. As finding the contact information of maintenance managers is difficult, and it is aimed to reach as many managers as possible; the necessity of communicating with them through various associations in the country has been emerged for the implementation of the survey. These associations include International Association of Facilities Technical Managers (UTTMD), Association of Aegean Technical Managers (EgeTMD) and Bursa Technical Managers Platform. An electronic invitation containing the survey link is sent to all of the members by the heads of these associations. For enhancing the response rate, 10 selected large-scale buildings are visited without getting any appointment, in order to enter into a direct contact with maintenance managers. After giving information about the research and requesting them to participate in research, the survey link is sent.

- Gather and analyze the questionnaire data using statistical analysis programs. Entire responses are collected and displayed immediately in a corresponding Google Forms spreadsheet. In order to analyze the survey results; all statistical analyses are carried out using Statistical Package for Social Science (SPSS version 19). Frequency distribution, median, mean and SD is used as descriptive statistics. Reliability analysis is carried out to measure internal consistency and reliability of the sections which consist of Likert scale responses. Further analyses are carried out for comparing independent samples through non-parametric tests of Mann Whitney U and Kruskal Wallis.

Assessment results of the survey data and the comments obtained from the respondents provide the areas of concern that should be considered in order to improve building maintainability.

Development of the model

Considering the areas of concerns revealed from the survey, short and long-term strategies are developed for the improvement of building maintainability in Turkey. First of all, a flowchart diagram for building life cycle is created for the building industry. Moreover, for creating awareness in the industry and for achieving the tasks in the flowchart to be carried out in effective and proper way, long-term strategies are developed in order to overcome the shortcomings of current practices in Turkey regarding building maintainability.

Verification of the proposed model

Proposed model is presented to the Head of the International Association of Facilities Technical Managers (UTTMD) in order to verify the effectiveness and usefulness. Then, final conclusions are developed and presented.

2 BUILDING MAINTENANCE

2.1 BUILDING MAINTENANCE CONCEPT

Prior to World War II, maintenance was considered to be an additional cost burden of the facility which did not increase the value of product. Thus, in this period maintenance process was restricted to fixing the unit when it breaks because it was the cheapest alternative and was accepted as a reaction to the most immediate crisis rather than a planned activity (Mselle, 1997; Shenoy and Bhadury, 1998). With the development of advanced engineering and scientific technologies after World War II, the concept of maintenance was formally initiated by the military services of United States in early 1950's (De Silva et al., 2004).

As it includes cleaning, inspecting, repairing, replacing and care of the building's various systems and components, maintenance is a vital tool in the life span of every structure. Until recently, building owners and users spent too much money on excessive maintenance components for their buildings; in other instances, they let buildings deteriorate into a state from which it is very difficult and costly to recover (Arditi and Nawakorawit, 1999a). Due to the increasing economic concerns; building maintenance has attracted growing attention in recent years.

2.1.1 Definitions

There are many different definitions of building maintenance, which is a major field of activity within the scope of facilities management discipline. Standards, definitions and expectations develop and change over time. For example, BS 3811: 1964 (British Standards Institution, 1964) defined maintenance as "work undertaken in order to keep or restore every facility, i.e. every part of a site, building and contents, to an acceptable standard". Committee on Building Maintenance (1972) developed this definition with adding the word 'improve' to reflect the fact that most buildings have long life expectancies and acceptable standards of amenity and performance will rise substantially over their lifetime (Scarrett, 2011). Therefore, building maintenance was defined as “work undertaken in order to keep, restore or improve every facility, i.e. every part of a building, its services and surrounds, to a currently accepted standard and to sustain the utility and value of the facility”. Finally British Standard Institute in BS 3811 (BSI, 1993) has revised the definition and widely accepted one; "building maintenance is the combination of all technical and administrative actions, including supervision actions, intended to retain an item, or restore it to a state in which it can perform a required function". Arditi and Nawakorawit (1999a) summarize the definition of maintenance briefly as the preservation of a building so that it can serve its intended purpose.

In light of these definitions it could be stated that maintenance is important in order to achieve the necessary standards of performance. However, of equal importance is the need to consider methods of planning and organizing the maintenance work.

2.1.2 Need for Building Maintenance

It is highly desirable, but hardly feasible, to produce buildings that are maintenance free. Like human bodies, buildings and their entire components age naturally as time goes by. Nevertheless, it doesn’t mean that aged buildings always pose problems, unless they have deteriorated due to lack of maintenance. All building structures, materials, finishes, and services start to deteriorate from the moment they are completed due to the adverse effects of climatic and environmental conditions, usage and wear and tear. Henceforward, the need for maintenance of all building assets begins in order to be minimize all of these negative effects.

In physical aspects; the main role of building maintenance is to keep the function and performance of the building to a required standard and prolong the useful life of the building. Besides, while minimizing the negative effects mentioned in the paragraph above, the image of the building will also be maintained. Along with the contribution to longer asset life; maintenance practices are also enable three pillars of sustainability –social, economic, environmental-.

In social aspects; building maintenance activities increase the comfort, health and safety of the users/occupants as well as maximize the aesthetic value of the building. Thus it will ensure the satisfaction of the users. In addition; a building may have historical and/or architectural value for the country where it is located, building maintenance ensures these values of the building to be conserved.

By minimizing the effect of physical deterioration and depreciation on the value of all building components, building maintenance has great importance for the purpose of maximizing and/or maintaining the investment value of the building. Besides, a properly planned maintenance minimizes repair and replacement costs due to fewer breakdowns and reduced wastage of material. The building maintenance is also significant for the economy not only in terms of the scale of expenditure involved, but also to ensure the stability of a nation's stock of buildings due to the considering rapid development of construction industry and increasing costs of new construction (Zulkarnain et al. 2011; Seeley, 1987).

In addition to economic, social and physical aspects, building maintenance is also required for legal aspects. For instance occupiers –facility managers and/or owners- are required to take responsible steps in maintaining their properties. In the absence of maintenance, they are liable for any injury or damage to persons or goods caused by their property (Lau, 2008).

According to Alner and Fellows (1990) the objectives of building maintenance are to:

- ensure that the buildings and their associated services are in a safe condition;
- ensure that the buildings are fit for use;
- ensure that the condition of the building meets all statutory requirements;
- carry out the maintenance work necessary to maintain the value of the physical assets of the building stock; and
- carry out the work necessary to maintain the quality of the building.

Lastly, it should be stated that these benefits of building maintenance can be accrued in short or long term.

2.2 BUILDING MAINTENANCE MANAGEMENT

Even though there is a significant need for building maintenance activities for economic, physical, social and legal aspect as mentioned in the previous section, how to carry out maintenance activities plays an important role at this point. Thus, implementing maintenance activities in a proper and systematic way should be provided. Along with the importance of building maintenance activities, awareness regarding efficient management practices has not been raised until recently.

Generally building maintenance has been regarded as a "necessary evil" and an inevitable cost burden (Moua and Russell, 2001, pp.239). When the economy is bad, building maintenance budgets are too much subject to reduction and even in good conditions, there is usually a reluctance to spend in order to preserve the condition of the building. Hence, maintenance standards are usually met at the barest minimum rather than aiming for the optimum standards (Chew et al., 2004a). In cases where optimum standards are ensured, owners and facility managers complain about the raising maintenance costs. Thus, there is a need for a building maintenance management system to meet the optimum standards at the minimum cost.

Building maintenance management is an operation involving the interaction or combination of technical, social, legal and fiscal determinants that govern and manage the use of buildings (Yik et al., 2002). According to Wordsworth (2001) the main objective of a maintenance management organization is to ensure the required or acceptable standards and level of services provided in the building continuously at the minimum cost. Horner et al. (1997) states that the main objective is to minimize the need of repair on building defects by enhancing planning and implementation, adopting suitable materials and tools at the appropriate time and minimizing the total LCC.

While managing the maintenance activities; the maintenance policy plays a vital role as it compels procedures, maintenance plans and operations are used in the entire process. Thus; building maintenance management should be implemented within an agreed policy which is a written document, and provides a management framework for the maintenance staff to determine appropriate maintenance strategy and standard (Figure 2.1) (Lee and Scott, 2009).

Figure 2.1. Sequences for formulating building maintenance policy and strategy (Lee and Scott, 2009)

Maintenance policy is formulated with three main elements which are choice of maintenance strategy, defining maintenance standard and allocation of maintenance resources. Maintenance strategy in general includes corrective, preventive or condition-based maintenance and it is explained in detail in the next section. Furthermore, maintenance standard is difficult to agree with top management (Zavadskas et al., 1998; Wood, 2003). An acceptable maintenance standard depends very much on available maintenance resources with consideration of common factors such as characteristics related to building, user, technical, administration and political factors (El-Haram and Horner, 2002). Hallberg (2009) developed a model to describe the building maintenance management process as shown in Figure 2.2.

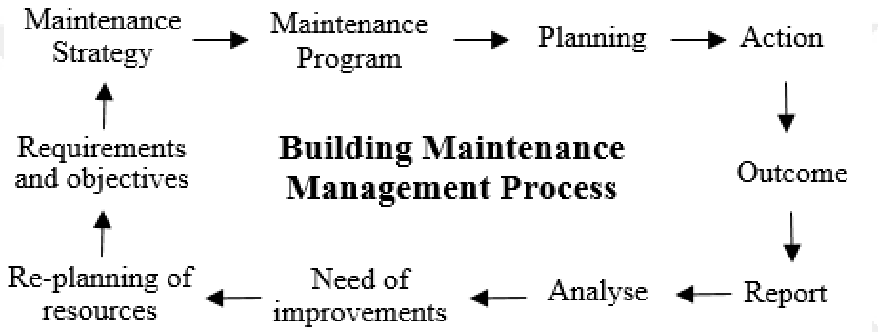

Figure 2.2. The building maintenance management process (Hallberg, 2009)

Lo and Wong suggested that three dimensions -namely cost, quality and time- need to be defined when formulating the maintenance policy and details are shown in Table 2.1 (Lau, 2008). Accompanied by an agreed maintenance policy, effective maintenance management targets the following issues (Lo and Wong, 1998 cited in Lau, 2008):

1) reliability of the operation,

2) recovery after breakdown,

3) customer focus service and

4) total quality of the process

Table 2.1. Three dimensions to be defined in formulating the maintenance policy (Lo and Wong, 1998)

Dimension	**Details**
Cost	The budget available for maintenance and the likely sources of finance
Quality	The standards to which the building and its facilities should be maintained
Time	The life expectancy of the building and its ancillary facilities The response time requires

In their research, Shohet et al. (2003) focused on identifying the main key performance indicators in the maintenance of hospital facilities and they identified four key performance indicators to increase the efficiency of hospital maintenance. These indicators are performance management, composition of labor, efficiency of maintenance and organizational effectiveness and it was stated that these key performance indicators could also be used in the maintenance of any other types of buildings.

Building maintenance management effectiveness has always been an issue that significantly affects the maintenance cost and building performance. Poor building maintenance management practices are neither cost effective nor optimum, and often cause a lot of problems, such as cost overruns, defective building, poor building functionality and others (Ali et al., 2010).

Building maintenance management together with budget constraints, involves decision-making under multiple objectives and uncertainty. Any decisions made have implications on cost, quality, duration, and resource allocation of the building maintenance activities. Therefore several strategic options exist for management of building maintenance. These are explained in the next section.

2.2.1 Types of Maintenance

There are many strategic options available to maintenance manager when maintaining a building. For instance, a maintenance manager needs to decide whether an item should be repaired or replaced, and whether a periodic maintenance should be carried out at fixed intervals. In some cases, a maintenance manager may simply decide to respond to the requests of the users after a failure has occurred. Based on a review of the maintenance literature, it is understood that different strategic options, in other words maintenance types are adopted. They are classified under two categories as planned maintenance and unplanned maintenance (Leong, 2004; Chanter and Swallow, 2007; BS 3811, 1984). According to Horner et al., (1997) and Zuraidi et al., (2011) building maintenance types can be divided into three main strategies as corrective, preventive and condition-based. A commonly held view is that maintenance work load will consist of a mix of all following strategies (Figure 2.3 and Figure 2.4);

- Planned maintenance
- Unplanned maintenance
- Preventive maintenance
- Corrective maintenance
- Emergency maintenance
- Scheduled maintenance

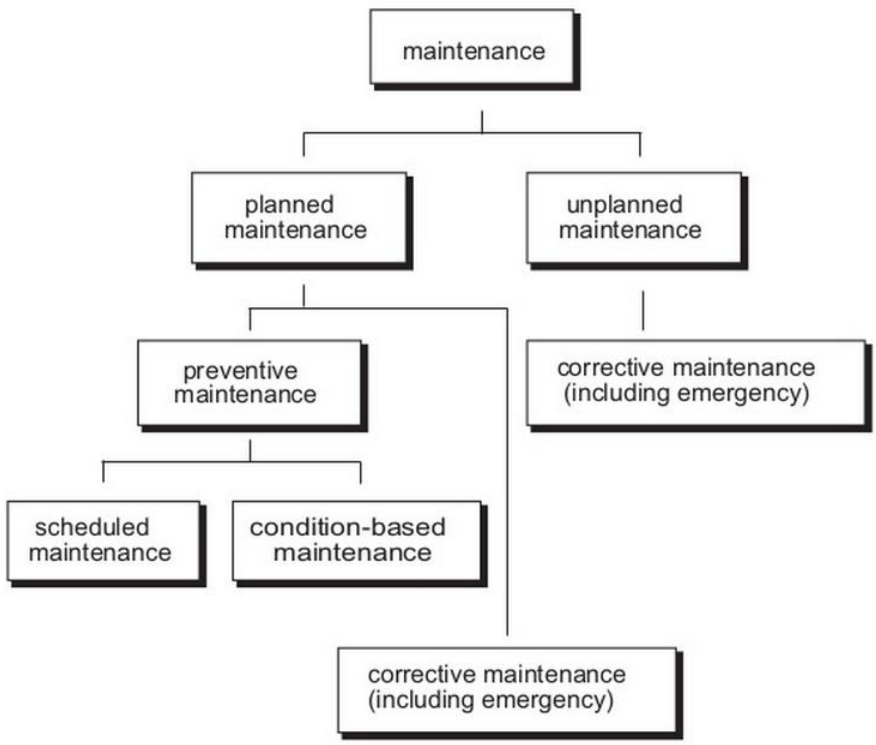

Figure 2.3. Types of maintenance (BS 3811 cited in Chanter and Swallow 2007)

2.2.1.1 Planned Maintenance

Maintenance is organized and carried out with forethought, control and the use of records, to a predetermined plan. Planned maintenance can be divided into two functions, which are preventive maintenance and corrective maintenance (including emergency maintenance).

a) Preventive Maintenance

This type of maintenance was introduced to overcome the disadvantages of corrective maintenance and keeps a building operating at peak efficiency. Among various maintenance strategies, the effectiveness of planned preventive maintenance (PPM) is more challenged by the top management (Horner et al., 1997; Wood, 2003; Lee and Scott, 2009).

Preventive maintenance is carried out in accordance with a predetermined plan at regular, fixed intervals. It is intended to reduce the probability of occurrence of failure, avoiding sudden failure and the performance degradation of an item. In other words, preventive maintenance is carried out to catch small problems before they become big and expensive. Such a strategy is frequently applied to external or internal paint work (BS 3811, 1984; Zuraidi et al., 2011). This strategy can be divided into two sub-strategies as scheduled-based or condition-based maintenance.

- Scheduled-based maintenance is preventive maintenance carried out to a predetermined interval of time, number of operations, mileage, etc. It implies that actions are taken place at a predefined point of time, irrespective of component condition. This strategy requires general knowledge and experience about the risk of failure and service life of the component (BS 3811, 1984; Hallberg, 2009).
- Condition-based maintenance is preventive maintenance initiated as a result of knowledge of the condition of an item from routine or continuous monitoring. A condition-based strategy aims at detecting eventual degradation and incipient failures, so that measures can take place in advance of devastating failures (BS 3811, 1984; Hallberg, 2009).

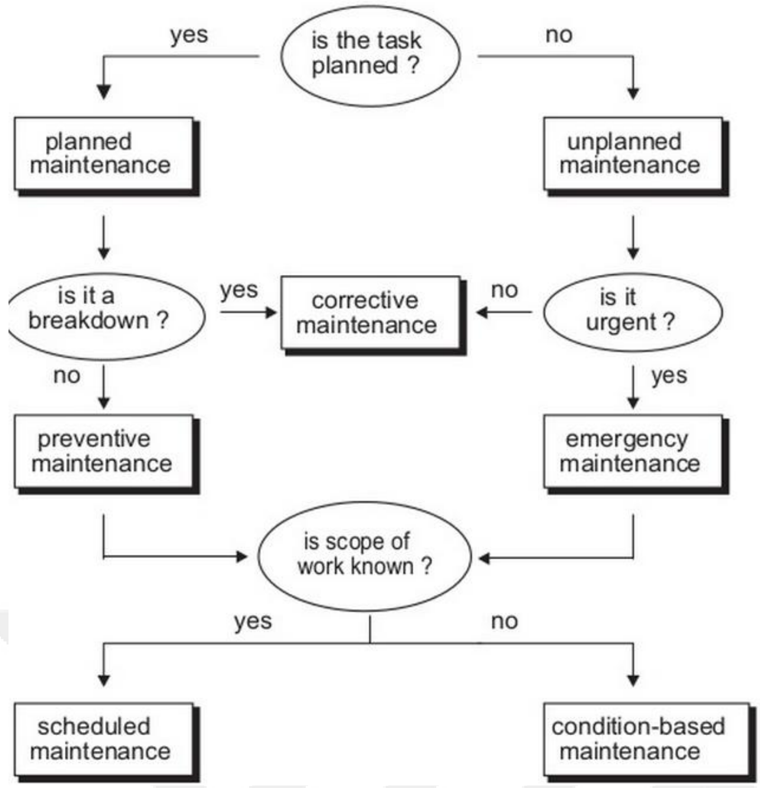

Figure 2.4. Decision-based types of maintenance (BS 3811 cited in Chanter and Swallow 2007)

b) Corrective Maintenance

Corrective maintenance is the simplest type of maintenance strategy, where maintenance activities are not performed until an element in a building breaks down. It covers all activities, including replacement or repair of an element that has failed to a point at which it cannot perform its required function (Zuraidi et al., 2011; Horner et al., 1997). According to King et al., (1984) it consists of repairs to the building and equipment due to natural wear and tear or faulty preventive maintenance. With equipment problems, there may be a question as to whether the particular item should be repaired or replaced.

Corrective maintenance which also includes emergency maintenance is generally applied when preventive strategies are not economically justifiable, in other words, when inspections and monitoring routines or other preventive actions are too expensive compared to economic consequences of failure and correction. Nevertheless, the consequences of unpredicted failures may be devastating such as a failure of an item can cause a large amount of consequential damage to other elements in the building. For instance, failure of the roof could cause damage to the ceiling and the interior of the building (Hallberg, 2009; Horner et. al., 1997).

2.2.1.2 Unplanned Maintenance

This refers to ad hoc maintenance carried out with no predetermined plan, i.e. work having to be carried out immediately as a reaction to damage or to demands from owner or the occupier. This maintenance stage also involves corrective and emergency maintenance in the same way that planned maintenance does (Zakaria et al. cited in Shahidan et al, 2012).

For better understanding of the types of maintenance, a decision flow diagram is provided by BS 3811 in Figure 2.4.

2.2.2 Factors Enhancing Building Maintenance Management

Along with planning and developing strategies and standards for maintenance, management of the maintenance activities also depends on some other parameters. First of all, maintenance activities are carried out in accordance with the budget allocated. To ensure good maintenance actions and to sustain the required level of performance of a building and its components, sufficient resources such as staffing, equipment, building materials and consumable items are needed (Lee and Scott, 2009). Even all of these resources to carry out maintenance activities are procured from the maintenance budget, it has been revealed from the previous research that insufficient budget due to inadequate allocation or lack of funds emerge as one of the foremost problem that leads to the failure of maintenance program (El-Haram and Horner, 2002; Chew and De Silva, 2003; Ali, 2009; De Silva and Ranasinghe, 2010; Ali et al., 2010, De Silva et al, 2012; Hassanain et al., 2013; Omotehinshe et al., 2015; Ganisen et al., 2015). Owing to inadequate allocation of budget, planned and required maintenance tasks will be postponed which will cause interrupting of regular activity of users, major repairs in the future, as well as higher maintenance costs. Moreover, as a result of the survey conducted by De Silva (2011); it was found out that even some of the earliest high rise buildings were left with no maintenance due to insufficient budget. Therefore, during the operation process of the building; the responsibility should be taken on by maintenance stakeholders such as building managers and building owners to give additional importance to the allocation of maintenance budget. While managing maintenance activities, effective use of budget based on past experiences, selection of most cost-effective and appropriate strategies could enable adequate budget allocation (Flores-Colen and de Brito, 2010).

As the requirement of replacing the spare parts and materials used in building components, elements and services will show up during the maintenance, proper selection of the spare parts and materials are other determinants that should be considered while managing the maintenance activities (El-Haram and Horner, 2002; Ali et al., 2010; De Silva et al., 2012; Hassanain et al., 2013; Ganisen et al., 2015). Use of poor quality of spare parts and materials during maintenance will lead to an increase in the frequency of maintenance cycles due to requirement of re-works and replacement of these parts. Thus; maintenance management planning will be hindered through the increase of maintenance efforts and consequent maintenance costs (Al-Hammad et al., 1996).

Documentation of maintenance activity also should be an integral part of the management system in order to ensure efficient maintenance planning (Chew and De Silva, 2003; De Silva and Ranasinghe, 2010; De Silva, 2012; Hassanain et al., 2013). Documenting and recording the activities carried out, effort and time spent as well as the consequent costs are essential for enhancing future maintenance activities.

Documented information will provide following benefits:

- Using the information as a base for prospective maintenance to avoid implementing procedure that would result in high cost of maintenance (Lam, 2001).
- Establishing database regarding material, equipment and system performances in order to provide background information to project stakeholders for further projects.
- In case of unexpected changes in managing organization, it will form a basis for further maintenance activities.

2.3 MAINTAINABILITY OF BUILDINGS

The term maintainability of buildings refers to ease of conducting maintenance effectively. Fledman (1988) defined maintainability as the condition for an item or a surface that permits its repair, adjustment or cleaning with reasonable effort and cost. A more current definition of maintainability was proposed by Chew et al. (2004a) as "achieving optimum performance throughout the building life span within minimum life cycle cost". Apart from these definitions, Dunston and William (1999) considered maintainability from constructability point of view. Accordingly optimal maintainability is "the design characteristic which incorporates function, accessibility, reliability and ease of servicing and repair into all active and passive system components that maximizes costs, and maximizes benefits of the expected life cycle value of a facility".

The importance of effective building maintenance and of assessing the total costs which occur during the whole life span of the building is being increasingly recognized throughout the developed world, as owners and/or facility managers encounter high maintenance costs. Even though, quite a few studies and life cycle cost analysis which have been made recently proved that the lowest initial cost may not be the most economic choice; many clients, contractors and designers only pay attention to initial cost to indicate economic feasibility of projects (Chew et al. 2004a; De Silva et al., 2004). This general opinion about taking in consideration the initial costs is due to the fact that predicting the design and construction costs is easy, however; it is difficult to predict costs in use which include operation and maintenance costs (Arditi and Messiha, 1996). However, the lowest initial cost may lead to highest maintenance cost as cheaper materials generally require more frequent replacement, repair and care.

While considering the construction industry, the initial cost of buildings, i.e. costs of design and construction are minor when compared to total life cycle costs of the building (Figure 2.5). It was suggested that generally maintenance and operation activities contributed around 50% to 80% while initial design and construction activities are contributed around 20% to 50% of the total LCC (Flanagan et al., 1989; Kirk and Dell'isola, 1995; Griffin, 1993; Becerik-Gerber et al., 2012).

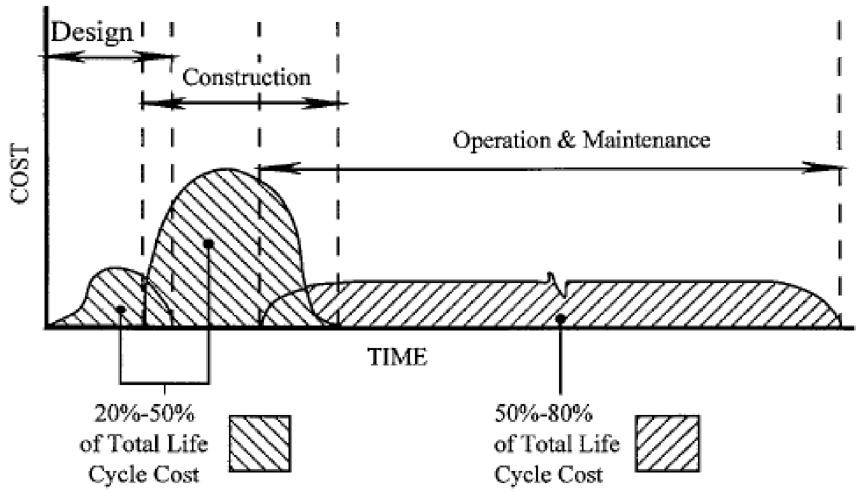

Figure 2.5. Life cycle costing profile (adapted from Griffin, 1993; [Dunston and Williamson, 1999])

Maintenance costs include overall cost or budget allocated to keep the building up to an acceptable standard or to preserve the building in good condition. That is to say, maintenance costs are the costs spent for cleaning, inspecting, repairing, replacing and care activities of the building's various systems and components. These costs stem from the maintenance resources such as material, labor and plants and tools as well as from the indirect costs such as administrative staff and overhead costs. Additional costs due to the unavailability of the building, reduction in the required level of performance or loss of revenue may also be included in indirect costs (El-Haram and Horner, 2002).

In the report of BMI (1996), total spending on building maintenance in the UK has increased by 66 % in the last ten years and maintenance of building stock represented over 5 % of Gross Domestic Product in 1996 (as cited in El-Haram and Horner, 2002). A more recent research conducted by Building Cost Information Service concluded that total maintenance expenditure over the last 10 years (2003-2012) was 20% and maintenance expenditure represents 3.35% of Gross Domestic Product (GDP) in 2012 for UK (BCIS, 2014). For USA, the increase of the maintenance expenditure over the last 10 years (1997-2007) was 3.3% for USA buildings (Whitestone Research, 2007). These reports and various research undertaken in this issue reveal that building owners, facility managers and local authorities are facing soaring maintenance costs and the user may also need to bear the burden of increased maintenance costs. Unfortunately, while maintaining buildings, a considerable proportion of the maintenance budget is spent on correcting the maintenance problems and latent defects (Adejimi, 2005; Ishak et al., 2007; De Silva and Ranasinghe, 2010).

El- Haram and Horner (2002) stated that maintenance costs can be reduced by minimizing the number of maintenance tasks and adopting the strategies below;

- reducing the number of maintenance tasks by selecting the most applicable and cost-effective maintenance strategy,
- reducing the duration of maintenance tasks by increasing the accessibility, planning maintenance resources in advance and training of maintenance staff,
- taking into account reliability, durability, maintainability and whole life costing at the design stage,
- reducing or controlling the impact of the factors which have an effect on maintenance costs.

It can be understood that in order to ensure the development of these strategies, not only decisions taken during the building occupation process but also decisions taken in previous phases play a significant role.

Within the context of maintenance management, maintainability is an important aspect for dealing with ever-increasing maintenance costs and their high ratio in building life cycle costs. Any significant decrease will be for the great benefit of the stakeholders, the industry and the national economy. As maintainability also provide the efficiency of maintenance activities which refers to the ease, accuracy and quality of activities beside safety of maintenance personnel, stakeholder satisfaction and users' safety and comfort, the consideration of maintainability issues should be paid attention not only by the researchers but also by the building professionals and the government.

In recent years, the construction industry has been experiencing an increase in higher building standard demands besides the development and use of new building materials and construction technologies. This has led to an increase in complexities of building systems, as well as maintenance problems and additional costs during the occupational phase (De Silva and Ranasinghe, 2010; Mohammed and Hassanain, 2010). Furthermore, Che-Ani et al. (2009) stressed that in near past it was thought that only old buildings are subject to maintenance because of material deterioration, weathering etc., but in contemporary time, the concept has totally changed because of designers, developers and construction teams. Now even newly built structures are subject to intensive maintenance and sometimes require revised design and reworks. Therefore to ensure the effectiveness and easiness of maintenance activities and to minimize related costs, there is a need to develop strategies towards aforementioned negative consequences by identifying and assessing the maintainability factors that affects ease of maintenance and/or cause problems during the occupational phase. Dunston and Williamston (1999) recommended an approach that incorporates maintainability as a part of the constructability process which will have significant impacts toward improving design and construction processes. Development of a "best practices" database model that employs the values of "lessons learned" throughout the design and construction phases will allow for improved operation and maintenance of buildings as well as improved assessment of future facilities.

As the benefits of maintainability of buildings in saving maintenance costs and achieving better function of buildings and its components have been widely recognized, identifying maintenance related problems and associated costs that occur during the useful life of a building and factors affecting the ease of maintenance have become one of the major concerns of research in developed and developing countries.

