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Mathematical Modeling of Quality Factors in Building Maintenance Projects in Bahrain

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Abstract

The purpose of this research is to explore the quality factors of building maintenance projects. It also examines the latent interrelationship among these factors and finally provides a mathematical model which can be used to measure the quality of building maintenance projects. A comprehensive literature review was executed as a primary stage to identify the quality factors, then the list of factors were amended by maintenance experts to end up with 40 quality factors of building maintenance projects. The quality factors were ranked using relative importance index (RII) by contractors, consultant (MoW) and combined ranking. The mathematical model was formulated using stepwise multiple regression technique. The combined RII ranking reveals that "Age of building" is the most significant factor affects quality of maintenance projects followed by "Unclear or Wrong scope and specification" and "Lack of direct supervision by contractor during execution of works" respectively. On the other hand, the quality model reveals that the Contractor's capabilities & quality management system has the highest contribution toward the quality of building maintenance project. This research represents the first endeavor to study the quality of building maintenance projects in the kingdom of Bahrain. The study provides mathematical model to measure the quality of these maintenance projects which shall assist project managers in assessment of performance of maintenance contractors.

Keywords: Building maintanence projects, quality factors, mathematical model for maintenance projects, quality management,

1. Introduction

Building Maintenance Projects had a significant growth and expansion in the last few years as a result of numerous construction projects that have been executed in line with National Strategic Master Plan for the Kingdom of Bahrain, outlook 2030. Government of the Kingdom of Bahrain draws the attention to the maintenance projects as the public buildings are being aged, which raise the question about their serviceability and safety. This consideration was translated by noticeable increments of the allocated budget to maintenance sector as published by Ministry of Finance in the consolidated final account reports as shown in Table 1.

Table 1: Budgeted amount and actual expenditures for maintenance sector (2006-2016)

#	Year	Budgeted Amount (BD)	Actual Expenditures (BD)
1	2006	34,037,670	31,430,332
2	2007	33,415,262	46,396,887
3	2008	44,433,242	44,344,947
4	2009	40,475,899	47,425,199
5	2010	38,868,205	44,395,501
6	2011	54,539,899	59,014,997
7	2012	55,322,892	60,761,332
8	2013	65,036,190	66,514,923
9	2014	68,324,831	69,058,155
10	2015	58,248,363	59,986,238
11	2016	57,587,636	66,362,748

Consequently, top management's expectations of maintenance projects quality became higher than before. However, building maintenance projects in the kingdom of Bahrain is characterized as poor quality which deduced by the following two indicators. The first indicator is the poor performance of maintenance contractors, Table 2 exhibits the contractors' appraisal of eight of largest maintenance projects implemented by Ministry of Works, Municipalities Affairs and Urban Planning during year 2016-2017.

Table 2: Contractors' appraisal of eight of building maintenance projects

#	Project Name	Contract Number	Contractor Appraisal	#	Project Name	Contract Number	Contractor Appraisal
1	Project A	BMD-17/16-17012	57%	5	Project E	BMD-16/18-WP17-006	50%
2	Project B	BMD-17/19-17009	67%	6	Project F	BMD-14/76-wP15-010	60%
3	Project C	BMD-17/52-17018	63%	7	Project G	BMD-14/76-wP15-011	52%
4	Project D	BMD-16/18-WP17-002	51%	8	Project H	BMD-14/76-wP16-003	67%

The second indicator is the reoccurrence of defects, many of maintenance projects especially those classified as emergency works such as repairing of structural cracks and water leakages were executed by Ministry of Works (MoW); however the same problems which were newly rectified reoccur again after a short period. This depicts clearly the problems related to quality of works in maintenance projects.

1.Factors affecting Overall Performance of Building Maintenance Projects

The success of building maintenance projects is affected by enormous number of factors. It is very important for the project team to be fully aware about those factors in order to control the project performance. One of the researches that studied this topic is done by Lam, Chan and Chan (2010a). They determined time, cost, quality, functionality, safety and environmental friendliness as key performance indicators (KPIs) for building maintenance projects. Moreover, a project success equation was formulated based on 110 responses of project participants by using Principal components analysis in order to assess the overall performance of the projects.