In an attempt to identify the implications of maintainability factors on maintenance costs, De Silva et al. (2012) firstly identified the maintainability risk factors of high rise buildings in Sri Lanka and then applied these factors to a real case study. Through extensive literature survey and a pilot survey with experts; 58 maintainability causes were identified and grouped under ten risk factors (e.g. design related, structural/detailing related, accessibility related, constructability and construction related). A high rise private hospital building was selected for the case study of which whole life maintenance cost was estimated from the records at 2.909.450 US$. As a result of analyzing and evaluating of identified ten risk factors to estimate the savings in maintenance cost; 35 % reduction (1.026.530 US$) in whole life maintenance cost was calculated. Therefore, it was concluded that the implication of maintainability factors to the maintenance budgets is considerable and is worthwhile to pay due attention. In other words, the overall maintenance cost can be controlled and reduced by taking appropriate measures at the initial stages of the life cycle. This conclusion also supported by another case study conducted by Seeley (1987), who revealed that one third of the building maintenance cost can be saved if appropriate decisions have been taken at building production process.

The causes for maintainability problems faced in occupational phase are due to poor design and planning with respect to maintainability at early design phase, substandard construction workmanship during the construction phase and ways of implementing maintenance at post-construction phase of a building. Further government policies, owners' attitude and users' behavior are also responsible for maintainability problems. (De Silva and Ranasinghe, 2010; El-Haram and Horner, 2002; Assaf et al., 1995; Al-Hammad et al., 1997; Adejimi, 2005). Thus addressing the maintainability concept right from the early planning and design phase has a considerable impact on the future performance of a building. Nevertheless, quite a few studies have revealed that the consideration of future maintenance activities are mostly neglected and ignored through the building life cycle by various groups of people who are involved at different stages of the building production.

The reasons behind the lack of knowledge or ignorance of maintainability considerations are several. Generally in traditional practice, neither designers nor other professionals involved at different stages of building production are responsible for the building once the building has been completed and this may be one of the major reasons behind the negligence of maintainability considerations. After completion the responsibility is taken over by facility manager who is responsible for the management of maintenance activities throughout the operational lifespan of the building. As a result of faulty decisions made in early phase of development processes, facility managers are faced with a multitude of frequent and costly building performance problems during the occupational phase and have very little control to minimize maintainability problems and defects.

Based on the survey of literature and the current practices in Turkey, it is clear that the contribution of the facility manager in the early phase of development process is not considered. There is also a lack of communication with facility managers to seek advice about the decisions based on their practical exposure to maintainability problems that are faced during the phase of occupancy. These deficiencies are the main cause of the lack of knowledge about maintainability considerations in the early phase of development and may be due to unfamiliarity of facility management profession in the local industry in Turkey. With increasing investments in construction industry in Turkey such as residences, shopping malls, multi-storey buildings due to either rapid growth of population or of construction industry, awareness about 'facility management' concept of which building maintenance management is one of the major fields of activity has begun to emerge.

Consequently, in order to improve maintainability of buildings and to develop strategies both in long and short term, identification of problem areas is of great importance. In the following Chapter, available research within the scope of the thesis will be discussed in detail in order to identify the factors affecting maintainability during the occupancy phase.

2.4 MAINTAINABILITY PROBLEMS OF BUILDINGS

Building maintainability problems and building defects are two different concepts even it is sometimes thought that they mean the same thing. There are various definitions of defect; the simple and comprehensive one is based on Oxford English Dictionary as "defect is a shortcoming or falling short in the performance of a building element”. Maintainability problems are generally due to human faults such that defects are the result of these faults, in other words, maintainability problems can be seen as contributory factors of defects. Also all building components eventually are exposed to defects with effects of nature. Pheng and Wee (2001) indicated that proper maintenance and the avoidance of human faults may delay the process, and thus the authors identified human-error related causes of defects, summarized and placed them into the relevant sub-system as shown in Figure 2.6.

Maintainability problems refer to the difficulty and inefficiency of performing maintenance activities and dealing with building defects. In other words, these problems cause the maintenance activities are carried out with more efforts, more time and more cost.

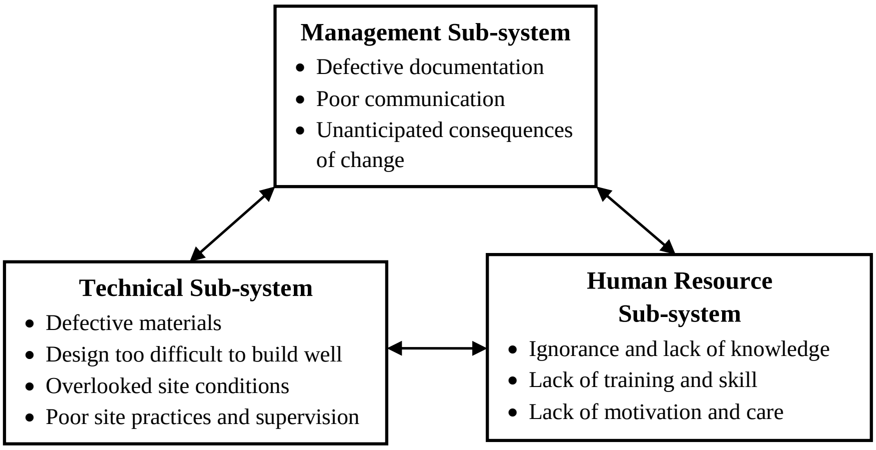

Figure 2.6. Sub-system of human-error related causes of defects (Pheng and Wee, 2001)

Even the fact that the efficiency, convenience, life span, economic viability, appearance and overall performance of a building can be affected by decisions taken at whole life cycle of a building (Arditi and Nawakorawit; 1999b); maintainability problems and their effects could be prevented or at least minimized through the right decisions at the right time. Therefore; the perception and identification of building maintainability problems is essential for improving the building performance and minimizing life cycle costs as well as for the easiness of maintenance activities.

The impacts of maintenance problems and latent defects caused by design, construction and maintenance management deficiencies were considered by De Silva et al. (2012) as risks of building maintenance. These risks were identified through literature survey and grouped into seven risk factors which are; accessibility for maintenance, characteristics of building materials and components, design detailing, environmental conditions, requirement for future maintenance, constructability and construction quality and maintenance management process.

As mentioned before, ever-increasing maintainability problems and maintenance costs during the occupation phase have recently become researchers' field of interest to create awareness and to develop strategies against them. In accordance with these purposes, some researchers have focused on the maintainability issue during the occupation phase for different building types in their own countries. It is observed that most of these countries are either developed or developing countries. When examining the research studies, it can be understood that they approached the subject from different viewpoints. Some of which assessed the factors that affect the ease of maintenance and some aimed to find out the defects and their frequency and/or contributory factors either by field works or by survey studies. Although there are also a number of studies solely focusing on the factors that increase the maintenance cost; as a matter of fact, factors that cause defects as well as factors affecting ease of maintenance have direct influence on maintenance costs. Further, all of these approaches could be evaluated under the concept of maintainability.

Considering the research made with regard to the increasing maintenance costs, it was revealed that there are several factors that affect the maintenance cost. According to El-Haram and Horner (2002), generally they can be divided into five main groups which are; building characteristics, tenant, technical and administration, political and other factors (e.g. third party vandalism, poor or lack of training). They conducted a survey for housing buildings in Scotland to identify and rank the most important factors affecting housing maintenance cost. 24 factors were identified by interviews which were then assessed by questionnaire survey. It was concluded that "high tenant expectations", "budget constraints", "improper use of property" and "failure to execute the maintenance right time" were the most important factors. Another research made for housing buildings in Malaysia by Ali et al. (2010) aimed to determine the factors contributing to rising maintenance costs. Findings due to questionnaire survey with managers show that five of the most influential variables are "high standards of expectation from residents", "building materials selected in the early design stage", "building services' failure", "building age" and "failure to execute maintenance at the right time".

Hassanain et al. (2013) conducted a study to identify and assess the factors that affect the cost of maintenance of hospital facilities in Saudi Arabia. Through literature review and interviews with facility managers 33 factors were identified and then classified into seven groups, namely; statutory requirements, design phase, construction phase, management of the maintenance department, budgetary estimates for maintenance activities, operations conducted by the maintenance group and community perception about the maintenance industry. These factors were assessed by a questionnaire with facility managers. According to the findings the most important factors are; "transfer of some problems from the construction phase to the maintenance phase for resolution", "lack of coordination between the construction and maintenance groups”, “lack of quality control measures during the installation of systems”, “the method of classifying maintenance contractors”, “errors conducted during the design of the project” and “lack of feedback from the maintenance group to the design team”.

Al-Khatam (2003) conducted a literature survey on the factors affecting the cost of maintenance in buildings and identified 34 factors. Then, these factors were classified into seven major groups, namely; engineering services, labor, building materials, environment, management and administration, budget and finance and building user behavior. Based on the result of the survey, the major causes for high cost of maintenance in buildings are; “absence of local material standards and specifications”, “concern about the initial cost by owners”, “poor supervision and management of projects”, “poor maintenance scheduling”, “absence of standardized maintenance contracts” and “faulty design and construction”.

Another survey conducted by Ali (2009) aimed to identify the dominant factors that affect the decision-making process with regard to the building maintenance cost in Malaysia. These factors include “existing building condition”, “building age”, “complaints received regarding building performance”, “client’s request”, “availability of funding” and “safety and health requirements”. It was revealed from the questionnaire survey with building managers that the maintenance performance suffers from inaccuracy decision made in allocation of maintenance cost. The significant factors are “existing building condition” and “complaint received regarding building performance”.

As we can understand from the above and similar research that focused on different countries and building types; "poor or lack of maintenance planning", "faulty construction", "faulty design" and "incompetency of maintenance manager" come to the forefront as common major causes of increasing maintenance cost. Also, it is clear that each of these factors is referred to different phases of building life cycle and responsibilities of different individuals.

When looking through the research regarding building maintainability problems without focusing on maintenance cost, it was observed that they approached the subject in different ways and handled the subject with considering different phases. In this section, the studies that are not dealing with a specific phase of building life cycle will be mentioned. Some studies attempted to find out the most frequent defects according to a particular building type. For example, the study by Abdul-Rahman et al. (2014) aimed to identify the types of defects in residential housing. A survey undertaken by 310 residents in Malaysia showed that leaking pipes, failure of water supply systems, cracking in concrete walls, faulty door knobs and concrete wall dampness were the most commonly occurring defects. It was stated that the contributory factors of these defects may be poor workmanship, inferior materials, and poor supervision and monitoring routines and weather conditions.

By focusing on defects in wet areas Chew and De Silva (2003) aimed to identify the maintainability problems of high-rise residential buildings in Singapore. Required data were collected through site investigations and defect reports. According to 222 cases from 67 buildings, water leakage was the most significant defects followed by paint and service pipe defects. Further, the causes of defects were investigated and it was concluded that "low-quality workmanship", "insufficient design detailing", "inadequate design for air movement", "ad-hoc maintenance practices" and "material performance" are seen as contributory factors for defects. The results of the research emphasized that the design, construction and maintenance parameters are the fundamental considerations to improve the maintainability of wet areas.

The study undertaken by De Silva and Ranasinghe (2010) was not focused solely on building defects, the contributory factors were also assessed. The authors in an attempt to establish a framework to enhance the maintainability of buildings, made a comprehensive research with regard to the maintainability problems of condominiums in Sri Lanka. The problems considered were due to design, construction and maintenance deficiencies. Therefore, the research is focused on identifying maintainability problems and subsequent risk factors involved. The maintainability problems and defects identified through field survey and interviews with maintenance managers were then assessed by questionnaire. It was found that "defects in the services (e.g. fire, lift and air conditioning systems)", "waterproofing failures –and subsequently the seepage problems-", "paint defects (most common were blistering, peeling, irregular cracking, discoloration and poor gloss)" were ranked as the highest critical defects. Most of these defects may occur due to the inappropriate materials selection at the design phase and the poor quality in application. "Piping, plumbing and ductwork defects" and "plaster defects (most common were cracking, crazing, efflorescence, peeling, dampness and rust staining)" were also ranked as critical. As a part of the research, by analyzing the causes for identified maintainability problems, maintainability risk factors were established for design, construction and maintenance phases and then assessed due to significance level. As a result; "provisions for temporary access system for cleaning and maintenance", "accessibility to the building elements and components for regular cleaning and maintenance", "allocation of annual maintenance budget", "no. of different access systems needed for cleaning and maintenance" and "consideration of future maintenance requirements" were appeared as most significant design factors respectively. For construction phase, "performance of consultant", "motivation of the workers", "site practice and workmanship" "performance of the contractor" and "testing and quality assurance procedures" moreover, for maintenance phase; "efficiency of maintenance activities", "procedure to have feedbacks from the users", "user satisfaction about the maintenance program", "adequacy of allocating annual maintenance budget" and "behavior of human traffic (usage)" were ranked as the most significant risk factors.

A survey conducted by Assaf et al. (1996) focused on individual and major groups of design and construction defects and their relative severity in large buildings in Saudi Arabia. 11 major groups were generated from 67 defects which were identified based on a literature review and interviews with owners and maintenance contractors. These groups are; defects due to; (1) consultant firm administration and staff, (2) construction drawings, (3) construction inspection, (4) civil construction, (5) contractor administration, (6) construction materials, (7) construction equipment, (8) specifications, further; (9) defects in civil design, (10) defects in architectural design and (11) design issues on maintenance practicality and adequacy. As a result of the survey; while owners ranked the group of "design defects in maintenance practicality and adequacy" as most severe - i.e. not considering space for maintenance workers-, as for maintenance contractors the most severe group was "defects due to construction inspection". However "defects due to contractor administration" group - i.e. not complying with specifications - was ranked by both parties as having the second highest effect on maintenance.

Arditi and Nawakorawit (1999a) while conducting a survey to find out the maintenance practices of property management firms in United States, property managers stated that the most important building maintenance problems they faced are caused by building design inefficiencies and poor construction quality.

It can be concluded from previous studies that future maintainability of building have not been considered and paid attention in whole life cycle of a building starting from the preliminary design until the occupation phase.

Several researchers have attempted to find out the decision process of building life cycle in which building defects were originated from through field and condition surveys. A survey conducted by Lam (2000) in Hong Kong has found that up to 40% of maintenance faults were related to design, up to 30% were related to construction or installation and up to 30% were related to maintenance management. Another survey that reviewed 4,389 records from 36 public housing areas in Malaysia showed that about 47% of defects were caused by design-related negligence, 18% from misuse of facilities, 17% from materials, 15% from construction, 15% from poor maintenance, and 5% from vandalism (Ramly et al., 2006). The Building Research Establishment in England conducted a survey of building failure patterns and their implications and found that 58% of defects were caused by faulty design, 35% from operation and installation, 12% from poor materials and systems and 11% from unexpected user's requirements (Seeley, 1987).

It can be understood that the construction process has a role for future maintainability of the building. Even if maintainability considerations are taken into account through right decisions in design process, construction faults through taking wrong decisions and performing improper actions have significant negative effects on future building maintainability and hence its performance. For example, poor specifications are generally the fault of designers but failure to comply with specifications is contractors' responsibility or the correct detailing as provided in the design can facilitate better maintainability only when the correct practices are followed during the construction (Chong and Low, 2006; De Silva, 2012).

Considering construction process, the most common problems faced during occupation are due to poor workmanship, lack of quality control measures and poor performance of the contractor. Apart from these, lack of coordination between construction and maintenance groups and lack of construction inspection are also considered as important faults in construction process. Poor workmanship refers to the quality of construction and poor installation methods such as poor mixing of materials, poor handling of material, failure to provide proper joints and gaps. It is crucial for many latent building defects such as cracks and waterproofing failures even though all the details are provided correctly. Condition survey carried out by Chong and low (2006) in Singapore revealed that 33% of identified defects in 74 buildings were preventable with better workmanship. Unskilled laborers, lack of motivation and cost-driven contractors may led to negligence in workmanship (Chew, 2010; Chong and Low, 2006).

Poor performance of the contractor causes faulty construction practices and consequently will reduce the service life of the building. It includes; not complying with specifications, implementing ineffective construction methods, using poor quality material, inability to read the drawings, insufficient site supervision, poor communication between the design firm and the owner, unqualified supervision, rushed completion or poor quality work, unqualified work force, and lack of construction experience (Assaf et al. 1996; Hassanain et al. 2013). To complete the construction works as shown in drawings and specifications, quality control has a vital importance. Lack of quality control or any deviation from the acceptable procedures will significantly affect the quality of construction and consequently it will cause increasing amount of maintenance activities and re-works during the building occupation process (Hassanain et al., 2013).

De Silva and Ranasinghe (2010) indicated that the construction faults can be avoided by having a proper site management, good performing contractors, consultants as well as efficient workers, proper coordination, planning and documentation and also use of the quality testing procedures.

According to all aforementioned previous research carried out to identify and assess building maintainability problems and defects; it can be understood that decisions taken in design phase have the highest effect on maintainability problems and latent defects. It should be kept in mind that the design phase implies architectural and engineering design practices and decisions. Ramly et al. (2006) stated that the design plays a major role in determining the condition of the building after completion mainly in aspects of defects and maintenance, also they stressed that design influences the performance and physical characteristic of building and its durability to withstand environmental condition, social interfaces such as graffiti and vandalism indirectly. Further; Chong and Low (2006) had shown that design is an important function in eliminating latent defects as the condition survey showed that 60% of defects found during the occupancy were preventable with better design practices. Another condition survey made by Low and Chong (2004) revealed that design could have prevented at least 66% of latent defects found during the occupation phase. In another survey made for university buildings in Nigeria, Omotehinshe et al. (2015) found out that majority (64.48% - 97.67%) of the problems faced in the management of maintenance on the defective elements were foreseeable and thus could have been taken care of during the design stage.

Along with the fact that design phase and designers' decisions have considerable effect on long term performance and life cycle cost of buildings, faulty decisions taken during design are mostly latent in nature and hard to detect at the early stage of construction. Moreover; design faults can lead to expensive mistakes since once a building is designed and constructed it becomes costly to rectify and modify. Thus the design team always should be conscious of the consequences of their irresponsible, poor and ill-considered designs and should pay attention on buildings' long term costs in use (Graham, 1979). In addition; decisions made in design phase also effect the decisions made in subsequent phases, Atkinson (1998) for instance mentions that most of faults that occur in construction phase are due to design errors and omissions or carelessness. Considering the fact that facility managers have a little control during the occupation to minimize maintainability problems and defects as a result of decision faults; it can be concluded that design is the most critical phase in the life cycle of a building as the most critical decisions are made at this phase. Therefore, several studies have been made with regard to maintainability considerations with focusing on the design phase.

According to Gibson (1979), faulty design decisions may be grouped as follows;

- failure to follow well established design criteria in the choice of structural system and selection of materials.
- ignorance of the basic physical properties of the materials.
- use of new materials or innovative forms of construction which have not been properly tested in use.

- misjudgment of user and climatic conditions under which the materials have to perform.
- difficulty in executing the design due to impractical issues.
- poor communication between members of the design and construction teams.

Sivanathan et al., (2012) described the types of design related problems that can be found during occupancy stage as; poor material selection, accessibility to building elements and components, lack of detail, poor communication, poor ventilation design, poor structural design, poor geotechnical design, ignoring environmental issue, lack of standardization and biological agent.

According to Ramly et al. (2006), there are four areas that can be easily linked to the results of design in terms of maintenance. These are; the main fabric –walls, floors, roofs, doors and windows-, internal finishes –ceiling and wall finishes as well as floors-, special design features –design and decorative elements for the doors, windows, glass, air vents, special face bricks etc.- and cleaning and housekeeping of all building components.

A survey undertaken by Chong and Low (2006) on 74 buildings in Singapore has identified design related defects with a detailed sub group analysis including floor, external and internal wall, doors, windows, mechanical and electrical systems, plumbing and sanitary system, roof, ceiling and external works. According to the study the most common defects were plaster crack and stain in internal walls; cracks, water seepage and tiles delamination in floors; water seepage, plaster cracks and stain in external walls; ironmongery damage in doors and windows and leakage in roofs. The results reveal that the three most important causes for defects were adverse weather conditions, occupants and loads and moisture from the wet areas.

De Silva (2011) aimed to identify the most frequent defects and the criticality of contributory factors related to the design phase in high rise buildings. As a result of the field survey and interviews that was held in Sri Lanka, "water seepage due to waterproofing defects", "doors, windows and joinery defects", "piping/ plumbing and duct work defects" and "tile defects" were ranked as the most frequent defects in high rise buildings. Thereafter significant maintainability problem causing factors related to design phase were established by interviews with maintenance experts. Findings show that consideration of future maintenance requirements -which includes “frequency and method of maintenance required”, “complexity of the building”, “availability of components” and “level and nature of usage”- is the most critical factor. Furthermore, it was found that involvement of facilities management personnel in the design phase, accessibility of future maintenance and considerations of climatic conditions are also play a vital role in the maintenance process.

Omotehinshe et al. (2015) examined the implications of design inadequacies on the maintenance of university buildings in Nigeria by means of physical observations, existing maintenance records and questionnaires. The results indicated that 62 buildings under review were not designed for future maintenance and "building shape", "structural stability", "environmental factors", "choice of materials", "lack of fund" and "users' ignorance" were the main causes of maintainability problems encountered. Furthermore, continuous presence of various kinds of latent defects was identified as physical evidences of poor maintenance issues which could have been inhibited through design inputs.

Razak and Jaafar (2012) in an attempt to determine the factors contributing to maintenance problems related to faulty design conducted a survey in 15 public hospitals in Malaysia. As a result, "inadequate definition of material type", "overlooking QA/QC construction procedures", "misjudgment of user's intended use", "specifying incompatible exterior finishes with the weather" and "ignoring climatic effects on exterior shapes" were found as the major factors contributing to maintainability problems.

Al-Hammad et al. (1997) aimed to identify design factors that affect building maintenance in the Eastern Province of Saudi Arabia and their overall relative importance based on the opinion of parties; namely contractors, designers and owners. 35 factors were identified based on a literature review and interviews with local contractors, owners and architectural/engineering firms. Thereafter, they were grouped under six categories as; defects in civil design, defects in architectural design, design defects in maintenance practicality and adequacy, defects due to consultant firm administration and staff, construction specification and construction drawings. Consequently, "inadequate structural design" and "hiring unqualified designers" were ranked by all parties as one of the most significant design defects. However, significance of other defects are changed according to parties. As to owners "ignoring access for maintenance equipment" and "ignoring aggressive environmental effects" were significant design defects. For contractors, "specifying incompatible exterior finishes which need complete replacement" and "ignoring aggressive environmental effects" and for A/Es "insufficient technical updating or staff training" and "lack of details in drawings" were ranked as significant design defects.

Previous studies reveal that; “ignoring climatic and environmental effects”, “ignoring accessibility”, “inadequate structural design”, “inappropriate choice of building materials” and “ignoring the nature of building usage” have come into the forefront as most common design decisions faults in all of these studies.

According to the survey by Arditi and Nawakorawit (1999b) which was conducted with designer firms in US; ease of maintenance -cleaning, repair and replacement- and accessibility are ranked by designers as the least important factors considered during their design. Chandler and Lewis (2011) carried out a similar survey focusing on designers of large multi-storey buildings in the Caribbean and it was also found out that designers consider future maintenance of building components and accessibility as the least important factors.

There may be several reasons behind neglecting and ignoring the consideration of maintainability and future maintenance activities of buildings through the design process. Razak and Jaafar (2012) stated that; factors such as inefficiency and inadequate knowledge of the design group lead to their inability to judge or consider the possible factors that could arise during maintenance. Furthermore; inadequate information, unawareness, wrong assumptions, organizational and motivational factors, lack of communication with maintenance experts are identified as significant factors for the faults at the design stage (Chong and Low, 2006; Razak and Jaafar, 2012; Omotehinshe, 2015). Besides all, the fact that there are such a wide range of alternative building materials and techniques in present times, increased both the freedom of design and the difficulty to find the most economic and maintainable choice.

One of the major reasons behind the ignorance of maintainability considerations may be due to the traditional practice. That is to say; traditionally, designers do not have any responsibility for their faults that cause maintainability problems and also for the cost that is spent to rectify and modify during the occupation. In other words, designers mostly feel free from their faults once the building has been built (Chong and Low, 2006; Ramly, 2006).

Due to encountered maintainability problems and the fact that the maintainability issues are not taken into consideration neither design nor any other building life cycle phases, there appears an immense need for a systematic framework for all parties who take part in building life cycle from clients to users.

Looking at the previous studies related with effects of decisions at building life cycle on maintainability issue, it can be understood that they conducted condition surveys with solely focusing on identification of problem factors, their severity and importance. Except the study of De Silva and Ranasinghe (2010) there has not been any established systematical framework. In their study De Silva and Ranasinghe (2010) proposed a simplified framework for maintainability of buildings through a risk identification process which was carried out by analyzing problem causing factors, risk analysis for establishing strategies for design, construction and post construction phase and exploring industry motivators. Further; it is clear that neither this study nor the majority of the previous studies have not been focused on a specific phase of building life cycle due to emerging problem factors is referred to different phases and responsibilities of different individuals. Studies solely focused on design phase also consist of different process and different professions from architect to structural engineer through to interior designers in itself. Accordingly, this way of approach is thought to be ineffective in practice. However, in an attempt to raise awareness for the individuals involved any of building life cycle phases for focusing on the key aspects with regard to their decisions and developing strategies against them; consideration of a specific phase and responsible individuals of building life cycle would be more useful and effective.

Considering the previous research regarding design phase, the most common decision faults about future maintainability of building are emerge from architectural design process. Besides, as a result of the interviews with the facility managers with the scope of current study; it is clear that the most common and frequent faults that are faced during the occupancy are arising from architectural design decisions.

As the early consideration of maintainability issues in architectural design was not considered as a common practice for the building industry in Turkey until recently; there is a need to develop a systematic framework for architects to improve their knowledge and awareness towards better maintainability of buildings.

Besides, it is understood that facility managers' / maintenance staffs' qualifications and decisions during the post-occupancy are also have high impact on the efficiency of maintenance activities. Especially in Turkey along with unfamiliarity of facility management discipline, there is also a lack of educational background of facility managers. This profession is practiced by people coming from various fields of education (e.g. mechanical engineer, electrical engineer, high school graduate etc.)

Along with the architectural and managerial deficiencies in practice, detailed academic studies to identify the maintainability problem factors that are significant in the local context; practices and culture for developing strategies are also lacking. These circumstances constitute an obstacle to the buildings', which require sizable investment, carrying on their activities effectively. Therefore, within the scope of this study it is aimed to develop a systematic framework for architects and to develop strategies for maintenance managers through identifying and assessing the most important maintenance problems that commonly emerge as a consequence of the poor management and inappropriate design decisions.

Maintainability factors that affect ease of maintenance and or cause problems during the occupational phase pertaining to architectural design and managerial decisions will be discussed in the next section separately and it will provide a basis for the development of the survey within the scope of the thesis.

3 FACTORS AFFECTING MAINTAINABILITY OF BUILDINGS

As a result of the analysis made in previous chapter (Section 2.5); factors are gathered under two groups as architectural design factors and factors pertaining to management process. These factors will be discussed in detail in Section 3.1 and 3.2 respectively in order to identify factors to be evaluated within the scope of this thesis and provide a basis for the survey to be conducted.

3.1 THE EFFECTS OF ARCHITECTURAL DESIGN DECISIONS ON MAINTAINABILITY

Building design is the result of a team effort including a multi-disciplinary group of designers, developers and clients, and the process consists of electrical, mechanical, structural and architectural design activities. Within the limitation of this thesis, focus will be on architectural design considerations due to further examination of responsibilities of one particular group is thought to be more useful to create awareness and knowledge. Building design can be defined as a compromise between many facilities and amenities which the building is intended to provide and the process involves both technical and creative efforts to provide all required information for construction according to the client's requirements while satisfying health, safety and welfare obligations (Merrit and Ricketts, 2001; Ramly et al., 2006). As to Ramli et al., (2013) building design encloses space in which certain activities can take place safely, comfortably and efficiently along with designers' aesthetic considerations.

Ashworth and Perera (2015) stated that the design of a project should be the combination of three facets which are function, technology and aesthetic considerations. Function refers to usefulness and comfort of the building by understanding of the way in which the project will eventually be used and by considering the ways in which this use may change over the lifespan of the project.

While aesthetic considerations deals with the physical appearance and building image, technological considerations include designers' knowledge and experience about materials and methods of construction and manufacturing of components. A designer also should be aware of the resources that are required for the design and the required technology is already available.

Even the building is designed to meet the intended purpose and client's requirement, it is not always mean that the building is designed in an effective way. The designer always should be aware of the ultimate effects of their design on user, owner, society and also on economy. In literature there have been made various descriptions for effective design. As stressed by Ashworth and Perera (2015); excellence in building is achieved only where aesthetic, soundness and usefulness of building have been developed together in a fully integrated manner with reasonable level of cost, both in respect of initial costs and cost in use. Further; Dunston and Williamson (1999) defined effective design as the design characteristic which incorporates function, accessibility, reliability and ease of servicing and repair into all active and passive system components that minimizes costs and maximizes benefits of the expected life cycle value of a facility. According to Ramly et al. (2006), two basic requirements, which are external and internal inputs, must be analyzed as design inputs to achieve a good building design in terms of optimum building performance, longer life spans, easy maintenance, comfort, safety and health conditions. While client, user, public, local community and authority factors can be categorized as external inputs; environmental considerations, materials, future maintenance, methods and technologies, economics and psychological needs are the requirements for internal inputs.

According to Arditi and Nawakorawit (1999b); designers should be sensitive not only to matters related to function, user comfort and environment, but also in striking the right balance between initial costs and costs in use. They also emphasized that decisions taken in design process affect substantially the efficiency, convenience, life span, economic viability, appearance and overall performance of a building. Consequently it is clear that designers bear great responsibility and play a significant role in determining the overall condition of a building after completion including costs in use.

Omotehinshe et al. (2015) emphasized that in order to ensure the delivery of building products with good form and aesthetic appeal which will economically perform its designed functions throughout its useful life, the link between building design and its maintenance during occupation phase is essential. A design may be executed well within the terms of reference that have been laid down, but the building may fail to perform properly if future maintainability of building are not taken into account (Arditi and Nawakorawit, 199b).

As it was revealed in previous chapter; lack of consideration for future maintainability of the building during design is a common problem and majority of the problems and consequential costs encountered during the occupation phase are due to faulty design decisions. Poor consideration of maintainability issues and/or not taking decisions for the use of all building components more efficiently in architectural design process may cause building defects -early deterioration and damage of the building components-, failure of managing these problems, difficulties for carrying out maintenance activities, user discomfort and increase of maintenance costs. Ramly et al. (2006) and Omotehinshe et al. (2015) emphasized that considerations for future maintainability during design should not only be seen in terms of increasing number of maintenance works or cost involved, designers also need to consider the impact of their design on structure and materials installed as well as the life cycle of each building component. As stated by De Silva (2012); maintainability considerations related with architectural design are as follows;

- Suitability of the design for building function
- Flexibility of the design for future demand
- Suitability of the architectural design detailing/finishes for climatic and exposure conditions (rain, moisture, heat, sound, fire, UV rays, corrosion, pests, fungi, etc.,)
- Suitability of the design for occupants of the building (e.g. habitual requirements, needs and social background)
- Suitability of the architectural features and fixtures

In present times; designing of modern and large scale buildings to meet the growing higher building standard demands and increasing aesthetical and functional requirement lead to an increase of project complexities and may also lead to the requirement of intensive maintenance even for new buildings. As a consequence; maintaining a modern building can become an expensive and complex affair, further buildings can become more vulnerable to get affected by maintainability problems. Since therefore; the effect of design on building maintenance is greater than ever before (Arditi and Nawakorawit, 1999b; Che-Ani et al., 2009; De Silva, 2012).

The most important aspect that is paid attention while evaluating the design is the shape and aesthetic value of the building by client and also by public. Thus, most of the designers put aesthetic considerations at forefront and the design decisions are taken based on these considerations. As also stated by Ramly et al. (2006) in general it is assumed that the more unique a building is designed to be, the more it gains artistic value and appreciation. Due to the attractive design of the building; the inability of the building to serve its intended purpose and to ensure proper function and performance of its all components has been generally ignored.

Considering previous studies that evaluated architectural design considerations on building maintenance; Al-Hammad et al. (1997) conducted a survey with local contractors, owners and architectural and engineering designer firms in Saudi Arabia. By focusing on design process, it was concluded that; during the architectural design process "specifying incompatible exterior finishes with the climate", "ignoring access for maintenance equipment" "lack of drawing details" and "designing narrow stairs, passages and doors" were identified as the most significant defects. Another survey was conducted by Assaf et al. (1996) with maintenance contractors and focusing on construction and design process of large buildings in Saudi Arabia. As a result; "not relating exterior material selection to climatic conditions", "ignoring maintenance requirements", "not considering space or exit equipment for maintenance workers" and "narrow stairs, passages and doors" were identified as architectural design defects which has highest severity.

Hassanain et al. (2014) in an attempt to identify and assess significant architectural defects that are attributed to lack of maintenance feedback to design team, conducted a survey made with maintenance managers of university buildings. It was found out that "inability to maintain vertical risers due to limited areas of the service shafts" was perceived to be extremely important by managers. "signs of stains and seepage due to improper rainwater drainage around windows", "specification of low-quality tiles that could be heavily stained or degraded due to heavy human traffic and weather conditions", "insufficient availability of specific building materials in the market when replacement of the same is required" and "inability to entirely reach and maintain fenestration due to the architectural form of the building" were ranked as "very important" architectural design defects.

Razak and Jaafar (2012) found out on their survey for hospital buildings in Malaysia that most important architectural design concerns were related to the choices of exterior finishes compatible with the weather, climate effects on exterior shapes and safety factors. Ramly et al. (2006) stressed that in most cases, main fabrics are the major areas that cause maintainability problems, especially if the defects occur at the exterior parts of the building. It was due to that part of the building is directly exposed to the climatic changes, pollution, sun and rain as well as to the forces of the wind. In the report of Quality in Traditional Housing which is conducted by BRE (Building Research Establishment); 1000 different kinds of faults were identified as a result of the survey of housing under construction. It was found out that about half of these faults were related to the external envelope, including external walls, windows and doors, and roofs (BRE, cited in Al-Hammad et al. 1997).

One remarkable example that shows how a decision taken in architectural design process affects the buildings' future structural and fabrics integrity can be seen from the study of Ilozor (2008). A building condition survey was conducted for two distinct buildings (Building A and Building B) located on the same block at one of the university in United States. Both buildings were built with similar bricks, and the most explicit architectural difference between two buildings is their roofing styles, that is to say; while Building A has overhanging eaves, Building B has uncovered and vertical parapet walls. The differences on their roof styles contribute to buildings' differing external envelop defects, as much as to their unique responses to moisture penetration and the elements. Even though Building B was built 30 years later than Building A; it was exposed to significant external brick wall, window lintels, jambs and sills deterioration while similar deterioration problems were less evident in building B. Thus the different roofing styles explain their differing structural and fabrics integrity overtime.

In this section; architectural design factors which affect building maintainability are examined, categorized and then analyzed from the previous studies that have been carried out with regard to architectural design factors affecting maintainability

Through examination, categorization and analysis of previous research that have been carried out regarding architectural design process, Table 3.1 is created. Table 3.1 exhibits the maintainability factors mentioned by various authors that have undertaken empirical studies in related literature. Note that, factors that appear in these publications are expressed in various different ways due to changes in terminology and scope. For this reason, such factors are located in appropriate groups identified by the author which are; “schematic design ", material selection", "accessibility" and "detailed design". Identified architectural design factors affecting maintainability of buildings will be discussed in detail in next headings.

3.1.1 Schematic Design Factors

Schematic design is the first process of architectural design in which taken decisions has significant impact on future performance of buildings. It includes schematic layouts for site and floor plans, and may also include basic exterior concept sketches. The considerations regarding maintainability of the buildings during schematic design process are shape and orientation of the building and ventilation provisions in accordance with climatic and environmental conditions and buildings intended use.

3.1.1.1 Environmental and Climatic Considerations on the Orientation and Shape of the Building

The shape of a building has great influence on the aesthetic value and the market price of the building. Although “function follows form” is a common motto in architecture; designers put most of their efforts especially in the shape of the building in order to create an attractive appearance at first glance and so it may gain artistic value and appreciation. This may be attributed to more appreciation means more reputation for the designer.

Table 3.1. Maintainability factors pertaining to architectural design process that have been evaluated by various field surveys

Architectural Design Factors		Assaf et al. (1996)	Al-Hammad et al (1997)	Chew and De Silva (2003)	Chong and Low (2006)	De Silva and Ranasinghe (2010)	Ali et al. (2010)	De Silva (2011)	Razak and Jaafar (2012)	Hassanain et al. (2013)	Hassanain et al. (2013b)	Omotehinshe et al. (2015)
Schematic Design	Suitability of building shape and orientation for environmental and climatic condition	✓	✓			✓		✓	✓	✓	✓	✓
	Consideration of the nature of building usage	✓	✓			✓		✓	✓			
	Consideration of prevailing wind direction in space design										✓	
	Adequate provision for indoor ventilation			✓							✓	
Material Selection	Selection of building materials not required frequent maintenance		✓			✓		✓	✓			
	Durability of building materials	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Suitability of exterior building materials and components for environmental and climatic conditions	✓	✓		✓	✓		✓	✓		✓	✓
	Consideration of the level of building usage	✓	✓		✓	✓		✓	✓		✓	
	Selection of demountable and sectional materials	✓	✓			✓		✓	✓			
	Availability of building materials	✓	✓				✓	✓	✓		✓	✓

Table 3.1. *(continued)*

Architectural Design Factors		Assaf et al. (1996)	Al-Hammad et al (1997)	Chew and De Silva (2003)	Chong and Low (2006)	De Silva and Ranasinghe (2010)	Ali et al. (2010)	De Silva (2011)	Razak and Jaafar (2012)	Hassanain et al. (2013)	Hassanain et al. (2013b)	Omotehinshe et al. (2015)
Accessibility	Accesibility to building elements, components and system	✓	✓			✓		✓	✓		✓	✓
	Accesibilty to all spaces of the building for maintenance staff	✓	✓			✓		✓	✓			✓
	Adequate number of building service areas					✓		✓			✓	✓
	Consideration of safety factor for maintenance activities								✓			✓
	Adequate space in building service areas for maintenance activities	✓	✓					✓	✓	✓	✓	✓
Detailed Design	Adequate provision for joints / detailing	✓	✓		✓	✓		✓	✓	✓	✓	✓
	Adequate provision for waterpoofing	✓		✓	✓	✓		✓			✓	✓

Along with the efforts made for the appearance, there should also be some important considerations for future maintainability of the building, since it was observed from previous studies that the shape of the building is one of the maintainability factors that obstruct maintenance activities. For instance; as stated by Ramly et al. (2006) the higher the buildings, the more easily they deteriorate and the more difficult they are to maintain. First of all; climatic and environmental effects on buildings should be taken into account while designing the building's exterior shape and orientation. The design should be in such a way as to prevent collection of water, moisture, dust, etc.

Building shape also has a significant impact on future maintenance activities in terms of accessibility which will be discussed later, under the heading of "Accessibility".

Building's exposure to the prevailing wind direction is another factor that should be considered due to most rainfalls are accompanied by wind and also wind force may alter the pattern of runoff flow on facade. Propagation of foul odor is another problem occurs due to placement of kitchens and toilets in the direction of the prevailing wind (Chew, 2010; Hassanain et al. 2014).

Thereby, by considering climatic and environmental conditions during decision process; maintenance efforts that are required for continuous repairing and cleaning of affected areas and consequential costs will be reduced (Al-Hammad et al., 1997; De Siva et al., 2012).

3.1.1.2 Ventilation Considerations

Due to indoor air quality, human health and thermal comfort are became an important issues; constant air exchange is required for building users. Thus; ventilation and air circulation in building is essential not only to supply adequate amount of oxygen and replaces the carbon dioxide produced in the space but also to remove any undesirable odors and contaminants and to extract humidity - as 90% percent human exhalation is humidity- (Sivanathan et al 2012; Passe and Battaglia; 2015). While air circulation and ventilation for building spaces can be achieved by mechanical or natural means, or a combination of both; natural ventilation can be provided by windows, exhausts and ventilation ducts and air passages (Ishak et al., 2007). Even lack of ventilation considerations cause user discomfort and health problem; they are not only building users, building components and hence their maintainability are also affected by the consequences of poor and inadequate air circulation. The main adverse effect especially in wet areas that has been identified is the occurrence of humidity and condensation problems which bring along the dampness penetrations through walls, stains and biological growths such as mold and fungi on floors, ceilings and walls (Sobottka and Thriene, 1996; Chew et al., 2004a; Chong and Low, 2006; Chew, 2010). Therefore occurrence of those defects means more maintenance efforts and consequence costs and further; installation of additional mechanical supplementary can be required to provide adequate ventilation. Along with the additional costs, newly installed systems, if no provisions are provided, may create different problems. For instance; in the study of De Silva (2012), one building was later converted to air-conditioned by fixing window type air-conditioners where the outdoor units are fixed on the balconies and this solution caused deterioration of the slab due to drainage water of the outdoor unit. As a consequence; ventilation decision taken in the design process can have an important effect not only on user comfort but also on the future performance and maintainability of the building.

3.1.1.3 Nature of usage

Designing of a building in accordance with the building's intended use, has a significant impact on facilitating the function of the building properly during occupation process. Once the building is designed and occupied, it becomes difficult and costly to make any functional change due to further user or building requirements. According to their intended use, buildings have specific requirements and attentions.

When considering hospital buildings; it should be kept in mind that majority of the building users are consist of patients. Thus more attention should be paid for health and safety considerations while laying out the functional relationships between spaces, selecting materials and specifying ventilation solutions. For instance; the way of access to building systems should be as easy as possible due to early response to malfunction has vital importance or special attention should be given to ventilation provisions in operating rooms. As another example; it should be kept in mind that the first priority for hotel buildings is to ensure maximum guest satisfaction during their stay. Thus building should be designed such a way to minimize maintenance requirements especially in guest rooms and if needed, maintenance activities should be taken without disturbing the guests like providing access for maintenance from the corridors. Providing adequate number of elevators based on the type of the building and user density is another example. It can be concluded that the consequences of faulty decisions or misjudgments regarding users' intended use may be severe in terms of maintenance efforts, user discomfort and costs for correcting actions.

Similarly as De Silva et al. (2012) mentioned; the flexibility of the design also have important role in further developments and expansions to meet the future demands. For instance; office buildings as compared with residences and hotel buildings, require large openings to ensure open-space systems and they are more prone to future changes such as expansion of the spaces and vice versa. The possible changes of user requirements and demands at later stages will create various problems, difficulties and high renewal costs due to lack of provisions for such changes. Together with architects, clients also play an important role regarding aforementioned issues. Client should define adequately his expectations and functional requirements for the building project in design briefing process to avoid misunderstanding.

3.1.2 Material Selection Factors

The selection of building materials during design plays a significant role in the life cycle of a building due to performance of a building is directly affected by performance of the materials. Faulty decisions taken in design processes for the selection of the materials could cause early deteriorations and building defects, frequent maintenance activities as well as high repair and replacement costs.

Considering previous field surveys and questionnaires conducted in an attempt to identify the most important factors either affecting maintenance costs or causing building defects as well as bringing on maintainability problems; selection of building materials in design process have been determined as one of the most important factor (Chew and De Silva, 2003; Chong and Low, 2006; Ali et al., 2010; Razak and Jaafar, 2012 and Omotehinshe et al., 2015). Ishak et al. (2007) highlighted that improper material selection and lack of knowledge regarding materials' physical properties will mostly cause; cracks, paint decay, thermal expansion, dampness and staining. Further, as a result of the survey undertaken by Chong and Low (2006) on 74 buildings in Singapore; it was found out that 53.08% of the design related latent defects could be prevented by using more appropriate materials.

Even though selection of the materials is a major issue for designers, it is becoming increasingly difficult. Now; the designers are faced with a large range of product alternatives and besides there are many important factors that should be considered during the decision process. These considerations are durability, availability, appearance, suitability for the environmental conditions, maintenance requirements – the frequency and the method of maintenance - and costs of the materials. Moreover; Arditi and Nawakorawit (1999b) stated that designers are often subjected to a great deal of lobbying to use one product rather than another, and they are bombarded with a plethora of publicity material. In general, using new materials that have not been sufficiently proved in terms of performance and capability of meeting the requirements may result in various material defects and hence maintainability problems. These consequences are also valid for the opposite situation, that is to say; selecting the materials that designers are familiar with whether or not it is the proper choice. Moreover; a material which is proven to be suitable in one place does not always mean it will work well in another place due to changes in environmental conditions.

The results of the study conducted in US by Arditi and Nawakorawit (1999b) revealed that most of the designers while specifying building materials, consider the cost of the materials as the most important criterion and this factor is followed by aesthetics and maintenance considerations. Similar study in Caribbean revealed that cost is considered by designers as most important criterion when selecting building materials, followed by maintenance, availability and aesthetics (Chandler and Lewis, 2011). Further, Omotehinshe et al. (2015) found out in their survey that designers (57%) in Nigeria mostly considered the factors of “client choice”, “functional requirements” and “durability” while selecting the materials. While client is generally interested in keeping the costs low, thus his choice will be on cost efficient materials. Therefore, according to these mentioned results; cost of the materials is the most prominent factor for designers. Under the circumstances it should be kept in mind that selection of low cost material does not mean it is the economic choice. Materials that require less maintenance are mostly more expensive than less durable materials; hence life cycle cost considerations of materials should be taken into account by designers.

Material selection factors that should be considered by designers in terms of maintenance during occupation phase will be discussed in detail below.

3.1.2.1 Environmental and Climatic Considerations

As the appearance of a building has great influence on the aesthetic value and the market price of the building, apart from the shape of the building, designers attach their importance to exterior surface materials in order to create attention, visual depth and contrast. Along with aesthetical concerns; materials to be used should be selected by considering climatic and air conditions in current area, due to exterior part of the building is directly exposed to the environmental impacts.

As mentioned in previous literature and as a result of the studies carried out by BRE, 1983 (cited in Al-hammad et al. 1997), Assaf et al (1996), Al-hammad et al. (1997), Chong and Low (2006), De Silva and Ranasinghe (2010), Razak and Jaafar (2012), Hassanain et al. (2014), and Omotehinshe et al. (2015); exterior materials were identified as major areas that cause maintainability problems. Ramly et al. (2006) stressed that in most cases, main fabrics are the major areas that cause maintainability problems, especially if the defects occur at the exterior parts of the building. It was due to that part of the building is directly exposed to the climatic changes, pollution, sun and rain as well as to the forces of the wind.

Therefore; selection of exterior materials as well as colors according to prevailing wind direction and velocity, amount of rainfall, atmospheric temperature, air humidity and air pollutants – dirt and dust – in current area would prevent numerous problems that may occur during the building service life. Painting the buildings using dark colors in a dusty or industrial area that require a large amount of cleaning and using paints that cannot resist heat and humidity are some examples given by Al-Hammad et al. (1997). Again for dusty areas, selecting exterior materials with rough surfaces or indented designs of exterior walls could collect dusts and could hinder the cleansing effect of rain. Another example for the improper selection of materials is using glass panels in hot climates. In their survey conducted in Sri Lanka, De Silva et al. (2012) found out that even in new buildings, glass panels were faded due to direct exposure to the sunlight. Cook and Hinks (1992) stated that using different type of exterior materials can lead to differences in absorption pattern of each material that will cause concentration of water run off with different pattern and staining on the façade.

3.1.2.2 Durability

The durability is related with the inherent characteristics, quality, life span and level of maintenance requirements of the materials. While specifying building materials designers should consider the materials' performance against most frequent defects such as cracking, chipping, wear and tear, deterioration, dampness, biological growth and social impacts such as vandalism and graffiti. Also resisting of materials to moisture and stains in wet areas also should be taken into account due to quite common waterproofing failures (Chong and Low, 2006; De Silva, 2012). Further, the quality of a material has significant impact on material's durability and hence on satisfying its objectives and performance throughout its life.

In addition, the frequency of materials' maintenance mostly depends on the materials' durability. Even the durability and quality minimize the need of repairing and renewal of building materials; it may require frequent care. Thus, while specifying the materials, choices that require minimum maintenance activities should be taken into account. Every material has its maintenance needs as it is anticipated that some materials, such as roofs, will need to be replaced; whereas other materials need only be maintained, such as the paint on an external wall. That is to say; how materials are to be used in a building in conjunction with their intended function and their overall contribution to the building's performance should be considered (ICC, 2006). Therefore, decision to select more durable materials and thus minimizing the frequency of maintenance requirements could significantly lower both the maintenance costs and downtime loss and could also improve user comfort (e.g. using materials which are dirt resistant and can be cleaned easily). At this point; performance of a material throughout its life cycle should be taken into account regardless of their initial costs.

3.1.2.3 Level of Usage

Buildings' level of usage with regard to its intended use is another consideration that should be taken into account by designers while selecting interior materials. The density of human circulation and load impacts differs according to intended use and type of the building as well as for different areas of usage of one particular building. It is thought that high usage requires more effort to maintain and in their study Shohet (2003) has found out that maintenance costs are increased if the level of usage is high. As a result of the field surveys undertaken by Chew et al. (2004b), Chong and Low (2006), Ramly et al. (2006), De Silva (2012) and Hassanain et al. (2014); due to heavy usage and human circulation interior materials, more particularly floors are subjected to degradations. These degradations were seen as wears and tears, cracks, delaminations and stains for floorings. Therefore flooring materials that can better resist abrasion should be used in heavy usage areas. For instance, heavy-duty flooring materials are more recommended for factory buildings as compared to hotels or residential buildings. Ramly et al. (2006) stated that some factories are provided with vinyl floors, however; it requires frequent scrubbing, polishing and replacement due to the life-span of vinyl is very short and it gets dirty easily (Ramly et al., 2006). For an another example, in their survey Chong and Low (2006) and Hassanain et al. (2014) found out that the wall edges were subjected to frequent damages due to heavy human circulation. Thus installing metal or rubber protections on edges of walls in where there is heavy human and load circulation could prevent such defects. In the long run, the cost of protection edges can be significantly lower than the cost of future repairs (Chong and Low, 2006).

3.1.2.4 Availability

Building materials may be required to be replaced at the end of their useful life or in case of any damage. In such a case selection of rare materials that are difficult to substitute or materials that is costly and imported from foreign countries will cause difficulties. For instance, when the replacement of any part of an unavailable material is required and replacing it by using similar material may destroy the integrity in terms of visual and performance aspects. Thus, it may be required to replace the total area to provide integrity which will also cause significant increase of maintenance cost. Therefore, the availability of the same materials for future replacement is another point to be considered while selecting building materials to minimize maintenance costs and to prevent mismatches. Materials should be commonly available and used in the current location in terms of their color, shape, size and quality (De Silva, 2012; Hassanain et al., 2014).

3.1.2.5 Demountable and Sectional Materials

According to previous field surveys in literature; another factor that affects the ease and efficiency of maintenance activities is the way of fixing and installation of building materials (Assaf et al., 1996; Al-Hammad et al., 1997; De Silva and Ranasinghe, 2010; Razak and Jaafar, 2012). It is obvious that demountable and sectional materials and components could enable maintenance team to carry out maintenance activities easily, in a short time and in a safe manner. Thus, designers should avoid using of permanent fixations of materials and components which require continuous maintenance and complete removals during maintenance works (e.g. carpet, external window etc.). This consideration also gains importance for repairing the defective areas. Instead of changing the material totally, it will be possible to change the affected part which will have considerable effect on maintenance cost.

3.1.3 Accessibility Factors

All building materials, equipment and components need regular inspection and other maintenance works to maintain the required performance during their lifespan. Thus; even the future performance for maintainability has been taken into account in terms of material, component and equipment selection which have been mentioned in previous headings, it makes no sense if the accessibility considerations for maintenance activities during the occupation have not been taken into account in design phase.

As a result of the survey conducted by Bu Jawdeh (2013) for Middle East region; the problem of access for maintenance was indicated by facility managers as the most frequent problem that they are facing especially while maintaining HVAC equipment, replacing lighting fittings and attending to leakage problems. Similarly, in another field surveys conducted with maintenance managers by Al-Hammad et al.

(1997), De Silva and Ranasinghe (2010) and De Silva (2011); accessibility for future maintenance is identified one of the most significant design factors.

The consequence of poor design for accessibility such as some complex shapes of the external facade, insufficient spaces and number of service areas provided etc. would cause delay and/or inability to perform the maintenance activities and correspondingly escalating number of defects. Furthermore, there would be a significant increase of the maintenance cost due to the need of remedial actions or using special access systems (Ishak et al., 2007; De Silva and Ranasinghe, 2010). Consequently, accessibility considerations for ease of maintenance should be part of the design criteria for designers in order to all building elements could maintain their performances throughout their life time.

3.1.3.1 Ease of Access

The most significant accessibility considerations for maintainability are the provisions for easy access to building services/host systems, underground drainage systems as well as building elements that require regular maintenance such as external wall, window and roof. Along with these considerations, design should ensure the safe access of maintenance staff with their equipment to any place and all parts of the building that will need to be maintained during its life. At this point access should be considered to provide clear door openings to enable further replacement of any equipment.

Building elements should not be obstructed and maintenance should be fulfilled without interrupting the buildings operation and without disturbing the building users (Al-Hammad et al., 1997; Gray and Hughes, 2001). For example; De Silva (2012) stated that obtaining permission to carry out repairs is not always possible if the access doors are located inside the residential units and he further added that even some buildings have provided access doors outside, in most instances, alternative solutions suggested to correct the situation were left unattended, due to impracticality of the solutions. Further, access to services should not cause any damage or deterioration to finishes, e.g. access to services above suspended ceilings should be through access panels and not through individual tiles (Gray and Hughes, 2001). While providing all of these requisites; provisions to be taken into account are the safety access, access ways and access methods -whether permanent or temporary-.

Designers also play significant role for providing safe accessibility and safe working place for staff during maintenance. Gürcanlı (2011) stated that falling from or through the roof is one of the most frequently encountered accidents during the maintenance and one of the main reasons identified is the use of skylights. Designing permanent guardrails around skylights or skylight screens to eliminate the danger of falling from roof are some measures that should be taken during design process.

Another probable maintainability problem is due to the complex and irregular exterior shape of a building. Discontinuities of the surface, sharp corners, number of corners and some permanent architectural fixtures hinder the accessibility for maintenance activities. Considering one example given by De Silva et al. (2012) from their survey; the external shape of one high rise building that had not been designed for easy access for a gondola, temporary scaffolding had to be erected for each painting cycle and as a consequence the painting cost of external wall was doubled. Besides; when the entire exterior surface cannot be accessed by a single system, the utilization of more than one system for maintenance will be required and hence maintenance costs will be considerably increased when compared to maintaining a building with regular shape. Designing complex and irregular exterior shapes, along with increase of maintenance cost, may lead to remedial actions to be postponed and escalating number of defects due to failing to access for maintenance.

In case of designing such an external shape, installation of special equipment fixed permanently to the structure of the building to provide a platform for carrying out maintenance that is required would be one of the solution (Ramly 2006).

Roof is another difficult and unsafe part of the building while maintaining, especially when buildings are constructed high. Further; roof leakage, water seepage and materials blown away by wind are frequently encountered problems and required frequent maintenance (Chong and Low, 2006; Ramly et al., 2006). Thus, easy and safe access to the roof should be considered elaborately by designers, e.g. access to roofs should be from inside the building where possible.

3.1.3.2 <u>Provisions for Service Areas</u>

While providing easy access to all building elements; designing of building service areas through considering adequate space and number of access systems has vital importance for the efficiency of maintenance activities in terms of practicability and ease of maintenance activities and providing a safe working place for staff (Chew, 2010; De Silva et al., 2012; Hassanain et al., 2014).

First of all, designers should consider sufficient working space in service shafts -electrical and mechanical shafts-, air ducts, maintenance corridors and rubbish chute etc. to ensure maintenance staff with their equipment could carry out maintenance in an easy way and in a safe manner. Moreover, adequate number of service areas should also be provided during design. Separate service ducts and shafts should be provided for each service; for instance electrical and technical shafts have to be separated or air ducts should not be placed in plumbing ducts (Küçükçalı, 1999). Another example is; apart from passenger lift, providing service lifts inside the building when there is no other means of access way for carrying materials and equipment during maintenance. In his research De Silva (2012) found out in a building that removal of the waste material resultant from re-waterproofing of the roof was carried out in the passenger lift, as no other means of access were available.

3.1.4 Design Development Factors

Detailed design as a sub process of schematic design, provides the proper applicability and sustainability of the final design. Adequate and proper detailing of all building materials and components as well as their joints and connection points is the integral part of a design. Moreover; developing solutions to ensure the materials selected could be able to maintain their performance properly and to avoid defects and early deteriorations also should be taken into account by designers for buildings' future performance. Nevertheless; as a result of the previous research regarding maintainability which have been examined and also mentioned in heading number 2.5; inadequate and lack of provisions for waterproofing and detailing of joints during detailed design come into the forefront.

3.1.4.1 Provision for Waterproofing

Considering previous field studies that were conducted in different locations and for different types of building; waterproofing failures and consequence defects are identified as the very most common maintainability problems encountered during the operation (Chew and De Silva, 2003; Chong and Low, 2006; Ilozor, 2008; De Silva and Ranasinghe, 2010; Chohan et al., 2011; Hassan et al., 2011; De Silva, 2011; Hassanain et al., 2014; Abdul-Rahman et al., 2014; Omotehinshe et al., 2015). Even the fact that adequate provisions made during design process has considerable effect on minimizing waterproofing problems and hence maintenance interventions; nevertheless, almost in every building repetitively faced with these kind of problems regardless of the type and location of the building.

The most frequent defects encountered are; paint peelings, stains, blistering, efflorescence and fungal growth on walls and ceilings and cracks on floors. Primary reasons of defects are due to moisture penetration and migration, water leakage, seepage and water ponding, to which structural members, internal and external finishes (wall, floor and ceiling) and fixtures and fittings are exposed. Especially wet areas are more vulnerable to deterioration and it requires more attention and more maintenance due to the severity of effect of any failure. The essential point is segregating the dry zone from the wet zone. Providing proper waterproofing membranes and materials where it is required and vapor barrier where there is a high degree of humidity as well as their quality has vital importance in order to prevent such defects. Even these provisions are met by designers; not reflecting them in their drawings will lead efforts be wasted due to faulty implementation. Therefore; construction drawings regarding insulation details should be ensured in a correct and adequate way in order to be executed properly during construction.

Considering the external conditions, rain water is main potential source of waterproofing problems, thus provisions for draining the rain water is an important point to be taken into account during design. In order to ensure drainage provisions for water seepages through open joints like window frames and for possible stains on external wall; installation of drip profiles at borders of joints and extending the eaves overhang of the roof to provide more shading to the facade from rainwater are some examples for preventive measures that can be taken while designing. The effect of wind is also need to be considered thus drainage system can function more effectively (Chong and Low, 2006). Proper channel and gradient for rainwater in flat roofs and adequate roof slopes in pitched roof to drain the water flow down to down-pipes is essential for roof leakage and seepage due to water ponding which is one of the common causes of defects (Ramly et al., 2006; Ali et al., 2013).

Along with all these considerations; using resistant and appropriate materials for walls, ceilings and floors that have the possibility of being exposed to moisture from direct wetting, high humidity and condensation –e.g. breathable type of paint, water resistant floors- can further minimize the negative consequences.

As for basements, the failure to ensure water-tightness is the most prominent problem (Chew, 2010; De Silva et al., 2012). Proper selection of the waterproofing system and appropriate drainage design detailing -that is capable of collecting, draining and discharging water away from the basement envelop- should be provided to avoid water built-up behind the basement walls and consequent water leakage and seepage.

3.1.4.2 <u>Provisions for Joints</u>

Buildings' and its components' movements in terms of structural and thermal, even seem like small, have considerable impacts on building maintainability. Even some of the movements are unavoidable, many of building material defects and early deteriorations encountered are attributed to inadequate provisions made for joint designings during detailed design. That is to say, providing movement joints between building components and their proper detailing for accommodating the movements is an important consideration that should be taken into account by designers.

According to previous research made; it has been identified that the primary design fault regarding joint designing is the inadequate or lack of provisions for *"expansion joints"*. Expansion joints have paramount importance for different thermal movements which are caused by the expansion and contraction of building materials with rising and falling temperatures. As stated by Chong and Low (2006); heat source encourages expansion and when this source is removed or moisture introduced to materials contraction occurs and thus cyclic expansion and contraction will cause cracks in building materials. The most frequently encountered damages are; plaster cracks, tile crackings and delaminations (Chong and Low, 2006; Ishak et al., 2007; Chew, 2010; De Silva and Ranasinghe, 2010). Along with providing expansion joints and adequate detailing, knowledge of building materials' performances under these conditions and selecting appropriate materials also has importance for minimizing defects. For instance; selecting dark colored panels for exterior material in hot climates will be inappropriate decision due to heat is absorbed better by dark colored panels and thus experience greater expansion. Even expansion joint is an effective defense system against thermal movements; it mostly encourages water and dirt infiltration (Chong and Low, 2006; De Silva, 2012). In order to get rid of both water and dirt; proper water and dirt dispelling system such as weep holes or flushing should also be provided during detailing

Other types of joints that should be provided are described as followings.

- *Structure/enclosure joint:* Between the structural frame of a building and its infill components or the place in a building where a non-structural component meets a structural component; joints should be installed for the potential exists for an unwanted transfer of forces.
- *Abutment joints:* These allow the movement for two different types of construction meet or abut each other such as a framed wall system abuts a masonry wall system.
- *Building separation joint:* Buildings that are large in horizontal extent or buildings with multiple wings, towers etc. attention needs to be paid to divide these sections to avoid the transfer of movements from one section to another (Allen and Rand, 2007; Arsenault, 2010).

Cracks and joints due to movements -thermal or structural- and/or poor detailings; are also among the main causes of water seepages. Moreover; Chew (2010) indicated that the lack of accommodation for movement between slab and wall can damage the waterproofing membrane. Thus, additional precautions such as flexible sealant or fiberglass mesh can help to reinforce waterproofing membrane at joints and to accommodate any stresses attributed to the movement at the abutment of wall and floor.

There are different reasons behind inadequate and lack of provisions for waterproofing and detailing of joints during detailed design. Designers' lack of knowledge about the nature and behavior of materials and using new materials without understanding their nature and behavior is one of the main reasons that lead faulty design decisions in detailing. Further; as in Turkey and also stated by Miles and Syagga (1987); the designer usually left the drawing of details to unqualified draughtsman. This will result in inadequate or incorrect detailings which are also will lead to incorrect implementation during the construction and thus these faults are often mistakenly recognized as faults cause by the workmanship (Che-Ani et al., 2009). Also design drawings which are lack of such joint, connection, drainage details and references will lead the contractor to carry out the works depending on his own understanding and experience. Thus poor quality and faulty implementations may be executed. All of these conditions will create various defects and maintainability problems which can only be discovered during the occupation of building.

Therefore; collaboration with suppliers and manufacturers while selecting and detailing the materials as well as designers' checking the drawings of draughtsman before they are issued are essential for adequate detailing of every building component especially in terms of waterproofing and joint design. As a result; this will preclude latent defects and maintainability problems and will provide less maintenance during the service life.

3.2 THE EFFECTS OF MANAGEMENT PROCESS ON MAINTAINABILITY

Management of maintenance activities are the tail end actions in order to ensure building maintainability. Even the fact that decisions taken during the design process have more control over the building maintainability, the way of carrying out maintenance activities during the occupation process have considerable effect on building performance throughout its entire lifetime. Literature review reveals that various factors pertaining to management process affect the efficiency of maintenance activities. These are summarized in Table 3.2.

The study of Ganisen et al. (2015) focused on identifying the causes of building maintenance problems and critical success factors to be applied by the maintenance organization to overcome these problems. Hence; questionnaire survey and interviews were conducted with building maintenance organizations for residential buildings in Kuala Lumpur. Findings show that "lack of trained maintenance personnel", "insufficient building service maintenance" and "limited number of staff" were among the factors identified as the main causes of maintenance problems. Further, "workforce development and training", "clear goals and objectives", "effective monitoring and feedback" and "management planning" were ranked as most crucial success factors that should be paid attention by maintenance organization.

At present there have not been any legislative regulations for conducting the building maintenance activities in Turkey, thus it is necessary for maintenance staff to develop their own regulations especially for large scale buildings. Identifying the problematic areas that are attributed to management process will be beneficial for maintenance experts and governments to develop strategies against maintainability of buildings.

In order to examine maintainability factors in detail, they are gathered under three main groups by the author based on the extensive literature review results presented in Table 3.2. These groups are; "efficient management strategies/practices", "qualification and capability of maintenance group" and "user interactions". The remaining part of this section aims to explain these factors.

3.2.1 Efficient Management Practices

Considering the maintenance management process during occupation, research studies have been indicated that failure to execute required maintenance in right time has been come to the forefront as one of the most common causes of maintainability problems encountered (El-Haram and Horner, 2002; Chew and De Silva, 2003; Ali et al., 2010).

According to findings of the survey conducted by De Silva (2012); effective maintenance strategies are paid no attention such as using condition-based maintenance, feedback systems, documenting systems and IT related tools. The same situation may also strongly be valid for many developing countries as difficulties are apparent in the fields of knowledge, qualification of staff, budget, existing regulations and attitudes.

The study conducted by Engelhardt et al. (2002) based on a project of over 50 years in operation; found out that increased level of maintenance program could save 32% of maintenance cost when compared with a minimum level of maintenance program.

Table 3.2. Maintainability factors pertaining to management process that have been evaluated by various field surveys

Management Factors		El-Haram and Horner (2002)	Chew and De Silva (2003)	Chong and Low (2006)	De Silva and Ranasinghe (2010)	Ali et al. (2010)	De Silva et al. (2012)	Hassanain et al. (2013a)	Omotehinshe et al. (2015)	Ganisen et al. 2015
Management Practices	Establisment of maintenance planning	✓			✓	✓	✓			✓
	Documentation of maintenance activities		✓		✓		✓	✓		
	Proper allocation of maintenence budgets	✓	✓		✓	✓	✓	✓	✓	
	Usage of spare parts and materials with adequate quality	✓				✓		✓		✓
Qualification and Capability of Maintenance Group	Qualification of maintenance staff	✓			✓	✓				✓
	Providing regular training to maintenance staff	✓			✓	✓	✓	✓	✓	✓
	Experience and knowledge of maintenance manager	✓				✓	✓	✓		
	Involvement of maintenance expert in architectural design process				✓		✓	✓	✓	✓
User Interactions	Regular feedback from users	✓			✓	✓	✓	✓		✓
	Providing property use manuals and rules	✓		✓	✓	✓	✓		✓	

The category of "efficient management practices" includes;

- Establishment of maintenance planning
- Documentation of maintenance activities
- Proper allocation of maintenance budget
- Usage of spare parts and materials with adequate quality

These factors have been already discussed in detail under the heading of building maintenance management in Section 2.3.

3.2.2 Qualification and Capability of Maintenance Group

3.2.2.1 Competence of Maintenance Group to Carry Out Maintenance

Qualification of maintenance staff who involved in carrying out the maintenance activities has significant effect for the efficiency of maintenance work both in short and long term. Defective works due to poor workmanship may cause damages on building components during carrying out maintenance and also may cause to create other defects during repairing a damaged component. These consequences may occur immediately or after a period of time, thus additional remedial actions and additional costs will be required (Ali et al., 2010). Defective works carried out by unqualified staff may also raise health and safety concerns for all. Therefore sufficient number of qualified staff will ensure maintenance activities be carried out as planned, in a safe manner and in accordance with budget allocated.

Along with the qualification; maintenance group should be aware of new developing technologies, as technology becomes a tool that assists maintenance staff for improving building maintenance process. Using intelligent equipment and technology applications such as infrared non-destructive testing that helps detecting building defects before they result in severe damage; computerized maintenance management systems for planning, scheduling and recording maintenance performance history are recommended to enhance the efficiency of maintenance as well as to achieve savings in labor and material (Tse, 2002; Lee and Scott, 2009; De Silva and Ranasinghe, 2010). It can be concluded that; due to the development of enhanced technologies for maintenance, providing regular training to maintenance staff and equipping them with knowledge are of great importance in order to accommodate new approaches for improving maintainability.

3.2.2.2 *Adequate Experience and Knowledge of Maintenance Manager*

Maintenance activities are managed either by facility manager or maintenance manager depending upon management policy. Facility manager has the responsibility for operating the facility during occupancy, which includes management of the built space, services, technology, maintenance, modification and adaptation, function and use, security, comfort, environmental health, costs and benefits of occupancy (Lavy and Shohet, 2004). Owing to his extensive responsibilities especially for large scale buildings, assignment of a maintenance manager is commonly required for managing ongoing maintenance activities.

No matter who manages, the purpose should be preserve the building in its initial states in terms of functional, structural and aesthetic aspects and further prolong the useful life of the building and its components and therefore retain its investment value. As he needs to ensure the building is properly maintained at optimum standard; he should establish cost-effective strategies, schedule maintenance tasks, document and record maintenance history and also should manage the maintenance group (Horner et al., 1997; Adejimi, 2005). To achieve these requisites, maintenance manager should have the necessary qualifications. Firstly, he should have received undergraduate or graduate education in the field of Facility Management. Moreover he should have experiences and technical backgrounds regarding not only performing maintenance activities but also managing the process and the peoples. Faulty decisions taken by maintenance manager due to inadequate experience and lack of knowledge will lead to poor administration of the maintenance department and poor maintenance strategies. As he is the most responsible person for maintenance activities to be carried out in a proper and efficient way, adequate experience and knowledge of the maintenance manager has great importance for building maintainability.

3.2.2.3 *Involvement of Maintenance Expert in Architectural Design Process*

Ever increasing complexities of building systems due to growing higher building standard demands, development and use of new building materials and construction technologies bring along an increase of maintenance problems and additional costs during the occupational phase. Accordingly, the management of the buildings is becoming more complicated and troublesome thus heavy burden is imposed on facility managers and maintenance managers. Even though effective management of building maintenance during the operation could minimize maintainability problems, managers have very little control over the maintainability problems that are attributed to faulty decisions taken project development process.

Previous research which are examined in detail in previous chapter have been revealed that the decisions made during the project development phases have a significant impact on the future maintainability of the building. Therefore; planning for maintenance should start during the design phase and continue throughout the useful life of the building. As opposed to general view regarding profession of facilities and maintenance management is limited with building occupation process, involvement of a maintenance specialist in project development processes are of great importance for maintainability.

Jaunzens et al. (2001) discussed benefits of the involvement of the facility manager during design process and stated that it should result in buildings which are:

- Better suited to meet business needs,
- More attractive,
- Easier to maintain and commission,
- Easier to manage and control,
- More cost-effective to operate and
- Better suited to the end users' needs.

From the point of view of maintainability, consulting an experienced and qualified maintenance expert to acquire knowledge on maintainability requirements will ensure high maintainable designs and will create awareness to avoid the repetition of faulty decisions taken in every new building. Involvement of maintenance expert during the design process will be beneficial for the following issues:

- Selection of maintainable materials, equipment and systems,
- Ensuring accessibility requirements,
- Providing adequate space in service areas,
- Accurate estimation of the expected maintenance budget,
- Understanding expected user profiles and user requirements,
- Understanding the types of activities to be carried out.

Based on the extensive literature review; it can be understood that the contribution of the maintenance expert from the early phase of development process is not considered commonly and there is a lack of communication with maintenance experts to seek advice about the decisions based on their practical exposure to maintainability problems that are faced during the phase of occupancy (Chong and Low, 2006; Ramly et al., 2006; De Silva and Ranasinghe, 2010; De Silva et al., 2012; Hassanain et al., 2013; Omotehinshe et al., 2015; Ganisen et al., 2015).

In the survey of Arditi and Nawakorawit (1999a) property managers stated that they would like to advice designers especially about functional design alternatives and choice of building materials and equipment to minimize anticipated maintenance problems. In another survey made by Omotehinshe et al. (2015), maintenance experts stated that their contributions to design factors such as the choice of building shape, choice of building materials, functional design alternative and cost alternative in maintenance would ensure the ease of future maintenance and better service conditions. According to the another survey conducted by Arditi and Nawakorawit (1999b) the large majority of the respondent designer firms in US agreed that maintenance consultants would be most effective when the projects are within the front part of the design process and they also emphasized that it would be most valuable especially in the schematic design stage. Based on the survey by Arditi and Nawakorawit (1999b); Chandler and Lewis (2011) carried out a research in order to find out designers attitudes about maintainability. The focus was on large multi-storey buildings in the Caribbean. Nearly half (43 %) of the designers stated that maintenance should be considered in the conceptual design stage and 30 % during the schematic design stage. According to both group of designers, they agree that maintenance input is most valuable early in the design process.

3.2.3 User Interactions

Ensuring users’ satisfaction and a good reputation should be one of the primary aims during the building operation process. Well functions of building equipment, appearance of building materials, clean, safe and healthy environment are major concerns of the users. To fulfill the user requirements and effective maintenance activities; getting feedback from users about complaints and concerns have great importance for taking actions to eliminate the concerns and formulating maintenance decisions (Arditi and Nawakorawit, 1999a; Ali 2009). Along with user satisfaction; being in communication with user will lead early response to building defects and failures and will decrease the rate of deteriorations and thus additional works and consequence costs (Wordsworth, 2001, Hua et al., 2005).

While measuring the performance of the building and satisfaction of user, benefit from some measurement tools will further provide other advantages. Considering Post Occupancy Evaluation as one of the most popular tools will help maintenance manager to document and record the deficiencies due to faulty decisions. These information can be used for the improvement of both future management decisions and the decisions taken during project development process. That is to say, maintenance manager will be able to provide a link between various parties e.g. users, clients and designers. Herewith; for instance, architects can be aware of their faulty decisions and decisions' effect on future performance of the building and thus same mistakes will not be repeated in the future (Che-Ani et al. 2009; Bu Jawdeh, 2013). As a result; communication with users at regular and frequent intervals and getting feedback from users will have a considerable effect on improving maintainability.

Yet another management consideration with regard to user interactions is preventing the damages due to improper use of the building. Users' ignorance on how building and its components perform conduces to maintainability problems in form of defects and deteriorations on building materials and services. De Silva et al. (2012) indicated that if user does not have the proper knowledge of using a particular building system, it will deteriorate faster due to the wrong usage. As a consequence, maintenance requirements due to remedial actions will increase. Further this will also lead to an increase of maintenance cost as it was also found out through the survey conducted by El-Haram and Horner (2002). Impacts from user also ranked as one of the most common causes of encountered maintainability problems in some previous research (Chong and Low, 2006; Ramly, 2006; De Silva and Ranasinghe, 2010; Omotehinshe et al., 2015). Therefore; in order to minimize these kinds of problems, knowledge for users regarding the use of the property should be ensured by providing manuals and rules etc. Besides, it should be taken into account that the consequences vary depending on the type of building, for instance special attention may be required for hospital buildings due to more serious consequences.

4 DATA ANALYSIS AND DISCUSSIONS

4.1 METHOD OF SURVEY

The success of achieving the objectives, that are determined within the scope of this thesis, is directly proportional to the accuracy of the assessment to be carried out. Therefore; depending on the aim of the survey, selecting the appropriate method and establishing the survey in a correct way have paramount importance.

The main aims of this survey are to

- identify the level of importance of the factors that affect building maintainability during the occupational phase pertaining to architectural design and maintenance management process,
- identify the frequency of occurrence of the maintainability problems during the occupational phase,
- identify the types of maintainability problems specific to a particular building type and assess whether the involvement of maintenance manager in building production phase provides benefits for an improved maintenance,
- identify the points that should be strengthened towards Turkey.

In order to achieve the aim of the survey, following steps are performed respectively;

- Selection of the appropriate data collection method
- Developing the data collection material
- Conducting preliminary survey
- Revision of the survey
- Conducting main survey

Description of the designing and executing the survey process according to above steps will be explained in the following sections.

4.1.1 Selection of the Data Collection Method

Data collection in research depends on a number of parameters such as the characteristics of target population, available resources and the nature of the topic of interest. There are various methods of data collection such as; surveys, experiments, quasi-experiments and single-case research, case studies, correlational research and action research.

While comparing existing conditions to standard ones or creating relationships between events at specific points in time, survey is the most common method to be used in gathering the needed data (Cohen et al., 2011). Surveys are described by Fink (2002) as a system for collecting information to describe, compare, or explain knowledge, attitudes and behavior. As stated by Gray (2009) survey is a common methodology in research as it enables the collection of significant amounts of data from a sizeable population (Cohen et al., 2011). There are generally two different types of surveys which are descriptive and analytical. Descriptive surveys are designed to measure the characteristics of a particular population, either at a fixed point in time or comparatively over time. They are used to measure "what" occurred, rather than "why". When the purpose of the research shifts from counting and describing to answering the question "why", analytical survey is then used to perform an analysis of causality. Analytical surveys attempt to test a theory in the field, their main purpose being to explore and test associations between variables (Oppenheim, 1992; Gray, 2009).

Surveys are conducted using a questionnaire, structured observation and structured interviews. Among them, questionnaire surveys are the most common and the best methods of gathering data as they can reach a large number of responses in various locations in a shorter time and with lower cost. Boynton and Greenhalgh (2004) argue that questionnaires offer an objective means of collecting information about people's knowledge, beliefs, attitudes, and behavior. Questionnaire can be self-administered or interviewer-administered. Interviewer-administered questionnaires are conducted by structured interview, telephone survey or focus group survey.

Interviewer-administered questionnaires are the most effective method in order to get more detailed responses and to ask complex and open-ended questions. Further, these methods allow the researchers to determine and revise the incorrect or incomplete answers and to clarify the questions in case there is a lack of understanding. Structured interview and focus group survey methods require large amounts of interviewer and respondent time, a significant proportion of which is often spent travelling to and from interviews. Moreover, the interviewing process can be time consuming and costly (Gray, 2009). Telephone surveys require short, simple questions and the kinds of response choices few and short, therefore when the questionnaire requires a large number of questions and/or long and detailed answers it won't be an appropriate survey method.

Self-administered questionnaires can be sent through the post, delivered by hand to each respondent and collected later or conducted by using the Internet. The advantages of delivering the questionnaire by hand are to ensure direct contact with the respondents and to convince them to complete the survey; however considerable time and effort should be spent. Further, when it is necessary to reach large number of respondents it will be highly inconvenient method of survey.

Mangione (1995) suggests that postal questionnaires are best option when;

- the research sample is widely distributed geographically,
- the research subjects need to be given time to reflect on their answers,
- the questions are mostly written in a close-ended style.

According to Gray (2009) postal questionnaires are most suited to the situation where the questions require relatively straightforward answers. Also in this way the respondents may complete the questionnaire in their own available time and the answers may be more honest than when faced by an interviewer, as they may be tempted to be impressed by the interviewer and provide exaggerated or socially desirable responses.

In order to take a step forward to postal questionnaire, in recent years additional approaches to data collection using the internet were introduced which also provide all of the advantages and conditions of postal questionnaires. It includes web-based data entry and direct mailing of online questionnaires (Schleyer and Forrest, 2000). They may be advantageous in that they are potentially time, effort and cost-saving when compared with other methods. Web-based survey which is an increasingly popular way, improve data quality since validation checks can be incorporated with prompts that alert respondents when they enter implausible or incomplete answers (van Gelder et al., 2010). While web-based surveys enable respondents to put the least effort, the response rate can also be considerably increased.

In this research, maintenance managers are the target population for gathering the required data. Due to a large majority of the professionals have been working in large-scale and high-use service buildings like hospitals, shopping centers, hotels etc., there is a limited number of competent professionals. For the sake of suitability and acceptability of this study, it was necessary to reach as many of the professionals as possible. Furthermore, due to the busy schedule of maintenance managers, it is hard to catch them in their free time for face to face interviews and also for meeting the quorum. Since the study covers the buildings in Turkey, it is necessary to get contact with the managers in different cities. Therefore along with the close-ended type of survey questions, web-based and self-administered questionnaire is found to be the most suitable and effective method for this research. Thereby survey link would be sent via emails and/or just with a message through social network sites to relevant person in various locations and cities and they would be able to fill the questionnaire survey whenever they want in their spare times.

4.1.2 Design of the Questionnaire

As mentioned above, web-based and self-administered questionnaire survey was developed and carried out for the research. Ali (2009) stated that the questionnaire should be short and simple in order to get a high response rate, meanwhile not taking much time for the respondents to answer. Accordingly the questionnaire survey was developed within this direction.

The questionnaire survey in this research includes a total of 60 questions and consists of four sections. 16 of the questions which constitute the first two sections are mostly close-ended and require check-box responses. The remaining 44 questions in third and fourth section require responses on a 5-point Likert scale which is one of the accepted methods for measuring individual attitudes toward independent variables (Saghatforoush et al. 2009).

First section comprises of personal information of the respondents such as job definition/position and educational background. Second section includes questions about the building characteristics such as city, age, area, number of floors and type of the building and general information about maintenance managers' attitudes while maintaining the building (the building production phases that they were involved, maintenance planning and user considerations).

Third section of the survey focuses on identifying the level of importance of the factors that affect the ease of maintenance and/or cause maintainability problems during the occupational phase pertaining to architectural design and managerial decision. While establishing the third section which forms the main concept of the survey, primarily; factors which will be assessed were determined through detailed literature review with consideration of current situation and practices in Turkey. Another consideration is about maintenance managers' unfamiliarity associated with architecture-related technical terms. Questions, hence the factors are determined as they can understand and assess them in a correct way.

Consequently a total of 30 factors identified for the third section of the survey. These factors were categorized in two groups. 20 of them pertaining to architectural design decisions and the remaining 10 are related to managerial decisions. Based on their experience, the respondents were asked to rate the importance of identified factors depending on their effect on ease of maintenance during the occupational phase. A 5-point Likert scale ranging from "not important" to "very important" was provided to rate the importance. It was also important to make it clear to respondents what was meant by each factor, therefore detailed information of each factor as a pdf document was prepared. A web link was provided in third section of the survey in order to get access to the pdf document.

Fourth section aims to find out the frequency of occurrence of the maintainability problems during the occupational phase. Maintainability problems that were considered in this section are determined due to the consequences of maintainability factors pertaining to architectural design decisions that were identified in third section. After all, the section comprised of 14 maintainability problems and the respondents were asked to indicate the frequency of occurrence of each problem on their buildings. A 5-point Likert scale ranging from "never" to "always" was provided to indicate the importance.

Before the implementation of the questionnaire, a preliminary survey was conducted with two maintenance managers who have long experience in managing high-use buildings. The aim of this preliminary survey was to assess the validity and acceptability of the developed questionnaire, especially maintainability factors and problems take into account. According to their remarks, revisions were made on identified maintainability factors and related problems. Finally, the questionnaire was checked over by a Professor of Statistic in Mimar Sinan Fine Arts University, thus the survey could be organized in a correct and proper way in order to ensure accurate assessment of the results. To convert the prepared questionnaire to a web-based survey, Google Forms tool was used. The final questionnaire is provided in Appendix A.

4.1.3 Survey Process

In the survey implementation process it was aimed to reach as many of the maintenance managers as possible across the country, although there are limited number of competent professionals as mentioned before. Besides, having difficulties in finding the contact information of maintenance managers led to the necessity of communicating with them through some associations. Large majority of the members of these associations are comprised of technical managers of large-scale buildings like shopping centers, hotels and hospitals etc.

First sample was drawn from the members of the International Association of Facilities Technical Managers (UTTMD) in Turkey. It has the highest number of members (approximately 150) as it also covers the members of other associations. Containing the scope and the aim of the research and also the survey link, a letter from the Head of UTTMD was mailed to all of the members requesting that they participate in the survey. However; only 26 responses were obtained and thus considering the insufficient response rate, the necessity of communicating with managers in another way was arisen. Then, contacts were made with the Head of Association of Aegean Technical Managers (EgeTMD) and one of the members of Bursa Technical Managers Platform. They were required to transmit the survey to the members. Also an announcement including the aim and scope of the survey as well as the survey link was made on the website of EgeTMD. With 11 more responses as a result of these efforts, 37 responses were obtained totally. As it is clear from the literature that the survey response rates are unfortunately generally low for questionnaires, this was an expected outcome due to busy schedules of managers. Due to the fact that a low response rate was obtained in the first round, a final effort was made to increase the participation. 10 selected large-scale buildings were visited in order to enter into a direct contact with maintenance managers without getting any appointment and they were requested to participate in the survey. After giving information about the research and getting their email addresses, the survey link was sent and 7 of managers responded the survey. Eventually 44 responses were achieved. The total number of usable 44 responses was above the limit of acceptability based on the central limit theorem which states that once the sample size is above 30, it is sufficient to provide results that are statistically significant (Stephens, 2006).

The survey implementation process was hardly completed and the duration of gathering responses from maintenance managers took so long time (nearly 6 months) than expected. Detailed analysis of the survey results, based on which discussions and comparisons with literature are explained in the following sections.

4.2 DATA ANALYSIS

The responses obtained from the survey were analyzed within the scope of the research. Out of 44 responses, 42 were found to be acceptable for further analysis and the remaining two responses were not taken into account as building type which these respondents currently managing are small-scale housing and school buildings. The focus of the study was on high-use and/or large scale buildings due to their complexity and higher degree of maintainability challenges.

There are a number of statistical techniques for measuring descriptive features, looking at reliabilities, relationships and differences. The appropriate techniques should be determined according to the purpose of the analysis, level of measurement and number of variables. In the current study, all statistical analyses were carried out using Statistical Package for Social Science (SPSS version 19). Frequency distribution, median, mean and SD were used as descriptive statistics.

Reliability analysis is carried out to measure internal consistency and reliability of developed measuring instrument which is most commonly used when the questionnaire is developed using multiple likert scale statements and therefore to determine if the scale is reliable or not. Cronbach's alpha is a measure of internal consistency and the most common form of reliability coefficient. It is expressed as a correlation coefficient, and its value ranges from 0 to +1. By convention, alpha should be 0.70 or higher to retain an item in a scale. Within the scope of this study, reliability analysis was carried out in order to measure internal consistency and reliability of developed third and fourth section of the survey which consist of Likert scale responses. Further it was also performed to find out how closely related a set of factors are as a group. Analysis results and details will be indicated under the related headings.

Since the survey data was not normally distributed; non-parametric tests were used;

- to compare the importance degree of maintainability factors and the occurrence frequency of the maintainability problems with specific building type, and
- to identify if there were any variance in the occurrence frequency of the problems in case that the maintenance team got involved in design stage or not.

Among non-parametric tests; Kruskal Wallis and Mann Whitney U are used to determine if there are statistically significant differences between two or more groups of an independent variable. In this regard, Mann Whitney U test was used to compare factors with two levels of measurement and Kruskal Wallis test was used when more than two levels were present.

4.2.1 Demographics and Maintenance Practices

The respondents of the survey are the maintenance managers get involved directly in building maintenance, although they have different job definition as the concept of maintenance manager is not common in Turkey. Demographic profile of the respondents is evaluated from the information at first section of the survey and demonstrated in Table 4.1. The profile shows that almost 80 % of the respondents are technical managers or maintenance managers and the remaining are comprised of deputy technical managers, chief technician.

The result also indicates that 69 % of them have bachelor degree, whereas 31 % have high school or associate (two-year education) degree. Apart from high school graduates, majority of the graduated respondents are from electrical engineering department (31%). It is followed by mechanical engineering graduates (23%) and two-year electrical technician program graduates (20%).

Table 4.1. Demographic profile of the respondents

Number of responses	**42**	**%**
Job definition/position		
Technical manager	33	79
Deputy technical manager	3	7
Chief technician	4	9
Other	2	5
Educational background	**42**	
High school degree	3	7
Associate degree	10	24
Bachelor degree	24	57
Postgraduate	5	12
Graduate department	**39**	
Civil engineering	3	8
Mechanical engineering	9	23
Electrical engineering	12	31
Electrical technician	8	20
Other	7	18

A number of 42 surveyed maintenance managers represent 42 different buildings. From the outcomes of the second section the characteristics of the buildings are demonstrated in Table 4.2. Accordingly, nine types of buildings are identified and these include hospital (19%), hotel (21%), shopping center (17%), office (17%), industrial (9%), residence (5%), education complex (5%), airport (2%), and multipurpose (Shopping center and office) (5%) buildings.

When examining the percentages of the intended use of the buildings; it is understood that hospital, hotel, shopping center and office buildings constitute the majority. Nearly half (43%) of the buildings are more than 10-storey and almost 80% have more than 10.000 m^2 building area. Further only 5% of the buildings are more than 30 years old. Considering the intended and actual usage of the buildings; it is found that five of them (12%) are actually planned for a different usage. Three of these buildings are built as an office building but two of them serve as a multipurpose building (shopping center and office) and other one serves as a hospital. Remaining two are planned as a residence but they are currently being used as an office.

Table 4.2. The characteristics of the buildings

Building number	**42**	**%**
Number of floors		
≤ 5	10	24
5 - 10	14	33
≥ 10	18	43
Area		
m^2 < 1000	3	7
1000 < m^2 < 10.000	6	14
m^2 > 10.000	33	79
Building age		
< 10	20	47.6
10 - 30	20	47.6
30 - 50	2	4.8
Building type		
Hospital	8	19
Hotel	9	21
Shopping Center	7	17
Office	7	17
Industrial	4	9
Residence	2	5
Educational Complex	2	5
Airport	1	2
Multi-purpose	2	5

The questions in the second section of survey also intend to find out some important points about current maintenance practices. The findings are illustrated in Table 4.3. First of all; the respondents were asked to indicate which phase or phases they had taken part in building production in order to find out if the involvement of maintenance manager in building production phase provides benefits for an improved maintenance. According to the findings, it have been realized that maintenance managers have been mostly involved (43%) in construction phase of the building that they are currently managing and only 24% and 21% of the respondents have taken part in design and feasibility phase respectively. Besides, half (50 %) of the respondents states that they have not been involved any of the building production phases. Thereafter, it is aimed to understand whether maintenance activities of the buildings are carried out in a planned manner. As a result, big majority of the respondents (81%) indicate that they already have pre-prepared a maintenance plan in which all of the maintenance activities, procedures and their periods are documented.

Table 4.3. General information about management practices

Involved building production phases	**%**
Feasibility	21
Design	24
Construction	43
All phases	12
None	50
Availability of maintenance plan	**%**
Yes	81
No	19
Methods for obtaining maintenance requirements	**%**
Electronic system reports by staff	55
Verbal/written notice by staff	83
Methods for obtaining user requirements and complaints	
Questionnaire	24
Personal statements by user	7

In final part of the second section, it is tried to find out which methods are being used for obtaining unforeseeable maintenance requirements and user requirements. Respondents stated that maintenance requirements are reported by maintenance staff through verbal/written notice (83%) and electronic systems (55%). Besides; only 24% of the respondents stated that they are paying attention to user feedback and thus in order to obtain requirements and complaints questionnaire surveys are carried out. Along with questionnaire surveys; 7% of the respondents also consider personal statements by users.

4.2.2 Factors Affecting Maintainability

Third section of the survey focuses on identifying the level of importance of the thirty identified factors that affect the ease of maintenance and/or cause maintainability problems. As to reliability analysis, Cronbach's alpha value of .825 shows acceptable reliability of 30 factors which were measured in third section. Thereafter, these factors are evaluated under two different groups as architectural design group and management process group. This is due to the fact that decisions taken in each group are related with different phase of a building life cycle and then it would be easier to develop and suggest appropriate strategies. Thus, reliability analysis is carried out for each group and it is revealed that both architectural design and management process factors have acceptable reliability according to Cronbach's alpha value of .754 and .724 respectively.

For further consideration, each architectural design and management process factor is gathered under different groups in order to explore further relationships to establish the maintainability strategies. In this regard; architectural design factors were categorized according to the similarity of their nature and grouped under four main headings as (1) material selection, (2) detailed design, (3) accessibility and (4) schematic design. For the internal consistency of the categorization, reliability analysis was made for each group of factors. Regarding Cronbach's alpha values (.553) it was revealed that each group has unacceptable consistency. However, a low coefficient alpha does not always mean a low degree of internal consistency and vice versa. This is because alpha is also affected by the length of the test. If the test length is too short, the value of alpha is reduced (Streiner, 2003; Tavakol and Denninck, 2011). Therefore, along with the poor inter-relatedness between factors, a low value of alpha could also be due to low number of factors as in this study. Nevertheless, assessment and discussion of these factors will not be handled under the groups within the scope of this research and each factor will be considered separately.

The corresponding percentages of 5-point Likert responses for architectural design factors are shown in Table 4.4. Further Table 4.5 demonstrates the ranking of 20 architectural design factors that affect the maintainability of buildings with respect to their importance degree.

Table 4.4. Percentages of responses for architectural design factors

Architectural Design Factors	Not important	Of little importance	Moderately important	Important	Very important
17. Suitability of exterior building materials and components for environmental and climatic conditions	0	0	2.4%	19%	78.6%
18. Suitability of building shape and orientation for environmental & climatic condition	0	0	7.1%	42.9%	50%
19. Durability of building materials	0	0	0	26.2%	73.8%
20. Selection of building materials not required frequent maintenance	0	0	9.5%	31%	59.5%
21. Availability of building materials	0	4.8%	16.7%	38.1%	40.5%
22. Selection of demountable and sectional materials	0	2.4%	33.3%	45.2%	19%
23. Consideration of prevailing wind direction in space design	0	7.1%	23.8%	31%	38.1%
24. Adequate provisions for indoor ventilation	0	0	7.1%	9.5%	83.3%
25. Adequate provisions for joints / detailing	0	2.4%	7.1%	66.7%	23.8%
26. Adequate provisions for waterproofing	0	0	0	14.3%	85.7%
27. Consideration of the level of building usage	0	0	11.9%	40.5%	47.6%
28. Consideration of the nature of building usage	2.4%	0	7.1%	28.6%	61.9%
29. Adequate space in building service areas for maintenance activities	0	0	4.8%	21.4%	73.8%
30. Adequate number of building service areas	0	0	7.1%	69%	23.8%
31. Accessibility to roof	0	0	4.8%	47.6%	47.6%
32. Accessibility to drainage systems	0	2.4%	2.4%	59.5%	35.7%
33. Accessibility to building service areas	0	0	2.4%	40.5%	57.1%
34. Accessibility to exterior walls and windows	0	0	19%	64.3%	16.7%
35. Provisions for accessibility to all spaces of the building for maintenance staff	0	0	4.8%	38.1%	57.1%
36. Consideration of safety factor for maintenance activities	0	0	7.1%	45.2%	47.6%

It is understood from the mean values that big majority of the architectural design factors are considered as important, however they have different importance degrees and they are ranked according to these degrees. As shown in the table; “adequate provision for waterproofing”, “suitability of exterior building materials and components for environmental and climatic conditions”, “adequate provision for indoor ventilation”, “durability of the building materials” and “adequate space in building service areas for maintenance activities" are seen as prominent factors that should be considered from the beginning of the architectural design process for maintainability of buildings. On the other hand, "selection of demountable and sectional materials", "accessibility to exterior walls and windows", "consideration of prevailing wind direction in space design", "adequate provisions for joints/detailing" and "availability of building materials" are ranked by the respondents as the least important architectural design factors.

Table 4.5. Architectural design factors affecting maintainability

Architectural Design Factors	**N**	**Mean**	**Std. Dev.**	**Rank**
26. Adequate provisions for waterproofing	42	4.86	.354	1
17. Suitability of exterior building materials and components for environmental and climatic conditions	42	4.76	.484	2
24. Adequate provisions for indoor ventilation	42	4.76	.576	2
19. Durability of building materials	42	4.74	.445	3
29. Adequate space in building service areas for maintenance activities	42	4.69	.563	4
33. Accessibility to building service areas	42	4.55	.550	5
35. Provisions for accessibility to all spaces of the building for maintenance staff	42	4.52	.594	6
20. Selection of building materials not required frequent maintenance	42	4.50	.672	7
28. Consideration of the nature of building usage	42	4.48	.833	8
18. Suitability of building shape and orientation for environmental & climatic condition	42	4.43	.630	9
31. Accessibility to roof	42	4.43	.590	9
36. Consideration of safety factor for maintenance activities	42	4.40	.627	10
27. Consideration of the level of building usage	42	4.36	.692	11
32. Accessibility to drainage systems	42	4.29	.636	12
30. Adequate number of building service areas	42	4.17	.537	13
21. Availability of building materials	42	4.14	.872	14
25. Adequate provisions for joints / detailing	42	4.12	.633	15
23. Consideration of prevailing wind direction in space design	42	4.00	.963	16
34. Accessibility to exterior walls and windows	42	3.98	.604	17
22. Selection of demountable and sectional materials	42	3.81	.773	18
Valid N (listwise)	42			

In the concern of factors pertaining to management process, they are grouped under three topics which are (1) efficient management practices, (2) qualification and capability of the maintenance group and (3) user interactions. As a result of the reliability analysis carried out for each group, “efficient management practices” have low consistency (i.e. alpha value is .221), yet “qualification and capability of the maintenance group” and “user interactions” have mediocre consistency (i.e. alpha values are .658 and .639 respectively). As pointed out earlier that low values could also be due to low number of factors, thus assessment and discussion of the managerial factors will not be considered under the groups as in the case of architectural design factors.

The percentages of responses for the importance of management factors are shown in Table 4.6 and the rankings of these 10 factors that affect maintainability is shown in Table 4.7. Similar to architectural design, it is clear from the mean values that big majority of management factors are also considered as important, still they have different importance degrees.

Table 4.6. Percentages of responses for management factors

Managerial Factors	Not important	Of little importance	Moderately important	Important	Very important
37. Involvement of maintenance expert in architectural design process	0	7.1%	9.5%	38.1%	45.2%
38. Adequate experience and knowledge of maintenance manager	0	0	2.4%	33.3%	64.3%
39. Establishment of maintenance planning	0	0	0	28.6%	71.4%
40. Proper allocation of maintenance budget	0	0	4.8%	54.8%	40.5%
41. Qualification of maintenance staff	0	0	0	26.2%	73.8%
42. Providing regular training to maintenance group	0	2.4%	4.8%	52.4%	40.5%
43. Documentation of maintenance activities	0	0	4.8%	50%	45.2%
44. Usage of spare parts and materials with adequate quality	0	0	7.1%	47.6%	45.2%
45. Providing property use manuals and rules	0	4.8%	16.7%	57.1%	21.4%
46. Provisions for regular feedback from users	0	4.8%	19%	50%	26.2%

The first point that draws attention is the poor importance given to the factors that are associated with user interactions such as “provisions for regular feedback from users” and “providing property use manuals and rules”

The other two groups namely “qualification and capability of the maintenance group” and “efficient management practices” appear to have similar importance for maintenance managers. Above all factors associated with the qualification and capability of maintenance group such as “qualification of maintenance staff” and “adequate experience and knowledge of maintenance manager” appear at the top of the ranking list. Besides, the adoption of a systematic management of maintenance activities seems to be important concerns for respondents' point of view.

Table 4.7. Management factors affecting maintainability

Managerial Factors	**Mean**	**Std. Dev.**	**Rank**
41. Qualification of maintenance staff	4.74	.445	1
39. Establishment of maintenance planning	4.71	.457	2
38. Adequate experience and knowledge of maintenance manager	4.62	.539	3
43. Documentation of maintenance activities	4.40	.587	4
44. Usage of spare parts and materials with adequate quality	4.38	.623	5
40. Proper allocation of maintenance budget	4.36	.577	6
42. Providing regular training to maintenance group	4.31	.680	7
37. Involvement of maintenance expert in architectural design process	4.21	.898	8
46. Provisions for regular feedback from users	3.98	.811	9
45. Providing property use manuals and rules	3.95	.764	10
Valid N (listwise)			

In an attempt to compare the level of importance of the decisions regarding two different phase of a building life cycle, namely architectural design and managerial decisions are evaluated together. Table 4.8 shows the overall ranking of architectural design and management factors that affect maintainability of buildings. It consists of 20 architectural design and 10 management factors. It is clear that among the total of 30 factors, the most important 15 factors comprise of mostly (80%) architectural design decisions. Two factors associated with user interactions which rated as the least important among the managerial decisions, appear again at the end of the ranking list with “selection of demountable and sectional materials” when considering together with architectural design factors. It can be understood from the Table 4.8 that according to maintenance managers' point of view, architectural design decisions have higher impact than maintenance management process on building maintainability.

Table 4.8. Overall ranking of factors pertaining to architectural design and management process

Architectural Design and Management Factors	N	Mean	Std. Dev.	Rank
A) Adequate provision for waterproofing	42	4.86	.354	1
A) Suitability of exterior building materials and components for environmental and climatic conditions	42	4.76	.484	2
A) Adequate provisions for indoor ventilation	42	4.76	.576	2
A) Durability of building materials	42	4.74	.445	3
M) Qualification of maintenance staff	42	4.74	.445	3
M) Establishment of maintenance planning	42	4.71	.457	4
A) Adequate space in building service areas for maintenance activities	42	4.69	.563	5
M) Adequate experience and knowledge of maintenance manager	42	4.62	.539	6
A) Accessibility to building service areas	42	4.55	.550	7
A) Provisions for accessibility to all spaces of the building for maintenance staff	42	4.52	.594	8
A) Selection of building materials not required frequent maintenance	42	4.50	.672	9
A) Consideration of the nature of building usage	42	4.48	.833	10
A) Suitability of building shape and orientation for environmental and climatic condition	42	4.43	.630	11
A) Accessibility to roof	42	4.43	.590	11
A) Consideration of safety factor for maintenance activities	42	4.40	.627	12
M) Documentation of maintenance activities	42	4.40	.587	12
M) Usage of spare parts and materials with adequate quality	42	4.38	.623	13
A) Consideration of the level of building usage	42	4.36	.692	14
M) Proper allocation of maintenance budget	42	4.36	.577	14
M) Providing regular training to maintenance group	42	4.31	.680	15
A) Accessibility to drainage systems	42	4.29	.636	16
M) Involvement of maintenance expert in architectural design process	42	4.21	.898	17
A) Adequate number of building service areas	42	4.17	.537	18
A) Availability of building materials	42	4.14	.872	19
A) Adequate provisions for joints / detailing	42	4.12	.633	20
A) Consideration of prevailing wind direction in space design	42	4.00	.963	21
A) Accessibility to exterior walls and windows	42	3.98	.604	22
M) Provisions for regular feedback from users	42	3.98	.811	22
M) Providing property use manuals and rules	42	3.95	.764	23
A) Selection of demountable and sectional materials	42	3.81	.773	24
Valid N (listwise)	42			

4.2.3 Maintainability Problems Encountered Due to Architectural Design Decisions

Fourth section of the survey aims to find out the frequency of the occurrence of the maintainability problems during the occupational phase as a consequence of both architectural design factors that were evaluated in previous section and improper use of the building by users. Respondents indicate the frequencies of 14 maintainability problems on a 5-point Likert scale ranging from “never” to “always”. According to the reliability analysis, Cronbach’s alpha value (.923) shows high degree of consistency of measured maintainability problems.

With the exception of the improper use of the buildings, four main topics as identified for architectural design factors are applied for maintainability problems, namely (1) material selection, (2) detailed design, (3) accessibility and (4) schematic design. The rankings of the occurrence frequency of maintainability problems due to their mean values are presented in Table 4.10, besides corresponding percentage of responses can be seen in Table 4.9.

Considering the rankings of the respondents, it can be concluded that as a result of architectural design decisions; problems due to “inadequate provision for waterproofing”, “inappropriate selection of building materials”, “inadequate provisions for indoor ventilation”, “improper building shape and orientation for environmental & climatic conditions” and “inadequate provisions for joints / detailing” are more frequently encountered by maintenance managers during the occupation phase. The second maintainability problem that is encountered is ranked as “misuse of the building by user”. Furthermore, rankings show that the least encountered problems are due to “ignoring the nature of building usage”, “ignoring the prevailing wind direction in space design”, “lack of provisions for accessibility to all spaces of the building for maintenance staff” and “inadequate number of building service areas”.

Table 4.9. Percentages of responses for maintainability problems encountered

Maintainability Problems Due to;	Never	Rarely	Sometimes	Often	Always
47. Inappropriate selection of building materials	0	26.2%	40.5%	26.2%	7.1%
48. Improper building shape and orientation for environmental & climatic conditions	7.1%	9.5%	54.8%	28.6%	0%
49. Ignoring the prevailing wind direction in space design	16.7%	47.6%	21.4%	11.9%	2.4%
50. Inadequate provisions for indoor ventilation	7.1%	23.8%	28.6%	33.3%	7.1%
51. Inadequate provisions for joints / detailing	4.8%	31.0%	31.0%	23.8%	9.5%
52. Inadequate provisions for waterproofing	0%	23.8%	33.3%	33.3%	9.5%
53. Ignoring the level of building usage	16.7%	21.4%	42.9%	11.9%	7.1%
54. Ignoring the nature of building usage	40.5%	26.2%	19%	7.1%	7.1%
55. Inadequate space in building service areas for maintenance activities	4.8%	28.6%	45.2%	19%	2.4%
56. Inadequate number of building service areas	9.5%	33.3%	38.1%	16.7%	2.4%
57. Lack of provisions for accessibility to building components and service areas	14.3%	23.8%	40.5%	16.7%	4.8%
58. Lack of provisions for accessibility to all spaces of the building for maintenance staff	26.2%	14.3%	47.6%	9.5%	2.4%
59. Ignoring the safety factor for maintenance activities	23.8%	9.5%	38.1%	23.8%	4.8%
60. Misuse of the building by user	4.8%	21.4%	28.6%	33.3%	11.9%

Table 4.10. Frequency of maintainability problems encountered

Maintainability Problems Due to;	N	Mean	Std. Dev.	Rank
52. Inadequate provisions for waterproofing	42	3.28	.944	1
60. Misuse of the building by user	42	3.26	1.083	2
47. Inappropriate selection of building materials	42	3.14	.899	3
50. Inadequate provisions for indoor ventilation	42	3.10	1.078	4
48. Improper building shape and orientation for environmental & climatic conditions	42	3.05	.825	5
51. Inadequate provisions for joints / detailing	42	3.02	1.070	6
55. Inadequate space in building service areas for maintenance activities	42	2.86	.872	7
59. Ignoring the safety factor for maintenance activities	42	2.76	1.206	8
57. Lack of provisions for accessibility to building components and service areas	42	2.74	1.061	9
53. Ignoring the level of building usage	42	2.71	1.111	10
56. Inadequate number of building service areas	42	2.69	.950	11
58. Lack of provisions for accessibility to all spaces of the building for maintenance staff	42	2.48	1.065	12
49. Ignoring the prevailing wind direction in space design	42	2.36	.983	13
54. Ignoring the nature of building usage	42	2.14	1.241	14
Valid N (listwise)	42			

For further examination; non-parametric test of Kruskal Wallis test were used to identify maintainability problems specific to a particular building type and Mann Whitney U test were used to assess whether the involvement of maintenance manager in building production phase provides benefits for an improved maintenance. Asymptotic p-values generated from both test shows the degree of the variances of the responses between compared factors. P value higher than 0.05 ($p>0.05$) means there is no any variances between responses. Nevertheless; according to both test results and asymptotic p-values, there haven't been found any variation between the responses except a few ones. This may be attributed to the sample size of the survey. Thus further examinations will be carried out and discussed by the author from the mean values in case of meaningful differences are seen as tentative results should be interpreted with caution.

4.3 DISCUSSION OF THE FINDINGS AND COMPARISONS WITH PREVIOUS STUDIES

This section provides a discussion of the survey findings and comparisons with previous studies and knowledge available in the literature. The outcomes are obtained and interpreted through detailed analyses of survey results and relevant comments of the respondents. Presented interpretations are made by the researcher.

4.3.1 Evaluation of Architectural Design Factors

Waterproofing Failures

Considering the occurrence frequency of maintainability problems; maintenance managers ranked problems due to “inadequate provisions for waterproofing” as the most frequent problem which was encountered during the occupation phase. The frequency of the problem was ranked as often and always by % 43 of the respondents. Further examination has been made in order to understand whether the occurrence frequency of waterproofing problems is changed according to particular building type. As a result, there have not been seen any type of building come to the forefront.

All this results show consistency with the great majority of previous studies regarding maintainability that were conducted in different countries and for different buildings. In their condition and field surveys Chew and De Silva (2003), Chong and Low (2006), De Siva and Ranasinghe (2010), Hassan et al. (2011), De Silva (2011), Hassanain et al. (2014) and Abdul-Rahman et al. (2014) found waterproofing defects as the most frequently encountered defects within the examined buildings. Considering that these surveys have been carried out for different types of buildings (e.g. university, hospital, residential and high rise buildings) and in different countries (e.g. Singapore, Malaysia, Sri Lanka and Saudi Arabia) inadequate provisions made for waterproofing during design emerges as a major common problem almost in every building regardless of the type and location. Furthermore, this opinion is supported and shows consistency with the result of overall ranking - ranking includes both architectural design and management process factors - of this survey in which “adequate provisions for waterproofing” has been also ranked by %86 of the respondents as the most important factor that should be considered during design. This is also stressed by two maintenance manager on their comments. One maintenance manager of an industrial building indicated that:

“Adequate provisions for waterproofing on roof should be considered for preventing water leakage due to rain. Besides, precautions should be taken for preventing water ponding on roofs. Unfortunately, we are experiencing the negative consequences of this ignorance whenever it rains”.

The results of the survey revealed that, from the %43 respondents who ranked waterproofing problems as often and always encountered; %26 of them represent buildings less than 10 years old. As it can also be understood from the comment below; even new buildings are frequently confronted with this problem. In this respect, one maintenance manager of a 3-year old hotel building stated that:

“Not taking long term precautions with regard to waterproofing is one of the major difficulties encountered in our hotel. Especially water leakages from roof cause lots of problems and this is experienced in almost every hotel”.

As revealed from the comments and previous condition surveys; roofs are more prone to damages arise from waterproofing failures. It is clear that waterproofing problem of water leakage and seepage is the major cause of rapid deterioration of building materials and components. Depending on the severity of the effect of waterproofing failures, it requires more attention. Also, due to remedy of these faults is generally very difficult, costly and required extra efforts, it is not surprising “adequate provisions for waterproofing” come to the forefront as the most important factor. It should not be ignored that insulation problems and defects are not occurred only due to inadequate provision by designers, poor workmanship during construction is also responsible for these problem. Designers required doing their share by providing proper materials and accurate details as well as by taking preventive precautions against waterproofing problems.

Material Selection

Problems due to “inappropriate selection of building materials” have been appeared in the third rank among encountered problems. This includes; decision faults regarding selection of building materials considering; environmental condition, durability, availability as well as ease and frequency of maintenance. This is an expected result due to peer-reviewed literature as it have been mentioned in almost every study -both field and literature surveys- that inappropriate selection of building materials and ignorance of material performance during design are common and significant problem.

Considering frequency of problems arisen from materials in Turkey, along with designers' lack of knowledge of how materials perform during its life span; one of the main reasons of material selection failures is designers' paying attention to initial cost of the materials in order to indicate economic feasibility of the projects for clients and life cycle cost considerations are not taken into account.

Accordingly, one of the maintenance managers stated that;

“While selecting building materials it should not be assumed that they will not get damaged. Further; materials should not be specified randomly just to serve its purpose, taking into account of long life performance of materials has vital importance for future maintenance activities. This, in turn led to significant amount of cost overruns for us”.

Moreover, it is thought to be useful to examine the significance level of factors related with selection of building materials in order to determine in particular the most important points that should be taken into consideration during design. While examining the respondents' assessments, “suitability of exterior building materials and components for environmental and climatic condition” is occurred as the most important factor among all factors related with material selection. It is also ranked as second in overall ranking. The reason why it is ranked as important may be several. One reason may be due to the exterior part of the building is directly exposed to the environmental impacts and thus more vulnerable to building defects; and/or due to carrying out maintenance activities are more challenging in exterior parts of the building. The result is consistent with previous research of De Silva and Ranasinghe (2011), Chong and Low (2006), Omotehinshe et al. (2015), Razak and Jaafar (2012) and Al-Hammad et al. (1997) in which this factor was also revealed as one of the most important factors affecting maintainability. Two of the respondents who are managing shopping centers also emphasized the importance of this factor on their comments. They indicated respectively as below:

“While specifying exterior building materials, especially materials’ resistance to hot and cold weather should be taken into account. Selecting absorptive glass on curtain walls causes cracking due to expansion and thus we are facing with additional costs for the replacement and repair of damaged materials”.

“Specified exterior cladding material for this building has poor quality and cause frequent maintenance. For instance, whenever it rains there appear stains on façade so it affects adversely the psychical appearance and it draws attention, thus frequent cleaning is required”.

It can be understood from the comments that:

- Especially in rainy zones, exterior building materials should be selected as dirt-resistant. Besides, it is important to develop solutions and proper detailings to prevent the collection of dirt in joints and exterior windowsills, thus contamination of façade would be minimized during the rain.
- Resistance of exterior building material to weather conditions also has vital importance for maintenance manager. Apart from repairing costs, replacement of damaged part is not always possible for the materials that could not be repaired. Sometimes entire façade need to be changed with more additional costs and efforts.

As a result; all of mentioned considerations would substantially minimize the cleaning, repairing and replacement efforts and consequent costs as well as would avoid exceeding of the planned costs.

“Durability of the building materials” has been also identified as one of the most important factor that should be paid attention. Durability could be ensured with considering the life span, quality and maintainability of all building materials in design process. When considering the materials’ durability has considerable effect on all type of building defects, paying attention to even only the durability would minimize the negative effects on materials caused by other decision faults, such as inadequate provisions for waterproofing, environmental conditions and joints/detailing.

The reason of factors regarding material selection comes into the forefront is due to the fact that materials are the keystone of a building and the performance of the materials play a major role on the building performance and maintainability.

Moreover, majority part of additional maintenance costs comprise of renewal and repair costs of inappropriate building materials.

Nevertheless, “selection of demountable and sectional materials” has been ranked as the least important factor among all architectural design factors and in addition; the result shows consistency with the previous studies in literature. This may be due to dealing with permanent fixations of materials and components during maintenance do not create a significant problem for managers as compared with other maintainability problems.

Provisions for Ventilation

As a result of the survey “inadequate provisions for ventilation”, as opposed to previous studies in literature, found as one of the most important source of problem for Turkey. Even ventilation considerations are taken into account by designers, there seems to be a problem for providing the sufficient ventilation. One of the respondents managing a factory building stated;

“Both natural and artificial ventilation provided in our factory was insufficient to meet the need of fresh air, to distribute the heat generated by machines and to reduce the amount of airborne hazardous substances. Along with employees' health issues, in order to protect equipment and materials against fast deterioration we have to install new ventilation system that led to significant amount of additional maintenance cost”.

It is also found out from the responses that “adequate provision for indoor ventilation” has been identified as an important factor to be considered. Apart from its importance for the health of building user, building materials and equipment are also affected by poor or lack of ventilation provisions. This problem can be tackled in two different ways and both have their own difficulties. Assuming consequence building defects can be remedied, the main issue is that the defects will continue to recur and perpetual maintenance will be required. Even compensations through new ventilation methods are generally possible for maintenance manager; there requires troublesome efforts and significant amount of expenditures. All of these challenges can be the reasons for this factor is being given importance by maintenance managers. Thus, designers need to be aware of the ventilation requirements according to the nature of building, work performed and nature of equipment and materials to be used in the building.

An important point to mention here is that all of the managers of hospital buildings (100%) ranked “adequate provision for indoor ventilation” as very important. This may be attributed to the fact that majority of the building users are patients and there are specific and vital requirements peculiar to hospital buildings. For instance; adequate ventilation has vital role for the infection control in patient rooms. Therefore; more attention should be paid for hospital buildings while specifying ventilation solutions.

Provisions for Accessibility

Among the considerations regarding accessibility which has vital role for operating and maintaining the facility properly; factors of “adequate space in building service areas for maintenance activities” and “accessibility to the building service areas” have come into the forefront respectively as their importance degree. Considering the building types, a divergence has been found for hospital buildings about the importance degree of “accessibility to the building service areas” factor. This result makes sense due to the way of access to building systems should be as easy as possible due to early response to malfunction has vital importance in hospital buildings.

As for the aforementioned accessibility factors emerged as important, same sequencing has been seen in the ranking of occurrence frequency of problems as a consequence of ignoring these issues. Moreover, a big majority of the comments and suggestions obtained from the respondents are stressed on the ease of access and the space should be provided in service areas. The comments are given below;

“Architects should consider adequate space and easy access for service areas. Shafts also should be easily accessed and continue in their vertical direction and also should not be displaced”.

“Easy access with different alternatives to the service shafts is an important determinant for responding to the failures. When the time comes the replacement of all decayed pipes in shafts should be possible”.

“Rainwater drainage systems that are carried under the roof - not inside the building - will enable the ease of intervention”.

“In order to ensure building maintainability; accessibility failures such as designing skylights that please the eye but could never be accessed, decorative overhanging on exterior walls or inaccessible closed shafts should be avoided during design process”.

“Accessibility to skylights, which are designed with aesthetic concerns, must be provided in order to maintenance activities can be carried out in a safe manner, for this reason we are facing great difficulties in maintaining the skylights”.

“The main problems encountered in hotel buildings are; having difficulties in accessing to valve assembly and insufficient spaces provided in electrical and mechanical shafts”.

Another manager made a suggestion in order to prevent accessibility failures during design as below;

“Through communication with experts in relevant discipline, required number of air, mechanical/electrical service shafts and required area for these shafts should be provided during design”.

Differently from previous comments, an attention was drawn by manager of an office building to the interruption of building operation during maintenance.

“While providing the ease of access, developing solutions that maintenance activities can be carried out without interrupting the buildings operation is of great importance. We are also experiencing this kind of problem from the beginning and the client of the building is suffering from this issue”.

Provisions for Building Shape and Orientation

As building shape and orientation have a significant impact on future maintenance activities; the result of the survey revealed that; “improper building shape and orientation for environmental & climatic conditions” is another source of problem that comes into forefront. Even a design should be in such a way as to protect building materials and components against external factors and prevent collection of water, moisture, dust etc.; there appears; designers' considerations are lacking regarding environmental & climatic conditions while designing and thus maintenance managers are confronting difficulties. One maintenance manager emphasized the problem in his comment as below;

“Dirt accumulated in exterior clearances which cannot be accessed lead to contamination of facade whenever it rains”.

Among the architectural design factors; importance of “accessibility to exterior walls and windows” has been placed near the end of the list. Even irregular and complex external shape of a building hinders the maintenance activities for exterior walls/windows; the survey result makes sense due to the plain exterior shapes of the surveyed buildings. Generally, managers do not experience accessibility problems regarding this issue and this lead them to think that it is not a matter of priority and thus the factor is gained less importance.

Compatibility of Nature of Building Usage

As a result of the assessment of occurrence frequency of maintainability problems, it has been found out that the problems due to “ignoring the nature of building usage” was ranked as the least encountered. Nearly half (40.5 %) of the respondents indicated that they had never been faced with these kind of problems. It can be concluded that architects generally consider the buildings intended use in their designs. Further, considering the intended and actual usage of the examined buildings, 12% of them were found to be planned for a different usage. From this point of view, the responses were analyzed and it is appeared that buildings which were facing with these problems as “often” and “always” are not being used as intended. Accordingly one respondent managing a hospital which was planned as an office building emphasized that:

“We have been experiencing various kinds of problems with regard to building functionality such as not being able to interfere in the sizes of the space and having difficulties with the installation of some mechanical systems. I think the architect has no responsibility about this situation. The important point that should be considered is; the buildings should be used in accordance with the intended use”.

It has been revealed from the survey results that the frequency of encountered problems and importance of factors should be considered during design are mostly consistent with the previous studies in literature that have been carried out in different countries.

Further analysis, which have been mentioned in the heading number 4.2, carried out to understand whether the involvement of manager in building design phase create differences in the occurrence frequencies of maintainability problems. As a result; it has been found that majority of the responses are at an equal rate and the remaining responses did not show meaningful differences for the occurrence frequency of the problem. In other words; managers who stated that he had involved in design process had not made any contribution to designers for future maintainability of the building in terms of material selection, accessibility considerations or schematic design solutions. This result reveals the necessity of questioning the competence of the managers who involved in design process.

4.3.2 Evaluation of Maintenance Management Factors

Qualification and Capability of Maintenance Group

Considering the importance of maintainability factors pertaining to management process; “qualification of maintenance staff” and “adequate experience and knowledge of maintenance manager” appear at the top of the ranking list. This result indicates that qualification and capability of maintenance group are given great importance by managers.

Qualification of maintenance staff has significant impact on the efficiency of maintenance activities and hence carrying out maintenance as planned, in a correct and in a safe manner as well as in accordance with budget allocated. Thus it was an expected outcome that the qualification of maintenance staff is considered as the most important maintainability factor by managers. Since it has not been come into prominence in related previous studies, maintenance managers in Turkey seems to experience difficulties regarding this issue. Managers concerns have also been revealed from the numerous comments. As each of the respondents holds similar views; one of the comments is stated below;

“We do not have enough qualified staff in our department, thus improper implementations lead to corrective efforts and additional cost for us. For this reason, working with competent and educated staff with sufficient experience would make things easier”.

Along with qualification of maintenance staff; the importance of “adequate experience and knowledge of maintenance manager” become prominent as a result of the survey since it has direct impact on overall maintenance process and other maintainability factors. From this point of view; as there is a need for examining the qualification and competence of maintenance group, an investigation has been carried out within the scope of the thesis in order to understand current situation in Turkey. According to investigation; there have been neither undergraduate nor graduate education program in the field of Facility Management. Even one or two short-term certification programs are being existed, it is thought to be insufficient in order to develop such an area of specialization on a countrywide scale.

As it was revealed from the first section of the survey; 69% of maintenance manager have bachelor degree and majority of them were graduated from electrical engineering and mechanical engineering departments respectively. The remaining respondents (31%) have high school and associate (two-year education) degree from electrical technician programs. Therefore, contents of engineering programs of leading universities are examined and there have not been found any courses regarding the management of facilities. Management of a facility contains various responsibilities starting from the overall planning activities to developing strategies, management of departments and budgeting throughout the operational life span of a building. As a consequence, even if they have been well qualified with engineering knowledge and skills; that does not mean that they are able to manage a facility. In this direction one respondent stated;

"Employment of the construction site manager as a facility manager in the same building is very big mistake. Even those people have enough knowledge about the building, their lack of qualification with management skills create various problems".

Another respondent with 22 years of experience in the field, who is currently the head of the association of Aegean technical managers (EgeTMD) commented;

"Even though there is a facility manager concept, the criteria for hiring a facility managers in practice is solely based on candidate's experience in their field of expertise rather than his/her education and knowledge in managing complex facilities. These candidates are usually have an engineering education as a background, who do not have the skills necessary for managing complex facilities such as hospitals, shopping center or hotels. However, this profession requires that the person in charge is competent in budgeting, maintenance planning, managing the stuff and in providing a healthy and safe environment for building users. Thus; based on my experience, I suggest that universities develop education programs regarding the management of facilities and provide adequate knowledge and skills for participants".

As a consequence; it is more likely that the maintenance/facility managers who are currently managing large scale buildings lack required qualification.

Maintenance management practices

The adoption of a systematic management of maintenance activities seems to be important concern for respondents' point of view since “establishment of maintenance planning” is appeared as the second important factor affecting maintainability in the ranking list. Besides, “documentation of maintenance activities” also ranked near the top of the list by the respondents. Since maintenance planning contains procedures, scheduling and strategies for carrying out maintenance works; this result shows consistency with previous research as failure to execute maintenance right time is identified as one of the most common causes of maintainability problems (El-Haram and Horner, 2002; Chew and De Silva, 2003; Al-Khatam, 2003; Ali et al., 2010).

It was found out from the second section of the survey that 81% of the respondents have indicated that they already have a pre-prepared maintenance plan. However, the insufficient competences of maintenance managers lead question marks about the efficiency and accuracy of these maintenance plans.

Further analysis of the survey results shows hospital buildings put more emphasis on the importance of establishing a maintenance plan. As in case of any malfunction of the systems/equipment would cause serious problems and losses regarding health issues; hence, further attention should be paid to the preparation of maintenance planning for in hospital buildings. A maintenance manager of a hospital building suggested as below;

“A maintenance plan should be updated periodically and also should include strategies regarding emergency maintenance”.

Misuse of the Building

It was revealed from the survey results that problems due to “misuse of the building by user” has ranked second among the frequency of problems encountered. This result is in line with the previous research. According the condition surveys on buildings by Chong and Low (2006), Ramly et al. (2006), De Silva and Ranasinghe (2010) and Omotehinshe et al. (2015); users’ ignorance on how building and its components perform was identified as one of the major causes of maintenance defects from components to services.

When the responses are analyzed; it is figured out that while shopping malls are the most affected building type, hospital buildings are the least affected by misuse of the building. It makes sense when considering the fact that users are temporary and there is a high human density and circulation in shopping malls and thus, it is more difficult to control and educate the users. As for hospital buildings keeping in mind that all of them are private hospitals; inpatients constitute the majority of the users and the remaining user density is lower. Thus; the probability of damaging or vandalizing the building materials/components by user becomes lower as compared with shopping malls and other type of buildings.

User Interactions

Considering the factors pertaining to maintenance management process; "providing property use manuals and rules" and "provisions for regular feedback from users" are ranked at the end of the list in respect to their importance degree. Thus, it can be understood that interactions with users are not paid sufficient attention by managers as it was also revealed from the second section of the survey that only 24% of the managers are taking user feedbacks into consideration while maintaining their buildings.

While provisions for feedbacks are considered of least importance in general; analyses results are figured out that it gain importance for hospital -all of which are private- and hotel buildings respectively. This is understandable since ensuring user satisfaction has gain more importance for these type of buildings due to commercial concerns when compared with other types of buildings. As shopping centers also need to have concerns regarding user satisfaction, it may be thought to be difficult to get feedbacks from short-time users. Nevertheless; even getting user feedback is thought to be an important consideration for hospital buildings, none of the manager of these buildings ever have performed a method in this direction yet.

Apart from the satisfaction of users; feedbacks obtained from users can lead various benefits both for maintenance manager and for building industry regarding the improvement of maintainability. Through evaluating the obtained user complaints and demands; a manager can able to develop new strategies in the continuous improvement of the maintenance management process. Furthermore, for long-term these information can be used as a reference for clients and designers while developing new projects. Even getting user feedback has considerable impact for maintainability; there seems to be a lack of awareness since this factor is ranked as least important by maintenance managers.

In survey results; problems due to misuse of the building is appeared as one of the most frequently encountered problems. Nevertheless, “providing property use manuals and rules” is ranked by maintenance managers as the least important factor to be considered during the occupation process. Considering the type of the buildings, it is understood that the managers of hotel buildings paid more attention than others. Yet, one maintenance manager of a hotel building indicated that:

“It is necessary to provide information for ensuring the conscious usage of window blinds and air conditioning systems”.

Disregarding of this issue by maintenance manager may be attributable to the lack of knowledge and experience of user guides in Turkey or the misconception of managers' about usefulness of user manuals. Besides, encountered problems may also be caused by vandalism, so in such a case a user guide is thought to be useless. However, due to high occurrence frequency of this kind of problems, first of all it is essential for maintenance manager to provide users a guide regarding rules and how building and its components perform especially for electrical and mechanical systems (including HVAC, elevator etc.).

Involvement of maintenance expert

It has been revealed from various studies that big majority of maintainability problems encountered during the occupation are due to faulty decisions taken in design process. Even several studies have stressed on the significance and benefits of involvement of a maintenance expert in design process in order to minimize maintainability problems; it has not been paid sufficient attention by the respondents of the current survey. Even the importance of this factor is appeared near the end of the ranking, five of the respondents who ranked the factor as “very important” put emphasis on this subject in their comments. As the common idea is that maintenance expert should share their experience and knowledge before occupational process, discrepancies in comments are observed regarding recommendations. These comments are stated below.

"Actors both in design and construction process should get an advice from an experienced and competent person or legal entities that provide facility management services".

Two of the respondents agree with a different approach and one indicates as below;

"A facility management expert who should be involved in project development phase also should be attained for the management of the facility after completion. Therefore, problems to be encountered during occupation process could be solved in a more easy way".

Although this suggestion provide advantages during occupation, this may be hardly feasible in practice. Another respondent emphasizes the important considerations that should be taken into account as;

"Benefiting from an expert should be paid great attention by designers especially on accessibility and material selection considerations".

The respondent who is currently the head of the association of Aegean technical managers (EgeTMD) indicated that there have been legal obligations regarding this issue as below;

"There should be a legal obligation for the involvement of an expert into project development phase and this expert should have been graduated from facility management programs in universities".

As the survey result shows that the involvement of a maintenance expert in design process are deemed to have little importance by maintenance managers, aforementioned comments reveal there have been little awareness regarding such an important key solution. As a consequence, this result strengthens the opinion of majority of the maintenance managers are lack of adequate competency.

5 MODEL PROPOSAL FOR ENHANCING BUILDING MAINTAINABILITY

This chapter introduces a model proposal developed in order to enhance the maintainability of buildings in Turkey. Since faulty decisions taken in architectural design process and deficiencies in occupation process are identified as the root causes of building maintainability problems; it is aimed to develop strategies by focusing on these processes within the scope of the thesis. According to the analyses of survey results and the comments of maintenance managers, main areas of concerns have been identified regarding building maintainability through considering the current practices in Turkey.

The first attempt undertaken is developing short-term and long-term strategies against these concerns as introduced in Table 5.1. The first column in Table 5.1 presents the most critical factors for maintainability of buildings. These are provisions for waterproofing, ventilation provisions for indoor spaces, provisions for adequate space for service areas, suitability of exterior materials for environmental and climatic conditions, durability of materials, misuse of the building, competency of maintenance manager, qualification of maintenance staff and efficiency of maintenance management practices. The first eight factors are derived from the third and fourth sections of the survey. The last factor, namely efficiency of maintenance management practices emerged both from the interviews undertaken with maintenance managers and from the comments made for the open-ended question in the survey. While some of the strategies developed for overcoming such critical issues could be put into action immediately, others required a more collaborative approach which could only be achieved in a longer period of time. Thus the second and third columns of Table 5.1 demonstrate these short and long-term strategies suggested for resolving critical issues.

Table 5.1. Main areas of concern and strategies suggested

<table>
<tr><th>AREAS OF CONCERN</th><th>Short-term Strategies</th><th colspan="2">Long-term Strategies</th></tr>
<tr><td rowspan="2">Provisions for Waterproofing</td><td rowspan="2">Supplier involvement in design development process</td><td>• Introduction of obligatory waterproofing regulations</td><td rowspan="6">Providing educational programs for designers regarding maintainability</td></tr>
<tr><td>• Establishment of material database</td></tr>
<tr><td>Ventilation Provisions for Indoor Spaces</td><td rowspan="2">Maintenance expert involvement in schematic design process</td><td rowspan="2">Development of maintainability database for future considerations</td></tr>
<tr><td>Provisions for Adequate Space for Service Areas</td></tr>
<tr><td>Suitability of exterior materials for environmental and climatic conditions</td><td>Involvement of supplier and maintenance expert in design development process</td><td rowspan="2">Establishment of material database</td></tr>
<tr><td>Durability of Materials</td><td>Supplier involvement in design development process through the provision of information to maintenance expert</td></tr>
<tr><td>Misuse of the Building</td><td>Providing property use manuals and rules</td><td colspan="2">------</td></tr>
<tr><td>Competency of Maintenance Manager</td><td>------</td><td colspan="2" rowspan="4">Providing graduate/undergraduate programs for Facilities Management</td></tr>
<tr><td>Qualification of Maintenance Staff</td><td rowspan="2">Providing regular trainings for staff</td></tr>
<tr><td rowspan="3">Efficiency of Maintenance Management Practices</td></tr>
<tr><td>Development of user feedback systems</td></tr>
<tr><td>Obtainment of information for the maintenance requirements of materials and components</td><td colspan="2">• Development of maintainability database for future considerations</td></tr>
</table>

5.1 SHORTCOMINGS OF TRADITIONAL PRACTICE

Typical actors in traditional practice where the project involves the design, bid and build processes include client, project manager, designer, engineer, contractor and finally the technical manager in the operational phase. The technical manager is usually a professional who has an educational background in electrical or mechanical engineering. Figure 5.1 demonstrates the process flowchart of a typical construction project life cycle.

As it can be seen from the figure, no maintenance expert is involved in inception, design and construction stages until the operation of the building. Thus the extent to which the building under consideration is maintainable depends on the expertise and awareness of client and the designer. A formal cooperation between the designer and material suppliers does not also take place in usual practice. Thus the appropriateness of material and equipment selection in detailed design phase depends on the behavior of designers. Similarly the tendering process does not have an obligatory clause for a thorough evaluation of the material and equipment performance throughout the useful life of the building. While technical specifications could pave the way for a more comprehensive approach, it is not common practice.

As far as the operational phase is concerned, the maintenance management practices are limited to the development of maintenance strategies and obtaining user requirements. However, maintenance knowledge and the technical competencies of technical managers are highly questionable and may vary depending on personal expertise. This is because no formal education exists for cultivating maintenance managers in Turkey.

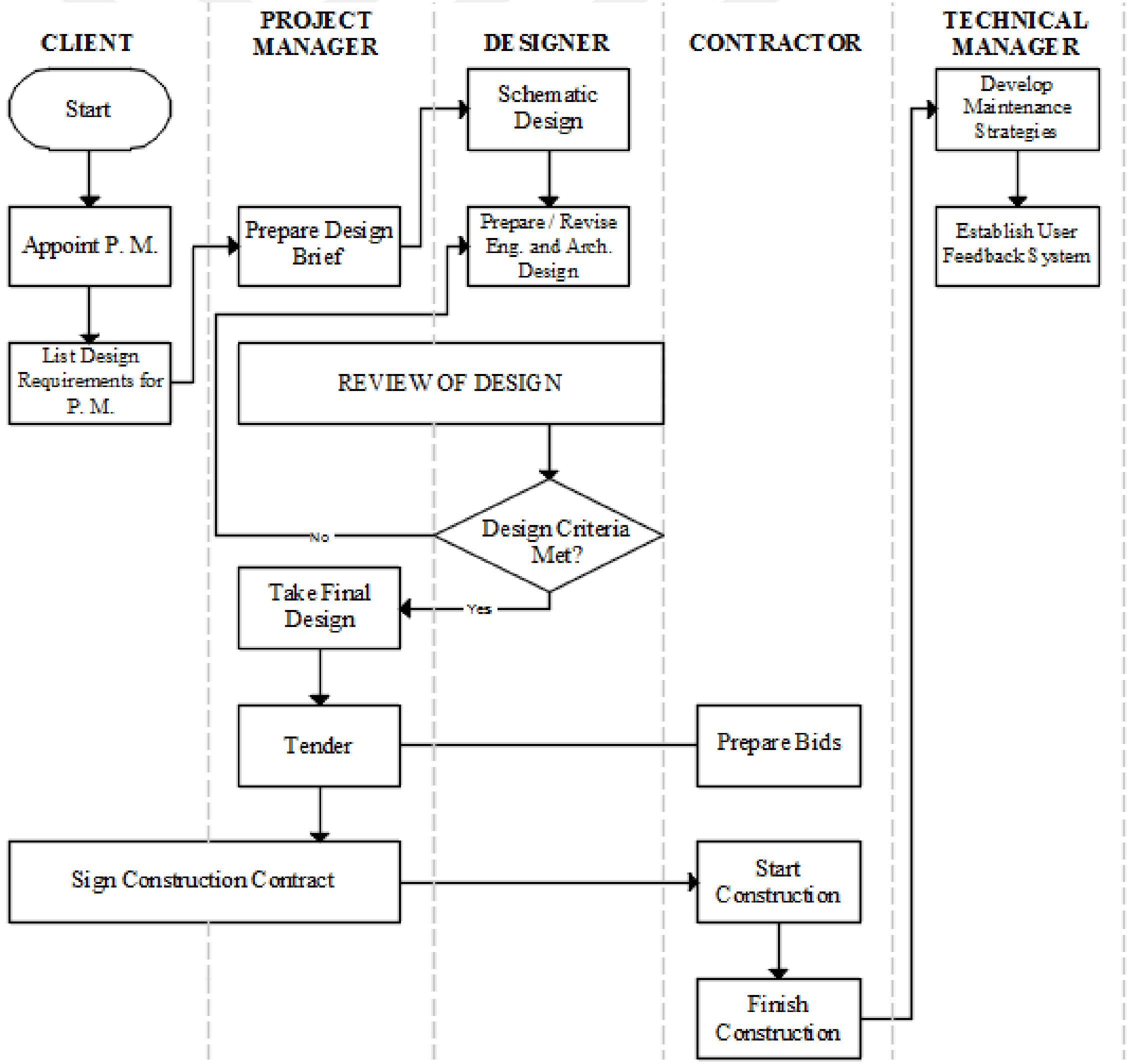

Figure 5.1. Traditional flowchart of building life cycle

5.2 MODEL PROPOSAL

The aforementioned suggested strategies and extensive review of related literature were used to provide a basis for the development of a model to enhance maintainability of buildings.

5.2.1 Short-term Strategies

The first part of the model is prepared as a flowchart that shows the specific tasks that will be assumed for each party as shown in Figure 5.2. It is seen in Figure 5.2 that new actors are introduced for building life cycle processes and also new tasks for the actors currently involved in traditional practices are proposed. On the top of the chart there are nine parties involved in the model; namely client, project manager, architects, engineering groups, maintenance expert, contractor, supplier, maintenance manager and users.

Proposed model is assumed to provide the following outcomes;

- to obtain solutions against the most critical maintainability factors that should be paid attention and against frequently encountered problems which emerged as a result of the questionnaire survey (Table 5.1),
- to overcome the shortcomings in current practices in Turkey which are revealed from the investigation and from the comments made for the open-ended question in the survey,
- to improve common building maintainability provisions acquired from the extensive literature review.

In this section, step by step explanations of tasks that should be assumed by each party are provided with regard to each building life cycle phase.

Initiation Phase

The aim of this phase is to identify the design requirements and to prepare design brief while promoting maintainability provisions in the design. Client, project manager and maintenance expert take part in this phase (Figure 5.2).

- The client decides to undertake a construction project on a traditional basis.
- The client appoints a project manager in order to coordinate all design and construction activities on his/her behalf.

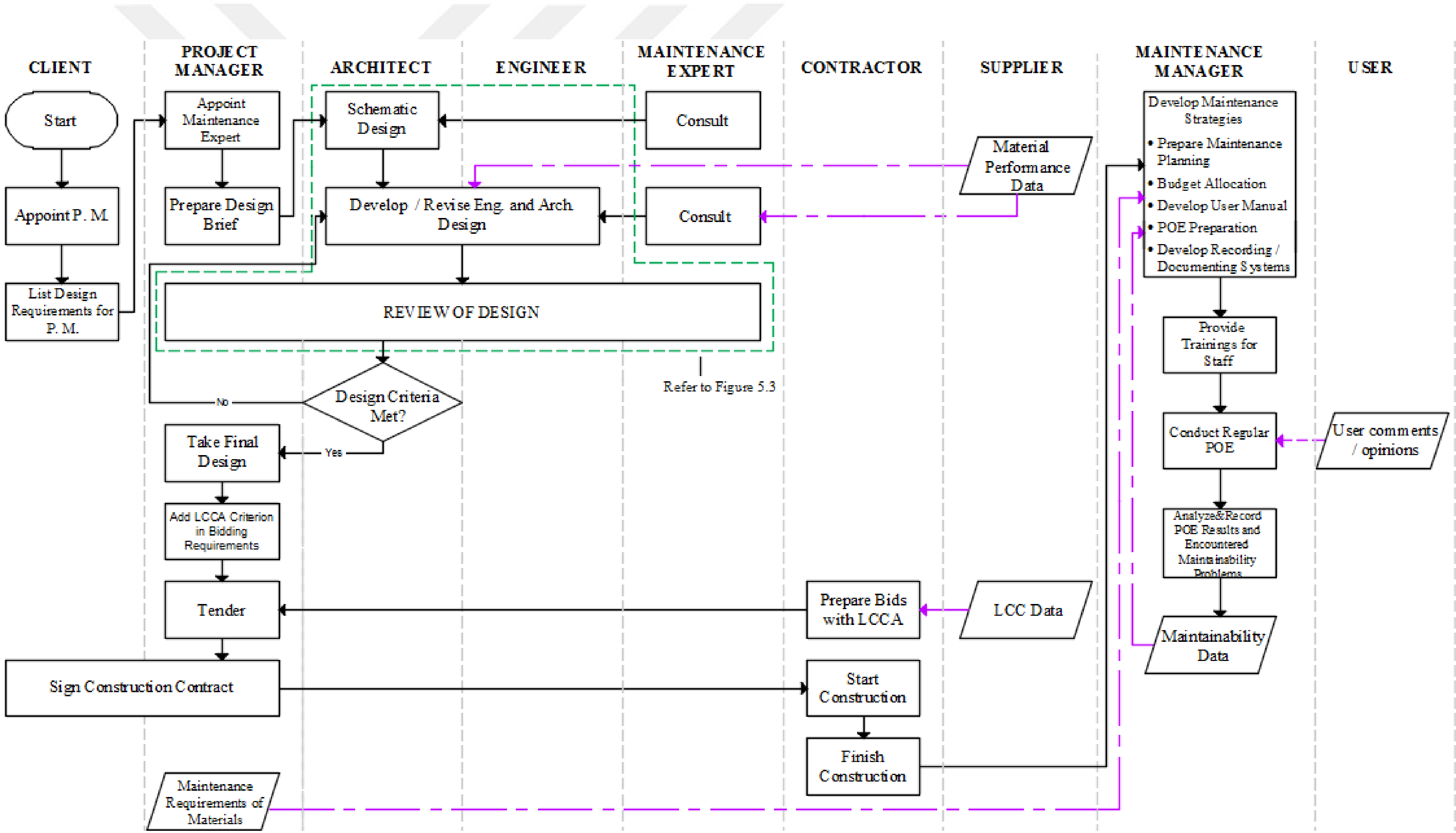

Figure 5.2. Flowchart diagram of proposed model

- The client prepares design requirements in coordination with the project manager.
- Project manager appoints an experienced maintenance expert before design process begins. The inclusion of maintenance expert is one of the novelties introduced in the proposed model. The maintenance expert in this phase should be selected based on his/her experience in managing similar facilities and on educational background. This individual might also later be employed as the manager of the facility under consideration. However this should not be obligatory as the maintenance expert, whether an individual or a company, might prefer to specialize in design consultancy. This approach might even prove to be more efficient as consultancy obtained from such specialized firms could provide multiple opportunities and benefits for project team and ensure high performance of future maintenance activities. Thus the inclusion of an expert in design phase could significantly contribute to the maintainability of the facility.
- The project manager prepares the final design brief that is approved by the client and submits it to the design team. Note that the same procedure applies in traditional practice in case project manager is involved in the organization.

Design Phase

This phase includes schematic design, design development, engineering design and design reviews processes with the involvement of architects, engineering group, maintenance expert, project manager and suppliers.

Even though Figure 5.2 sketches out the design phase; processes are further examined in detail by focusing on architectural design process and introduced in Figure 5.3. It shows the information provided and parties involved in each process of the design phase in the proposed model.

The tasks that should be performed in design processes are as below;

- Once the preparation of the schematic design begins, so do the duties of maintenance expert. At this stage maintenance expert provide consultancy on two main areas. The first one regards design layout considerations such as suitability of building shape/orientation for environmental and climatic conditions and provisions for functional requirements. Moreover, special attention should be paid to ventilation provisions for indoor spaces since from the survey it appeared to be one of the most frequent problem sources. The second area that the maintenance expert provides consultancy is accessibility considerations. These might be provisions for adequate space and number of building service areas, accessibility to all spaces of the buildings including building elements/components/systems and safety access considerations. Among the accessibility considerations, adequate space for service areas is deemed to be one of the most important considerations.

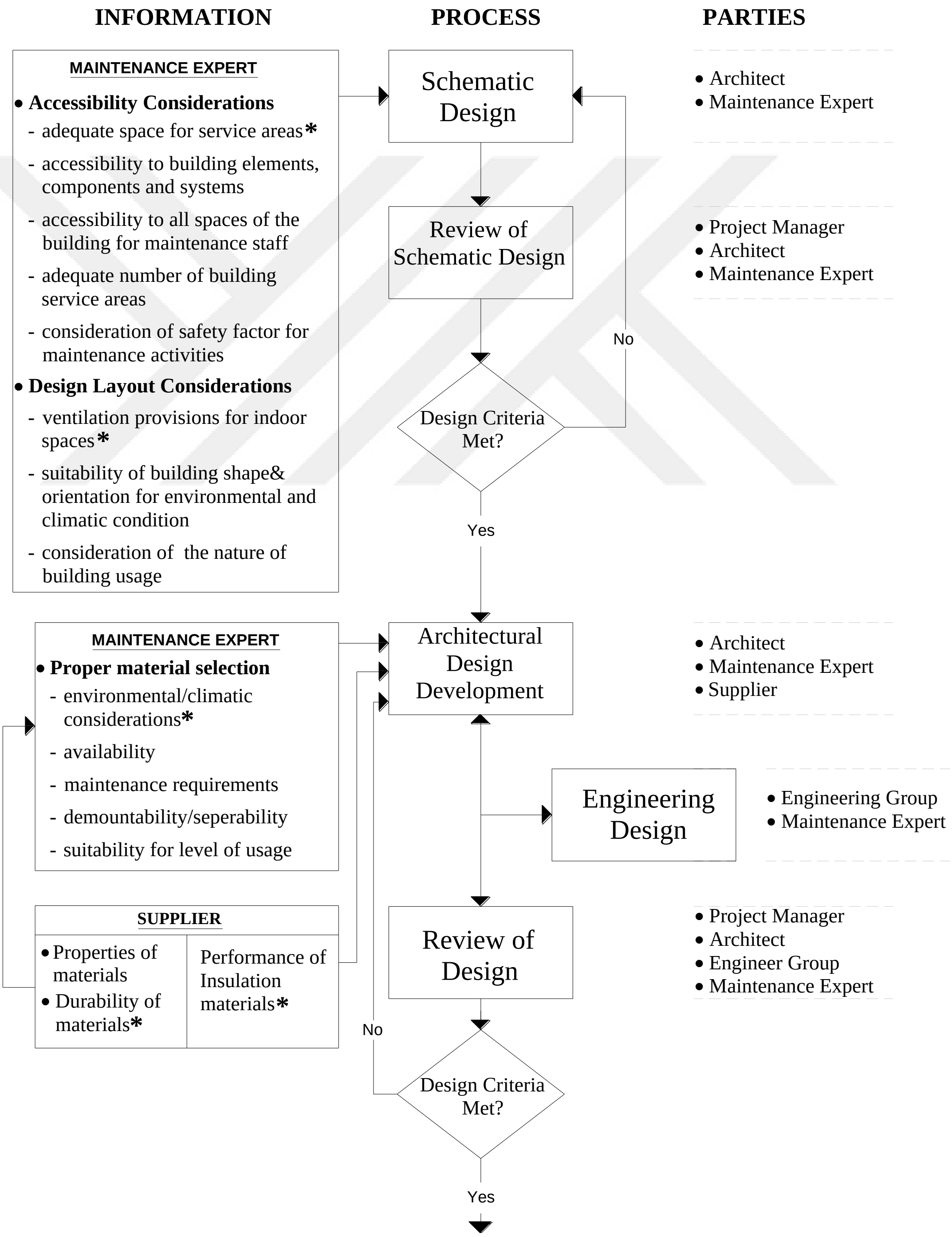

Figure 5.3. Scope of maintenance expert and supplier involvement in design phase

Note that; "∗" denotes those factors that have come into forefront in survey results

- When schematic design is completed, design reviews are carried out with project manager, architects and maintenance experts. If the schematic design criteria are met then design proceeds with detailed design development. In case schematic design does not satisfy the expected maintenance requirements then the necessary revisions should be completed.
- When it comes to design development phase; similar to schematic design phase, a new actor, the supplier is introduced in the proposed model for a number of reasons. While specifying building materials, designers should pay attention to the performance of the materials and their fitness for purpose. However it is becoming increasingly difficult as there are a large range of product alternatives in the market. As it was also revealed from the survey; inappropriate selection of building materials during design is one of the most common problem factors. Thereby, the supplier could play a key role in providing information and adequate knowledge regarding building materials.

  First, one of the main problem areas emerging from the survey results was the waterproofing problem and a close examination revealed that improper material selection and poor detailing were the main sources. The supplier could provide required information to the designer at this stage. For example, insulation performance of materials and proper detailing for such materials are of significant importance. As stated before; maintenance expert is also incorporated into the model at detailed design phase. Supplier may also provide information to the maintenance expert on properties and in particular durability of materials during this process. Since durability of materials emerged as one of the most important maintainability considerations in the survey undertaken for this research, such an approach could be extremely beneficial for the development of detailed design.

  The range of information that the designer may obtain from the maintenance expert at this phase include considerations regarding material selection. In this concept; availability, maintenance requirements, demountability, suitability for usage and environmental/climatic conditions should be the focus of attention. In particular, the latter should lie at the heart of discussions as it was deemed to be a crucial maintainability factor in the survey.
- Once the engineering design is also completed with a coordinated study between the engineering group and maintenance expert; the model proceeds

with design review. Project manager, architect, engineering group and maintenance expert should all attend to the design review process. Such a multidisciplinary review study is expected to enable a thorough examination of the final design in terms of maintainability requirements and fitness for purpose. If the design criteria are met, then the final design is submitted to project manager in order to prepare bidding requirements.

Tendering Phase

As a great number of studies have revealed that maintenance and operation costs account for 50% to 80% of the total life cycle cost; taking into account life cycle cost considerations from the beginning of the building procurement process would significantly decrease the maintenance costs and thus provide remarkable benefits both for client and facility/maintenance manager. In this regard; since tendering phase has the power of prompting the industry to the improvement of maintainability, current model proposes life cycle cost assessment (LCCA) should be added as a criterion in bidding requirements (See Figure 5.2). At this point, it should be emphasized that the determined mindset and behavior of the client is crucial for the successful integration of life cycle considerations into tendering phase. In this regard, compulsory incorporation of such considerations in public projects may pioneer the stimulation of private sector demand.

While preparing their bids, contractors should obtain life cycle cost data of building materials from the suppliers in order to carry out LCCA. During tendering, bids are evaluated based on both costs and life cycle cost analyses. After the evaluation of bids, the final contractor is selected and construction starts. As construction phase is out of the scope of this thesis, it is assumed that traditional practices apply at this phase.

Operation Phase

Once the construction finishes, the operation of the facility comes into prominence. In the proposed model, various types of new responsibilities and tasks are introduced for the maintenance manager (Figure 5.2).

- While survey results have shown that maintenance plans and budgeting are undertaken to a certain extent, insufficiency of these tasks was one of the main concerns in comments. As an important determinant; cost and performance data of materials and equipment throughout the useful life of a building should have been obtained. Thus, the proposed model introduces new inputs in order to improve maintenance planning designs and budgeting procedures. Since wide range of information regarding the maintenance requirements and life cycle costs of materials and equipment have already been collected by the project manager at tendering stage, this valuable data should not be wasted. Thus, the project manager submits the necessary information to the maintenance manager of the facility under consideration. Such an approach can overcome the aforementioned problems by facilitating the production of high performing and efficient maintenance plans and budgets.

Along with programming, scheduling and resource allocation of maintenance activities, a maintenance plan should also include effective user feedback systems for immediate response to problems and complaints. As stated before no regular user feedback system is adopted by the organizations in Turkey. Although 7% of respondents have indicated that building users report the problems from time to time, no systematic feedback system exists in these organizations.

- Other tasks of the maintenance manager at this stage, namely, developing user manuals, post occupancy evaluation (POE) and, monitoring and recording systems for maintenance activities carried out are novelties of the proposed model as only very few facilities have them in practice. Some of these novelties are ignored by managers despite their emerging significance in the survey. For example, although developing user manuals is perceived to have little importance for maintainability, misuse of the building emerges as one of the most prominent problem sources in the survey. Moreover in the proposed model, building users are involved in the maintenance process through regular POEs carried out by manager. As a common tool for measuring the building performance and user satisfaction, the outcomes of POEs have significant impact on the improvement of maintenance management planning and fulfillment of user requirements.
- As stated before, survey results have shown that poor qualification of maintenance staff is the most important maintainability factor pertaining to maintenance process. Thus providing regular training for staff on technical

and practical issues during operational phase is of significant importance in order to ensure the effectiveness of maintenance activities and facilitate the adaptation to new technologies. These trainings could be provided by facility/maintenance manager through organizing seminars and courses etc.

- The last two steps in the model include the preparation of a database that in turn should be used as an input in future maintenance planning. The database that will be prepared at this stage should include both the outcomes of POEs conducted and encountered maintainability problems and their solutions. The database may serve as an essential information resource for maintenance manager in order to revise the maintenance plan in-use and to improve future maintenance plans and programs.

In order to highlight the novelties in proposed flowchart of building life cycle, another diagram is presented in Figure 5.4. The diagram displays the traditional practices of building life cycle and shaded parts display the novelties introduced in the model while colored frames represent the improved areas.

Along with the tasks to be carried out in proposed flowchart given in Figure 5.2, there appears a need for the development of long-term strategies in order to overcome the deficiencies of current practices in Turkey regarding building maintainability. These strategies can be also regarded as supportive actions both for creating awareness in the building industry and for achieving the tasks in the flowchart to be carried out in effective and proper way.

5.2.2 Long-term Strategies for the Improvement of Building Maintainability

Since it has been revealed from various studies in literature which have been examined in detail under the heading of 2.4; maintainability of buildings suffers from the decisions taken in design process. From the pre-survey interviews carried out with facility managers and as a result of the survey carried out within the scope of the thesis; maintainability considerations were found to be neglected by designers especially in large-scale buildings. This may be due to inadequate knowledge, unawareness, wrong assumptions or ignorance of the designers. Therefore, there appears to be a need for also developing solutions that can ensure the production of maintainable designs in the long term.

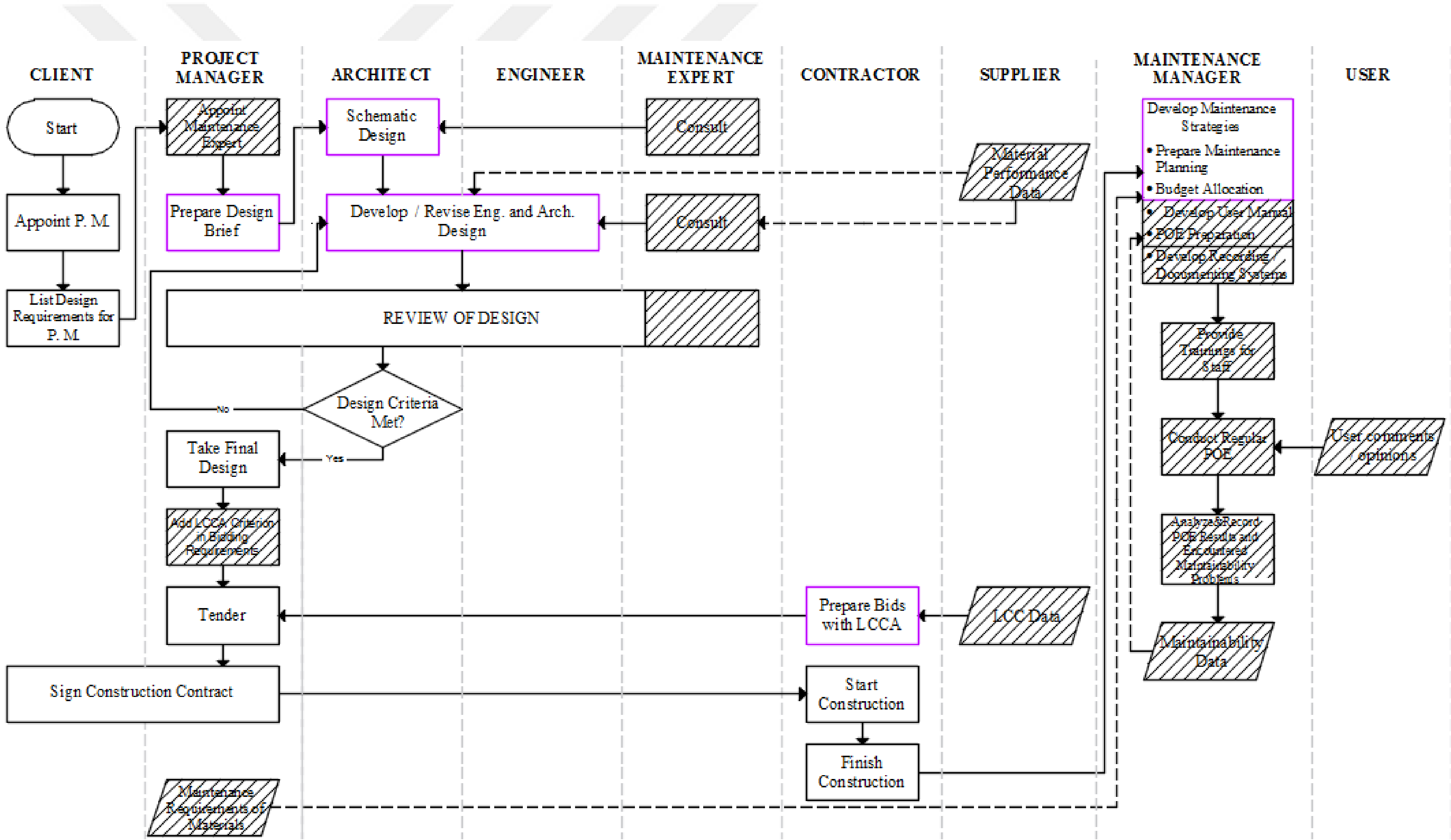

Figure 5.4. Novelties introduced in traditional flowchart of building life cycle

Note that; shaded areas refer to the novelties in proposed model, while colored frames represent the improved areas of life cycle

First of all, it should be ensured that designers are fully informed about building maintainability. In this respect, educational programs in universities play a pioneering role. Enabling courses concerning accessibility and design layout considerations, waterproofing provisions and material selection criteria for the ease of future maintenance activities and thus for ensuring the building maintainability could lead designers to gain awareness and sufficient knowledge. Moreover, non-governmental organizations (NGO) could organize and develop seminars and certification programs for designers in this regard.

A maintenance expert could play key role in the design of highly maintainable buildings due to his/her educational background and experience. Thus involvement of a maintenance expert in design phase and sharing his knowledge with designers by providing suggestions about aforementioned maintainability considerations are of great importance. However financial concerns and unawareness for the long-term benefits of building maintainability of clients may hinder this type of collaboration. Introduction of obligatory regulations by government for the involvement of a maintenance expert in design phase of large scale public projects could further create awareness for private initiatives.

In order to gain maximum benefit from the “maintenance expert” introduced in the design phase and to ensure a high performance by the maintenance manager in the operational phase, several modifications into the current education system should be considered. As no specialized education exists for training maintenance specialists in Turkey, maintenance management activities are carried out by either engineers or technical experts in facilities. However, this approach may have several drawbacks in particular for complex buildings as these professionals are usually not aware of the managerial requirements of such buildings such as making preventive maintenance plans, establishing user feedback systems and the need for considering maintainability requirements from the design phase. Therefore, the development of the profession should be considered by governments and universities through graduate and undergraduate educational programs. Encouragements for developing research projects regarding building maintainability could ensure further awareness and knowledge to be created in the building industry. Universities, government and NGOs should play a pioneering role in this context.

Preparation of a maintainability database by maintenance manager has already been suggested in the proposed model for improving management activities and maintenance planning (Figure 5.2). Established maintainability database through gathering, documenting and recording of the encountered maintainability problems and their solutions, and the outcomes of POEs could be used for further improvements in long-term. Idealistically the regular gathering of these data by the government could enable the formation of a nation-wide resource that could later shape the structure of educational programs suggested in the study. For example, courses and seminars designed to improve designers' knowledge regarding maintainability considerations may focus on critical areas that emerge from collective nation-wide data. However more importantly, the educational programs aiming to train the "maintenance expert" actor introduced in the present research could significantly benefit from the database. Moreover, this nation-wide source could be used as a reference both by designers through providing maintainability considerations that should be taken into account in their designs and any of maintenance managers for the development of management strategies. It can be concluded that maintainability database could provides a link between building users, designers, maintenance managers and government. Considering its great long-term benefits, incentives for the development of such a database should be provided by government.

Since the performance of a building is directly affected by the performance of the materials used, the appropriate selection of building materials plays a significant role in the life cycle of a building. While examining previous studies in literature and the result of the survey; problems due to improper selection and poor performance of materials have been found as a common concern. As faulty decisions could cause early deteriorations and building defects, frequent maintenance activities as well as high repair and replacement costs, performance and appropriateness of selected building materials is one of the most significant factors affecting building maintainability. Along with the short-term strategies mentioned in proposed model (Figure 5.3); there appears the need for developing long-term strategies for such a significant problem.

There are large ranges of product alternatives and continuous production of new materials and technologies however; the real performance of these materials and their ability to fulfill the commitments could only be realized while using them. In this regard; establishing a database through gathering the information about the performances of materials could provide a comprehensive source for the building industry. Such a database that consists of performance of materials in terms of durability, sustainability, maintainability and maintenance requirements could be established by the collaboration of the government, facility/maintenance managers and suppliers. A facility/maintenance manager could procure such information from the aforementioned maintainability database. Established database should be accessed by designers, facility/maintenance managers and clients in order to ensure appropriate materials to be selected and hence to provide high performance and maintainable buildings.

Introduction of obligatory regulations for waterproofing is another important suggestion. Waterproofing failures are responsible for the majority of the latent defects and maintainability problems in buildings as revealed from previous studies (detailed examinations exist under the heading of 3.1.4.1) and from the survey carried out. Lack of waterproofing provisions and improper insulation materials are the main waterproofing failures and almost every building repetitively faced with these kinds of problems regardless of the type and location of the building. Thus there should be a legal obligation in order to force designers, clients and contractors for waterproofing provisions to be carried out.

LCCA strategies in Figure 5.2 have already been discussed in previous section where emphasis was given to the role of the client, and in particular the pioneering role that public sector may play in promoting the dissemination of LCCA practices. Thus compulsory incorporation of LCCA in public projects may be an important step towards the adoption of such analyses in the private sector.

Long-term strategies that have been developed for the industry and the responsible parties are summarized in Table 5.2.

Table 5.2. Long-term strategies and parties concerned

LONG-TERM STRATEGIES	Universities	Goverment	N. G. O.	Maintenance Mngr	Supplier
Establishment of material database		●		●	●
Introduction of a legal obligation for the involvement of maintenance expert in design phase		●			
Introduction of obligatory waterproofing regulations		●			
Encouragements for developing research projects regarding maintainability	●	●	●		
Improvement of Designers' Knowledge Regarding Maintainability (Courses, Seminars)	●		●		
Providing graduate/undergraduate programs for Facilities Management	●	●			
Introduction of a legal obligation for adding LCCA as a criterion in tendering phase		●			
Incentives for developing maintainability database through encountered maintainability problems and POEs by mantenance manager		●			

5.3 VERIFICATION OF THE PROPOSED MODEL

In order to verify the effectiveness and usefulness of the proposed model and to understand its applicability in the current industry conditions, an interview has been made with the Head of the International Association of Facilities Technical Managers (UTTMD) in Turkey. As a result of the interview; the proposed model has been found to be useful, applicable and effective in order to enhance building maintainability. He also indicates following suggestions;

“Even though a maintenance expert should be involved in design phase, many of the designers are unwilling to get an advice or information from a maintenance expert thus; there should be an obligation in order to force designers to take into consideration the suggestions”.

“The maintenance expert involved in design phase should be assigned as a maintenance manager to the building under consideration”.

Although involving in design phase will provide further benefits for maintenance manager during the maintenance processes, this should not be obligatory as the maintenance expert might prefer to specialize in design consultancy. Further he suggested that:

“Terms of reference for facility and maintenance manager should be agreed, facilities should be categorized and technical staff should be selected within this direction and also there should be an obligatory regulation to force maintenance/facility managers to prepare a Facility Management Plan”.

In order to ensure aforementioned suggestions, first of all the facility management profession should be developed and awareness should be created for the building industry, thus these suggestions seem to be the next steps to take.

6 CONCLUSION

Prolonging the useful life of existing building stocks has become even more important for national economies with rapid development of construction industry and increasing costs of new construction. Moreover, the importance of effective building maintenance is being increasingly recognized as owners and facility managers encounter high maintenance costs. Even the fact that maintenance and operation costs constitute more than half of the total life cycle cost of a building; in practice many clients, contractors and designers neglect the life cycle considerations in their decisions, and thus this negligence leads to high maintenance costs. Furthermore continuous development of new construction technologies and building materials due to the rapid development of construction industry as well as growing demand for higher building standards cause an increase in the complexities of building systems thus maintainability problems and consequence maintenance costs during the operation phase.

Within the context of maintenance management, maintainability is an important aspect for dealing with ever-increasing maintenance costs and their high ratio in building life cycle costs. As maintainability also provide the efficiency of maintenance activities which refers to the ease, accuracy and quality of activities beside safety of maintenance personnel, stakeholder satisfaction and users' safety and comfort, the consideration of maintainability issues should be paid attention not only by the researchers but also by the building professionals and the government.

As it has been revealed from the literature; owners and facility managers have to deal with various maintainability problems due to the consideration of future maintenance activities are mostly neglected and ignored by various groups of people involved in different phases of building life cycle. Detailed examination of the previous studies figured out that faulty decisions taken in design phase have the highest impact on building maintainability amongst other phases of building life cycle.

As a result of the interviews carried out with facility managers in order to understand current situation in Turkey, maintainability considerations were found to be neglected by designers especially in large-scale buildings. It has been also revealed that there has been unfamiliarity of facility management discipline in the country. These findings and lack of research regarding these issues have shed light on the aim of this research. Accordingly the main aims of the research are; to identify building maintainability factors that should be paid attention during architectural design and maintenance management processes, to understand the frequency of occurrence of the problems due to faulty decisions and the shortcomings of current practices in Turkey. Then it was aimed to develop short-long term strategies for identified areas of concerns and further to propose a model peculiar to Turkey.

In accordance with the aims of the research, questionnaire has been conducted with maintenance managers of large scale buildings such as hospital, shopping center, hotel buildings etc.; out of 44 responses, 42 have been found to be acceptable across the country and each respondent represents different building. According to the survey results; considering the factors pertaining to architectural design, the main areas of concerns are as below:

- Provisions for waterproofing
- Ventilation provisions for indoor spaces
- Provisions for adequate space for service areas
- Suitability of selected exterior materials for environmental and climatic conditions
- Durability of selected materials

In order to provide solutions against these areas of concerns, following new tasks and parties are proposed for life cycle phases of a building within the scope of the thesis.

A maintenance expert could play key role in order to prevent faulty decisions taken during architectural design process that may hinder the maintainability of buildings during occupation phase. Thus, appointment of a maintenance expert to the design process could enable designers to take into account the maintainability considerations. Through his/her experience and knowledge, a maintenance expert should provide information regarding the points to be paid attention while selecting building materials, designing service areas and making provisions for ventilation requirements in indoor spaces. Moreover, this collaboration creates further benefits for layout considerations such as suitability of building shape/orientation for environmental and climatic conditions and provisions for functional requirements. Also, considerations for accessibility to all spaces of the buildings including building elements/components/systems while providing safe access could also be improved by the collaboration.

In order to deal with inadequate provisions for waterproofing, another new actor, supplier is proposed to be involved in design phase. As insulation performance of materials and proper detailing for such materials are of significant importance, designers could obtain the required information from the supplier. In addition involvement of the supplier during design could provide adequate knowledge to maintenance expert and designers regarding the performance of the materials and their fitness for purpose.

As materials used in the building are one of the main reasons of high maintenance costs, life cycle performances and costs of materials should be considered beforehand. For this purpose, adding life cycle cost assessment (LCCA) as a criterion in bidding requirements could force contractors about this issue. Thereby, clients could be able to select the optimal bid and thus it could enables maintenance costs to be significantly increased.

Considering maintenance management process, maintainability factors that come into forefront as revealed from survey and respondents' comments are:

- Efficiency of maintenance management practices
- Competency of maintenance manager
- Qualification of maintenance staff

Within the context of efficiency of maintenance management practices, the first point to be paid attention is the improvement of maintenance planning designs and budgeting procedures. In this regard, cost and performance data of materials and equipment throughout the useful life of a building are important determinants. This information could have been obtained from the project manager who has already collected wide range of information regarding the maintenance requirements and life cycle costs of materials and equipment at tendering stage. Moreover; as it was revealed from the survey that no regular user feedback system is adopted by the organizations, development of user feedback system should be considered in management process for immediate response to problems and complaints and thus for avoiding problems become worse.

Due to the fact that efficiency and accuracy of maintenance management activities depends largely on the experience and knowledge of maintenance manager, it can be concluded that the most significant determinant for the maintainability during operation is the competency of maintenance manager. As this section provides strategies to be carried out in building life cycle phases this factor will be considered in the long-term strategies.

Even providing user manuals and rules has not been paid attention by respondents “misuse of the building by user” has been appeared as one of the mostly encountered problems during occupation. Therefore in order to minimize such frequent problems user manuals and rules should have been provided.

As qualification of maintenance staff has significant impact on maintenance activities carried out in an effective and in a planned way, regular trainings should be provided for staff by facility/maintenance manager during the operation phase. Along with technical and practical issues, the adaptation of staff to the new technologies should be ensured through the trainings.

Independently from aforementioned strategies that focusing on main areas of concerns emerged as a result of the survey, following proposals are developed for maintenance management process in order to improve building maintainability.

Carrying out regular POEs, as a common tool for measuring the building performance and user satisfaction, is proposed for the improvement of maintenance management planning and fulfillment of user requirements. The outcomes of the POEs could also provide a basis for another proposal of the thesis which is the preparation of a maintainability database by maintenance manager. The database should include maintainability problems encountered, their solutions and the outcomes of POEs in order to revise the maintenance plan in-use and to improve future maintenance strategies.

Depending on the proposals mentioned above, a flowchart diagram is developed for life cycle phases of a building. Proposed flowchart can be regarded as short-term strategies as all proposals are regarding the tasks to be carried out and parties to be involved in various phases of a building life cycle. Therefore in order to overcome the shortcomings of current practices in Turkey with regard to building maintainability, long-term strategies should be developed which can also be assumed as supportive actions both for creating awareness in the building industry and for achieving the proposed flowchart to be carried out in effective and proper way. These strategies are indicated below.

- Improvement of designers' knowledge regarding maintainability through courses provided by universities and through seminars and certification programs organized by NGOs.
- Introduction of a legal obligation for the involvement of maintenance expert in design phase to impose an obligation for clients and to create awareness for private initiatives.
- Introduction of obligatory waterproofing regulations in order to force not only designers but also clients and contractors for waterproofing provisions to be carried out.
- Establishment of material database for the building industry by the collaboration of the government, facility/maintenance managers and suppliers in order to understand the real performances of materials in terms of durability, sustainability, maintainability and maintenance requirements. Such a comprehensive source could ensure appropriate materials to be selected and hence could provide high performance and maintainable buildings.
- Encouragements for developing research projects regarding maintainability to ensure further awareness and knowledge to be created in the building industry. Universities, government and NGOs should lead for these attempts to be carried out.
- Providing graduate/undergraduate programs for facilities management have significant impact for whole life cycle of the building in order to gain maximum benefit from the “maintenance expert” to be involved in the design phase and to ensure a high performance by the maintenance manager in the operational phase in terms of efficient management practices.
- Introduction of a legal obligation for adding LCCA as a criterion in tendering phase in order to impose an obligation for clients and to promote the dissemination of LCCA practices.

- Incentives for developing aforementioned maintainability database by maintenance manager could enable the formation of a nation-wide resource that could later shape the structure of educational programs suggested in the study and could be used as a reference by designers for maintainability considerations that should be taken into account. Also maintenance manager could benefit from the database while developing maintenance management strategies.

Consequently; proposals introduced and demonstrated under the flowchart diagram for life cycle phases of a building and long-term strategies mentioned above are assumed to provide following outcomes for the building industry.

- Awareness regarding building maintainability could be created for building industry such as clients, designers and contractors
- Production of maintainable architectural designs could be provided
- Effective and proper management of maintenance activities could be ensured

Thus, these outcomes could enable maintainability problems, building defects and consequent maintenance costs be minimized. Moreover, optimum performance of building along with its all components could be ensured throughout the lifespan. It should be noted that even the model proposed within the scope of the thesis is developed for traditional procurement system; it can easily be adapted to other procurement systems.

It can be concluded that recommendations made depending on the research activities carried out within the scope of the thesis; would be of great benefit to national economy and building professionals such as maintenance manager, clients as well as to building users. While maintenance managers would benefit by managing easily maintainable projects in the future, sustaining the investment value and the image of the building are of great importance for clients. Also, providing safe and comfort in living environments would retain the satisfaction of the building users.

At this point, the government plays a key role in improving the maintainability of buildings in nationwide through introducing new legal regulations and educational programs. Especially awareness of facility management profession should be created as no educational programs have been developed for this profession yet. Considering the developed countries, there have been both undergraduate and graduate educational programs, and thus such an area of profession have already been developed. Moreover, in order to provide integration between project development and occupation phases government policies have been made in developed countries such as United Kingdom, USA, China and Japan. These policies include the adoption of Private Finance Initiative (PFI) and Public/private partnership (PPP) procurements, and the adoption of Building Information Modeling (BIM). Thus, it can be understood that Turkey falls behind of developed countries for providing the integrations between life cycle phases that would enable the production of more maintainable buildings.

Since within limitation of the thesis, the architectural design and maintenance management processes are considered among the life cycle phases of a building, carrying out studies focusing construction and engineering design is recommended for future attempts.

REFERENCES

Abdul-Rahman, H., Wang, C., Wood, L.C. and Khoo, Y.M., 2014. Defects in affordable housing projects in Klang Valley, Malaysia. *Journal of Performance of Constructed Facilities*, **28**(2), 272-285.

Adejimi, A., 2005. Poor building maintenance in Nigeria: Are Architects free from blames?, *Proceedings of the ENHR international conference on Housing: New challenges and innovations in tomorrow's cities*, Iceland, June 29-July 3.

Ali, A.S., 2009. Cost decision making in building maintenance practice in Malaysia, *Journal of Facilities Management*, (**7)**4, 298-306.

Ali, A.S., Kamaruzzaman, S.N., Sulaiman, R. and Peng, C.Y., 2010. Factors affecting housing maintenance cost in Malaysia, *Journal of facilities management,* **8**(4), 285-298.

Ali, A.S., Keong, K.C., Zakaria, N., Zolkafli, U. and Akashah, F., 2013. The effect of design on maintenance for school buildings in Penang, Malaysia, *Structural Survey*, **31**(3), 194-201.

Al-Khatam, J.A., 2003. Buildings maintenance cost, *Master's Thesis*, Construction Engineering and Management, King Fahd University of Petroleum and Minerals, Saudi Arabia.

Al-Hammad, A., Assaf, S. and Al-Shihah, M., 1997. The effect of faulty design on building maintenance, *Journal of Quality in Maintenance Engineering,* **3**(1), 29-39.

Allen, E. and Rand, P., 2007. Architectural Detailing: Function-Constructability-Aesthetics, John Wiley and Sons.

Alner, G.R. and Fellows, R.F., 1990. Maintenance of local authority school building in UK: a case study, *Proceedings of the International Symposium on Property Maintenance Management and Modernisation,* Singapore, 90-9.

Arditi, D. and Messiha. H.M., 1996. Life-cycle costing in municipal construction projects, *Journal of Infrastructure Systems,* **2**(1), 5-14.

Arditi, D. and Nawakorawit, M., 1999a. Issues in Building Maintenance: Property Managers' Perspective, *Journal of Architectural Engineering*, **5**(4), 117-132.

Arditi, D. and Nawakorawit, M., 1999b. Designing Buildings for Maintenance: Designers' Perspective, *Journal of Architectural Engineering*, **5**(4), 107-116.

Arsenault, J.P., 2010. Building movement joints and BIM. *Architectural Record*, November.

Ashworth, A. and Perera, S., 2015. Cost Studies of Buildings, (6th ed.), Routledge, New York.

Assaf, S., Al-Hammad, A. and Al-Shihah, M., 1995. The effect of faulty construction on building maintenance, *Building Research & Information*, **23**(3), 175-181.

Assaf, S., Al-Hammad, A. and Al-Shihah, M., 1996. Effects of faulty design and construction on building maintenance, *Journal of Performance of Constructed Facilities*, **10**(4), 171-174.

Atkinson, A., 1998. The role of human error in the management of construction defects, *Proceedings of Construction and Building Research Conference (COBRA)*, RICS.

Becerik-Gerber, B., Jazizadeh, F., Li, N. and Calis, G., 2012. Application areas and data requirements for BIM-enabled facilities management, *Journal of Construction Engineering and Management*, **138**(3), 431-442.

Boynton, P.M. and Greenhalgh, T., 2004. Hands-on guide to questionnaire research: Selecting, designing, and developing your questionnaire, *British Medical Journal*, **328**, 1312-1315.

British Standards Institute (BSI), 1984. Glossary of maintenance management terms in terotechnology, BS 3811, London.

British Standards Institute (BSI), 1993. Glossary of Terms Used in Terotechnology, BS 3811, London.

Bu Jawdeh, H.M., 2013. Improving the integration of building design and facilities management, *PhD Thesis*, School of the Built Environment, University of Salford, UK.

Building and Construction Authority, 2000. Enhancing maintainability of buildings, BCA Pilot Study Report, Singapore.

Building Maintenance Information, 2000. Occupancy costs of offices, BMI Special Report, London.

Chandler, J. and Lewis, T.M., 2011. Designing buildings for ease of maintenance in the Caribbean, *The West Indian Journal of Engineering*, **33**(1-2), 50-55.

Chanter, B. and Swallow, P., 2007. Building Maintenance Management, (2nd ed.), Blackwell, Oxford, UK.

Chew, M.Y.L., 2010. Maintainability of Facilities for Building Professionals, World Scientific publishing, Singapore.

Chew, M.Y.L. and De Silva, N., 2003. Maintainability problems of wet areas in high-rise residential buildings, *Building Research and Information,* **31**(1) 60-69.

Chew, M.Y.L., Tan,S.S. and Kang, K.H., 2004a. Building maintainability-Review of state of the art, *Journal of Architectural Engineering*, **10**(3), 80-87.

Chew, M.Y.L., De Silva, N. and Tan, S.S., 2004b. Maintainability of wet areas of non-residential buildings, *Structural Survey*, **22**(1), 39-52.

Che-Ani, A.I., Chohan, A.H., Goh, N.A., Tahir, M.M., Surat, M. and Usman, I.M.S., 2009. Sustainable design formulation in achieving best practice of building maintenance, *World Accademy of Science, Engineering and Technology,* **29**, 1150-1154.

Chohan, A.H., Memon, Z.A. and Memon, A.W., 2009. Development of Conceptual Framework for Design Improvement in Urban Housing of Karachi, Pakistan, *Mehran Unıversity Research Journal of Engineering & Technology*, **30(**2), 225-236.

Chong, W.K. and Low, S.P., 2006. Latent building defects: causes and design strategies to prevent them, *Journal of Performance of Constructed Facilities*, **20**(3), 213-221.

Cohen, L., Manion, L. and Morrison, K., 2011. Research Methods in Education. (7th ed.), Routledge, Abingdon, UK.

Cook ,G.K. and Hinks, A.J., 1992. Appraising Building Defects: Perspectives on Stability and Hygrotermal Performance, Longman Scientific & Technical, London.

De Silva, N., Dulaimi, M.F., Ling, F.Y. and Ofori, G., 2004. Improving the maintainability of buildings in Singapore, *Building and Environment*, **39**(10), 1243-1251.

De Silva, N. and Ranasinghe, M., 2010. Maintainability risks of condominiums in Sri Lanka, *Journal of Financial Management of Property and Construction*, **15**(1), 41-60.

De Silva, N., Ranasinghe, M. and De Silva, C. R., 2012. Risk factors affecting building maintenance under tropical conditions, *Journal of Financial Management of Property and Construction*, **17**(3), 235-252.

De Silva, N., 2012. Risk analysis in maintainability of buildings under tropical conditions, *PhD Thesis*, Department of Civil Engineering, University of Moratuwa, Sri Lanka.

De Silva, N., 2011. Promoting the facilities management profession in the project development phase of high-rise buildings in Sri Lanka, *Built-Environment Sri Lanka,* **9-10**(1-2), 37-44.

Dunston, P.S. and Williamson, C.E., 1999. Incorporating maintainability in constructability review process, *Journal of Management in Engineering*, **15**(5), 56-60.

El-Haram, M.A. and Horner, MW., 2002. Factors affecting housing maintenance cost, *Journal of Quality in Maintenance Engineering,* **8**(2), 115-123.

Engelhardt, M., Skipworth, P., Savic, D.A., Cashman, A., Walters, G.A. and Saul, A.J., 2002. Determining maintenance requirements of a water distribution network using whole life costing, *Journal of Quality in Maintenance Engineering*, **8**(2), 152-164

Fink, A., 2002. How to Sample in Surveys, (2nd ed.), Sage Publications, Thousand Oaks, CA, USA.

Flanagan, R., Norman, G., Meadows, J. and Robinson, G., 1989. Life Cycle Costing Theory and Practice, BSP Professional Books, Oxford, UK.

Fledman, E.B., 1988. Building Design for Maintainability, McGraw-Hill, New York, US.

Flores-Colen, I. and De Brito, J., 2010. A systematic approach for maintenance budgeting of buildings façades based on predictive and preventive strategies, *Construction and Building Materials,* **24**(9), 1718-1729.

Ganisen, S., Mohammed, A.H., Nesan, L.J. and Kanniyapan, G., 2015. Critical Success Factors for Low Cost Housing Building Maintenance Organization, *Jurnal Teknologi*, **74**(2), 31-40.

Graham, H., 1979. Operational efficiency and planning in maintenance work, E.J.G. (Ed), Developments in building maintenance, Applied Science Publishers, London, 1-36.

Gray, C. and Hughes, W., 2001**.** Building Design Management, Butterworth-Heinemann, Oxford, U.K.

Gray, D., 2009. Doing Research in the Real World, (2nd ed.), Sage Publications, London.

Griffin, J.J., 1993. Life cycle cost analysis: A decision aid, in *Life cycle costing for construction*, Eds. Bull, J.V, Blackie Academic and Professional, London.

Gürcanlı, E.G., 2011. İnşaatlarda tasarım yoluyla iş güvenliği, *Türkiye Mühendislik Haberleri, İMO*, **469**, 56-68.

Hallberg, D., 2009. System for predictive life cycle management of buildings and infrastructures, *PhD Thesis*, Centre for Built Environment, Building Materials Technology, University of Gävle, Sweden.

Hassan, F.P., Ismail, Z., Isa, H.M. and Takim, R., 2011. Tracking Architectural Defects in the Malaysian Hospital Projects, *The 2011 IEEE Symposium on Business, Engineering and Industrial Applications (ISBEIA)*, Langkawi, Malaysia, September 25-28.

Hassanain, M.A., Assaf, S., Al-Ofi, K. and Al-Abdullah, A., 2013. Factors affecting maintenance cost of hospital facilities in Saudi Arabia, *Property Management*, **31**(4), 297-310.

Hassanain, M.A., Al-Hammad, A. and Fatayer, F., 2014. Assessment of architectural defects attributed to lack of maintenance feedback to the design team, *Architectural Science Review*, **57**(2), 132-138.

Hassanain, M.A., Fatayer, F. and Al-Hammad, A., 2015. Design Phase Maintenance Checklist for Water Supply and Drainage Systems, *Journal of Performance of Constructed Facilities,* **29**(3).

Hua, G.C., Sher, W. and Pheng, L.S., 2005. Factors affecting effective communication between building clients and maintenance contractors, *Corporate Communications: An International Journal*, **10**(3), 240-251.

Horner, R.M.W., El-Haram, M.A. and Munns, A.K., 1997. Building maintenance strategy: a new management approach, *Journal of Quality in Maintenance Engineering,* **3**(4), 273–280.

International Code Council (ICC), 2006. International Code Council Performance Code for Buildings and Facilities, Washington, DC: International Code Council, 115-118.

Ilozor, B.D., 2008. Architectural and building features disparity and preservation of structural and fabrics integrity, *Journal of Engineering, Design and Technology*, **6**(1), 33-47.

Ishak, S.N.H., Chohan, A,H. and Ramly, A., 2007. Implications of design deficiency on building maintenance at post-occupational stage. *Journal of Building Appraisal,* **3**(2), 115-124.

Jaunzens, D., Warriner, D., Garner, U. and Waterman, A., 2001. Applying facilities expertise in building design, Building Research Establishment, UK.

Kirk, S.J. and Dell'Isola, A.J., 1995. Life Cycle Costing for Design Professionals, (2nd ed.), McGraw-Hill, New York, USA.

Küçükçalı, R., 1999. Yüksek Yapılarda Tesisat ve Pratik Bilgiler, *IV. Ulusal Tesisat Mühendisliği Kongresi,* İzmir, 235-249.

Lam, K.C., 2000. Quality assurance in management of building services maintenance, *Southeast Asia Facility Management*, May/June, The Hong Kong Polytechnic Univ.

Lam, K.C., 2001. Quality assurance system for quality building services maintenance, *Proceedings of Chartered Institution of Building Services Engineers National Conference,* London, July 2.

Lau, W.K., 2008. Maintainability index for buildings: a model for building maintainability assessment in Hong Kong, *Dissertation,* Department of Real Estate and Construction, The University of Hong Kong, Hong Kong.

Lavy, S. and Shohet, I.M., 2004. Integrated maintenance management of hospital buildings: a case study, *Construction Management and Economics,* **22**(1), 25-34.

Lee, H.H.Y. and Scott, D., 2009. Overview of maintenance strategy, acceptable maintenance standard and resources from a building maintenance operation perspective, *Journal of Building Appraisal,* **4**(4), 269-278.

Leong, K.C., 2004. The essence of good facility management – A guide for maximization of facility assets' economic life and asset optimisation for reliable services and user satisfaction, *Buletin Ingenieur*, **24,** 7- 19.

Low, S.P. and Chong, W.K., 2004. Construction quality evaluation and design parameters for preventing latent defects in buildings, *Proceedings of the Joint International Symposium of CIB Working Commissions*, Singapore, 554–566.

Mangione, T.V., 1995. Mail Surveys: Improving the Quality, Sage Publications, New York, **40**.

Merritt, F.S. and Ricketts, J.T., 2001. Building Design and Construction Handbook, (6th ed.), McGraw-Hill, New York.

Miles, D. and Syagga, P., 1987. Building Maintenance: A Management Manual, Intermediate Technology Publication, London.

Mohammed, M.A. and Hassanain, M.A., 2010. Towards improvement in facilities operation and maintenance through feedback to the design Team, *The Built & Human Environment Review,* **3,** 72-87.

Moller, S. and McCartney, D., 2007. Facilities Management and Maintenance and Sustainable Commercial Building, Article from Your Building. Sydney, NSW: Your Building, Property Council of Australia. http://www.yourbuilding.org/

Moua, B. and Russell, J.S., 2001**.** Comparison of two maintainability programs, *Journal of Construction Engineering and Management*, **127**(3), 239-244.

Mselle, P.C., 1997. Management of maintenance records and their use in planning, *Proceedings of 5th International Conference on Inspection Appraisal, Repairs and Maintenance of Buildings and Structures*, Singapore, May, 211-215.

Omotehinshe, O.J., Dabara, D.I. and Guyimu, J., 2015. Design inadequacies and the maintenance of university buildings in Ile-Ife, Nigeria, Journal of Environment and Earth Science, **5**(2), 175-187.

Oppenheim, A.N., 1992. Questionnaire Design, Interviewing and Attitude Measurement. Pinter Publishers, London.

Passe, U. and Batteglia, F., 2015. Designing Spaces with Natural Ventilation: An Architect's Guide, Routledge, New York.

Pheng, L.S. and Wee, D., 2001. Improving maintenance and reducing building defects through 1SO 9000, *Journal of Quality in Maintenance Engineering*, **7**(1), 6-24.

Ramli, A., Akasah, Z.A. and Masirin, M.I.M., 2013. Assessing Safety and Health Factors Influencing Performance of Malaysian Low-Cost Housing, *Civil and Environmental Research,* **3**(3), 7-18.

Ramly, A., Ahmad, N. A. and Ishak, N.H., 2006. The effects of design on the maintenance of public housing buildings in Malaysia-Part two. *Building Engineer,* May, 34-36.

Razak, M. A. and Jaafar, M., 2012. An assessment on faulty public hospital design in Malaysia, *Journal of Design + Built*, **5**(1).

Saghatforoush, E., Hassim, S., Jaafar, S. and Kadir, R.A., 2009. Assessment of critical constructability activities among Malaysian building contractors, *American Journal of Scientific Research,* **3**, 15-25.

Scarrett, D., 2011. Property Asset Management, (3rd ed.), Routledge, Abingdon, Oxon, UK.

Schleyer T.K. and Forrest, J.L., 2000. Methods for the design and administration of web-based surveys, *Jourbal of the American Medical Informatics Association,* **7**(4), 416–425.

Seeley, I.H., 1987. Building Maintenance, (2nd ed.), Palgrave Macmillan, UK.

Shahidan, E.A., Hishamuddin, M.A. and Suwaibatul I. A.S., 2012. A Review of the Effect of Building Design on Maintenance Management, *Proceedings of 3rd International Conference on Business and Economic Research,* Bandung, Indonesia, March 12-13, 648-662.

Shenoy. D. and Bhadury, B., 1998. Maintenance Resources Management: Adapting MRP, Taylor and Francis, London.

Shohet, I.M., Lavy-Leibovich, S. and Bar-On, D., 2003. Integrated maintenance monitoring of hospital buildings, *Construction Management and Economics*, **21**(2), 219-228.

Sivanathan, S., Jibril, J.D., Jivasangeeta, J., Thanaraju, P., Dodo, Y. A. and Shika, S. A., 2012. An Overview of Design Deficiencies on Building Maintenance, *OIDA International Journal of Sustainable Development*, **5**(11), 105-111.

Sobottka, A. and Thriene, B., 1996. Sanitation programmes for living spaces and health risks involved, *Toxicology Letters*, **88**(1-3), 365-368.

Streiner, D.L., 2003. Starting at the beginning: an introduction to coefficient alpha and internal consistency, *Journal of personality assessment,* **80**(1), 99-103.

Tse, P.W., 2002. Maintenance practices in Hong Kong and the use of the intelligent scheduler, *Journal of Quality in Maintenance Engineering*, **8**(4), 369-380.

Van Gelder, M.M.H.J., Bretveld, R.W. and Roeleveld, N., 2010. Web-based questionnaires: the future in epidemiology?, *American Journal of Epidemiology*, **172**(11), 1292–1298.

Whitestone Research, 2007. The Whitestone Building Maintenance and Repair Cost Reference 2008-2009, (13th ed.), Whitestone Research, Santa Barbara, CA.

Wood, B., 2003. Approaching the care-free building, *Facilities*, **21**(3/4), 74-79.

Wordsworth P., 2001. Lee’s Building Maintenance Management, (4th ed.), Blackwell Science, London.

Yik, F.W.H., Lee, W.L. and Ng, C.K., 2002. Building energy efficiency and the remuneration of operation and maintenance personnel, *Facilities,* **20**(13/14), 406-413.

Zavadskas, E., Kaklauskas, A. and Bejder, E., 1998. Raising the efficiency of the building lifetime with special emphasis on maintenance, *Facilities*, **16**(11), 334-340.

Zulkarnain, S.H., Zawawi, E.M.A, Rahman, M.Y.A. and Mustafa, N.K.F., 2011. A review of critical success factor in building maintenance management practice for university sector, *World Academy of Science, Engineering and Technology*, **53**, 195-199.

Zuraidi, S.N.F., Akasah, Z.A., Rahman, A. and Ashraf, M., 2011. Civil engineering and architectural building features disparity and preservation of structural and fabrics integrity in heritage building: a review, *Proceedings of International Building and Infrastructure Technology Conference*, Penang, Malaysia, June 7-8, 94-104.

APPENDIX A Sample of Questionnaire Conducted with Maintenance Managers

T.C.
MİMAR SİNAN GÜZEL SANATLAR ÜNİVERSİTESİ
MİMARLIK FAKÜLTESİ

Sayı: B.30.2.MSÜ.0.44.00.01
Konu:

05.06.2014

Sayın Yetkili,

Mimar Sinan Güzel Sanatlar Üniversitesi Mimarlık Fakültesi Yapım Proje Yönetimi Programı tarafından "Binalarda Bakım-Onarım Verimliliğine Yönelik Mimari ve Yönetimsel Kararların İyileştirilmesi" başlıklı bir çalışma yürütülmektedir. Bu çalışmada bina kullanım aşamasında bakım-onarımı etkileyen faktörlerin tasarım ve yönetim açısından incelenmesi ve sonucunda tasarımcıya yardımcı olacak bir model önerilmesi düşünülmektedir.

Bu kapsamda, tesis teknik/bakım-onarım müdürlerinin deneyim ve görüşleri, gerek çalışmanın doğru yönlendirilmesi gerekse düşünülen model için bir temel oluşturması açısından oldukça önemlidir.

Sizlerin katkı ve görüşlerini alabilmek adına bir anket hazırlanmıştır. Aşağıdaki adresten ulaşabileceğiniz bu anket dört ana bölümden oluşmaktadır. Birinci ve ikinci bölümde sizlerden kişisel ve tesisinize yönelik bilgiler istenmektedir. Birinci bölümde bakım-onarımdan sorumlu yetkili kişi/kişilerin hangi pozisyonda bu görevi üstlendikleri, ikinci bölümde istenen bilgiler ise bina özelliklerine göre farklılıkların tespit edilebilmesi için gerek duyulmaktadır.

Üçüncü ve dördüncü bölümde yer alan sorular ise bakım-onarım kolaylığını etkileyen tasarım ve yönetim faktörlerine yöneliktir. Bu bölümlerdeki bilgiler, bakım-onarım kolaylığını etkileyen faktörlerin belirlenmesi ve bu doğrultuda tasarım aşamasında nelere dikkat edilmesi gerektiği yönünde bilgileri içermektedir.

Anketi cevaplamak için zaman ayırdığınız, katkı ve görüşlerinizi paylaştığınız için teşekkür eder, iyi çalışmalar dilerim.

Saygılarımla,

Prof. Dr. Se[illegible] ERGÖNÜL
Mimarlık Fakültesi
Dekan Yardımcısı

Bina Bakım-Onarımını Etkileyen Tasarım ve Yönetime ilişkin Faktörlerin Değerlendirilmesi

Anketin bir seferde doldurulması gerekmektedir

* Gerekli

1. BÖLÜM: Kişisel Bilgiler

1) Adınız Soyadınız

İsteğe Bağlı

Yanıtınız

2) Görev Tanımınız / Pozisyonunuz

Yanıtınız

3) Eğitim Durumunuz

- Ortaokul
- Lise
- Ön Lisans (2 Yıllık)
- Lisans (4 Yıllık)
- Lisansüstü (Yük. Lisans / Doktora)

4) Üniversite mezunu iseniz mezun olduğunuz bölüm

- İnşaat Mühendisliği
- Makina Mühendisliği
- Elektrik Mühendisliği
- Mimarlık
- Diğer:

2. BÖLÜM: Bina Özellikleri

5) Binanın Adı
İsteğe Bağlı

Yanıtınız

6) Binanın Bulunduğu İl
İsteğe Bağlı

Yanıtınız

7) Binadaki Kat Sayısı

Yanıtınız

8) Binanın Alanı (m2)

Yanıtınız

9) Binanın Ortalama Yaşı

- ○ 10'dan az
- ○ 10 - 30 arası
- ○ 30 - 50 arası
- ○ 50'den fazla

10) Binanın Kullanım Türü

- ○ Üniversite
- ○ Hastane
- ○ Konut
- ○ Otel
- ○ Ofis Binası
- ○ Okul
- ○ Sanayi/Endüstri
- ○ AVM
- ○ Diğer:

11) Bina orijinal yapım amacına uygun kullanılıyor mu?
Örneğin, konut olarak tasarlanmış binanın hastane olarak kullanılması

- Evet
- Hayır

12) Binanın orijinal yapım amacı neydi?
Önceki soruya evet yanıtı verdiyseniz; bu soruyu cevaplamayınız.

- Üniversite
- Hastane
- Konut
- Otel
- Ofis Binası
- Okul
- Sanayi/Endüstri
- AVM
- Diğer: ____________

13) Binanın bakım-onarım kolaylığı açısından bina üretim sürecinde dahil olduğunuz aşamayı veya aşamaları belirtiniz.
1'den fazla seçenek işaretlenebilir

- [ ] Fizibilite
- [ ] Tasarım
- [ ] Yapım
- [ ] Hiçbiri

14) Hazırlanmış bir bakım-onarım planı var mı?

- Evet
- Hayır

15) Binadaki öngörülemeyen bakım-onarım gereksinimleri nasıl belirleniyor?

- Birim görevlilerinin eloktronik sistemde verdikleri raporlar
- Birim görevlilerinin bakım-onarım departmanına sözlü/yazılı bildirimleri
- Diğer: ____________

16) Bina kullanıcılarının gereksinimleri ve şikayetleri nasıl değerlendiriliyor?

- [ ] Anket Sonuçları
- [ ] Kullanıcıların sözlü/yazılı bildirimleri
- [ ] Diğer: ____________

3. BÖLÜM: Bakım-Onarım Kolaylığını Etkileyen Faktörlerin Değerlendirilmesi

Sorumlu olduğunuz bina ile ilgili olarak değil, tecrübelerinize dayanarak aşağıda belirtilen faktörlerin bakım-onarım açısından genel olarak önemini 1 (hiç önemli değil)'den 5 (çok önemli)'e kadar önem derecesine göre işaretleyiniz.

* Aşağıdaki faktörlere ilişkin detaylı açıklamalar için linki tıklayınız.
http://msgsuyapim.com/images/Anket/e.pdf

BAKIM - ONARIMI ETKİLEYEN FAKTÖRLER *

A- Mimari Tasarım Faktörleri

	Hiç önemli değil	Az Önemli	Orta derecede önemli	Önemli	Çok önemli
17) Dış cephe elemanlarının ve malzemelerinin çevre ve iklim şartlarına uygun seçilmesi	○	○	○	○	○
18) Bina formunun ve oryantasyonunun çevre ve iklim şartlarına uygun olması	○	○	○	○	○
19) Dayanıklı yapı malzemelerinin kullanılması	○	○	○	○	○
20) Sık bakım gerektirmeyen yapı malzemelerinin / bileşenlerinin seçilmesi	○	○	○	○	○
21) Kolay bulunabilen yapı malzemelerinin / bileşenlerinin seçilmesi	○	○	○	○	○
22) Demonte edilebilen eleman ve malzemelerin seçilmesi	○	○	○	○	○
23) Mekan tasarımında hakim rüzgar yönünün dikkate alınması	○	○	○	○	○
24) İç mekanlarda yeterli havalandırma olanaklarının düşünülmesi	○	○	○	○	○
25) Yapı malzemelerinin ve yapı elemanlarının birleşim yerlerinin ve detay çözümlerinin doğru şekilde öngörülmüş olması	○	○	○	○	○
26) Su yalıtımı ile ilgili tasarımda tedbirlerin alınması	○	○	○	○	○
27) Binanın kullanım yoğunluğunun dikkate alınması	○	○	○	○	○
28) Binanın kullanım amacına uygun tasarlanması	○	○	○	○	○

Mimari Tasarımda Erişilebilirlik Faktörleri

	Hiç önemli değil	Az Önemli	Orta derecede önemli	Önemli	Çok önemli
29) Servis alanlarında bakım-onarım faaliyetleri için yeterli alanın sağlanması					
30) Servis alanı sayısının yeterliliğinin sağlanması					
31) Çatıya erişimin sağlanabilmesi					
32) Yeraltı drenaj sistemlerine erişimin sağlanabilmesi					
33) Bina servislerine /merkezi sistemlere erişimin sağlanabilmesi					
34) Dış duvar ve pencerelere erişimin sağlanabilmesi					
35) Bakım-onarım personelinin ekipmanları ile birlikte tüm mekanlara erişiminin sağlanması					
36) Bakım-onarıma yönelik güvenlik faktörünün dikkate alınması					

B- Yönetim Faktörleri

	Hiç önemli değil	Az Önemli	Orta derecede önemli	Önemli	Çok önemli
37) Bakım-onarım konusunda uzman bir kişinin tasarım aşamasına dahil olması					
38) Tesis/bakım-onarım yöneticisinin yeterli deneyim / niteliğe sahip olması					
39) Bakım-onarım planının oluşturulması					
40) Bakım-onarım bütçesinin doğru tahsis edilmesi					
41) Bakım-onarım personelinin yeterli nitelikte olması					
42) Bakım-onarım personeline düzenli eğitimin sağlanması					
43) Gerçekleşen bakım-onarım faaliyetlerinin dokümanlaştırılması ve arşivlenmesi					
44) Bakım-onarımda yeterli kalitede yedek parça ve malzeme kullanımı					
45) Kullanıcılara yönelik bina kullanım kılavuzu'nun bulunması					
46) Bina kullanıcılarından geri dönüş alınması					

4.BÖLÜM: Karşılaşılan Bakım-Onarım Problemlerinin Sıklığının Değerlendirilmesi

Sorumlu olduğunuz bina için aşağıda belirtilen bakım-onarım problemlerini; 1 (hiç bir zaman)'den 5 (sürekli)'e kadar karşılaşma sıklığınızın derecesine göre işaretleyiniz.

* Aşağıda parantez içinde belirtilen ilgili faktörlere ilişkin detaylı açıklamalar için linki tıklayınız; http://msgsuyapim.com/images/Anket/e.pdf

Bakım-Onarım Problemlerine neden olan faktörler *

	Hiç bir zaman	Nadiren	Ara sıra	Çok sık	Sürekli
47) Yapı malzemelerinin hatalı seçimi (17; 19; 20; 21; 22)	○	○	○	○	○
48) Binanın şeklinden/oryantasyonundan kaynaklanan problemler (18)	○	○	○	○	○
49) Mekan tasarımında hakim rüzgar yönünün dikkate alınmaması (23)	○	○	○	○	○
50) İç mekanlardaki yetersiz havalandırma (24)	○	○	○	○	○
51) Yapı malzemelerinin ve yapı elemanlarının birleşim yerlerinin ve detay çözümlerinin yetersiz olması (25)	○	○	○	○	○
52) Su yalıtımı ile ilgili tedbirlerin alınmamış olması (26)	○	○	○	○	○
53) Binanın kullanım yoğunluğunun dikkate alınmamış olması (27)	○	○	○	○	○
54) Binanın kullanım amacının dikkate alınmamış olması(28)	○	○	○	○	○
55) Servis alanlarında yeterli çalışma alanının (m2olarak) bulunmaması (29)	○	○	○	○	○
56) Servis alanları sayısının yetersiz olması (30)	○	○	○	○	○
57) Bina servis alanlarına ve bileşenlerine erişimin sağlanamaması (Çatı, drenaj, merkezi sistemler, dış duvar / pencere..) (31-34)	○	○	○	○	○
58) Binanın tüm mekanlarına erişimin sağlanamaması (35)	○	○	○	○	○
59) Tasarımda bakım-onarıma yönelik güvenlik faktörünün dikkate alınmaması (36)	○	○	○	○	○
60) Bina kullanıcıları tarafından binaya verilen zararlar	○	○	○	○	○

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