Zulkarnain, Zawawi, Rahman and Mustaf (2011) identified 24 critical success factors (CSFs) for building maintenance practice in university sector. Those success factors are derived from four perspectives which are customer, internal processes, financial and learning, and growth perspective. The most important factors in customer and financial perspectives are customer satisfaction and capital. The university management has to integrate all perspectives with their factors in any maintenance activity to achieve best level of maintenance performance. According to Akinsola, Hussaini, Oyenuga and Fatokun (2012), environmental and climate conditions, availability of funds, socio-political reasons and lack of appropriate knowledge of maintenance were the critical factors influencing the maintenance program of tertiary institutional buildings in southwest Nigeria, which partially corroborated the findings of study conducted by Idris (1998) for maintenance of large university building in Riyadh.

Waziri and Vanduhe (2013) generated 19 factors contribute to effectiveness of maintenance of residential buildings in Nigeria. 50 residents were asked to weigh the importance of each factor through structure questionnaires. The factors were ranked using relative importance index (RII). The study reveals that Lack of preventive maintenance, Faulty workmanship during construction and maintenance, Design deficiency affecting building resolution and Use of sub-standard of materials and building components are the most significant factors, whereas Technological change and fashion, Non availability of replacement parts, components and Lack of understanding the importance of maintenance work have the least significant effects. The study further stated that the lack of fund allocated for maintenance works by buildings' owners is a prominent cause of maintenance problems in Nigeria.

An identical research carried out in Nigeria indicated that the owners and users of houses assign low budget for maintaining their properties which ranked as the most factor responsible for poor maintenance work. The lack of awareness of importance of maintenance by owners has further contribution to maintenance problem. In the same context, the study pointed out that the maintenance works are not carried out unless the defect is occurred. In addition, the bad economy of the country and lack of maintenance expertise are fundamental factors affecting quality of maintenance works (Ogunmakinde, Akinola & Siyanbola, 2013).

Akasah and Alriwaimi (2015) identified 84 factors affecting the success of maintenance projects from former studies and review of previous literatures. The factors were categorized into eight groups namely; management factors, project participant related factors, environment factors, site related factors, time factors, quality factors, financial factors and health and safety factors. They further suggested to use structural equation model (SEM) technique in order to investigate the interrelationship among the factors and how it affects the success of project.

According to Ofori, Duodu and Bonney (2015), the top five ranked factors that governed the decision to undertake maintenance works of houses in Ghana are misuse of building after completion of the construction, faulty design, unavailability of skilled labor, poor financial support for maintenance work and not using preventative maintenance. They emphasized on the importance of quality of works during construction phase to reduce as much as possible the need of future maintenance. Finally, the study recommended that maintenance problems shall be taken into consideration during early stages of design and construction, and the government shall raise the awareness of residents for the essence of maintenance work and the adverse impacts upon its ignorance.

Abisuga, Ogungbemi and Oshodi (2017) assessed the factors affecting successful delivery of maintenance projects in developing countries. Based on project's stakeholders i.e. contracting firms, consultants and clients, eighteen factors were identified where the simplicity of program, effective maintenance, cost allocation budgeting, ease of techniques use, risk management and, communication and information flow were the top five ranked factors influencing the outcomes and deliverables of maintenance projects. The eighteen factors were reduced using factor analysis method to six main factors namely team integration and knowledge transfer, project learning and maintenance methodology, stakeholders' early project assessment, planning and control, information and communication management within project stakeholders, and quality and risk control. The close monitoring for all the factors is required by project's stakeholders to achieve the desired results.

1.1 Factors Influencing Quality of Building Maintenance Projects

Building maintenance projects encountering tremendous number of problems that lead to poor quality of outcomes and ultimately client dissatisfaction. The problems are grouped into six main categories which are as follow:

1. Design and Construction (Al-Khatam, 2003).
2. Contractor (Mahmoud, 1994).
3. Client/Owner (Mahmoud, 1994).
4. Administrative and Management (Mahmoud, 1994 & Al-Khatam, 2003).
5. Material and Equipment (Mahmoud, 1994 & Al-Khatam, 2003).
6. Financial (Mahmoud, 1994 & Al-Khatam, 2003).

Each category encompasses several sub-problems which are derived from previous researches. More elaboration and details are provided for each problem to understand its relation to quality issue in maintenance works.

1.2.1 Design and Construction

1.2.1.1 Faulty Design

Many defects and faults take place in buildings due to improper design. Some of design deficiencies are difficult to be rectified which cause several problems related to time, cost and quality during maintenance works. For example, if the designer does not consider the provision of expansion and contraction joint to absorb building movements, the building certainly will be subjected to structural cracks which may cause breakage of pipes, joint failure or other structural problems (Ofori et al., 2015).

Assaf, Al-Hammad & Al-Shihah (1996) categorized the faults of design and construction that affect building maintenance into 11 main groups. Three of them are directly related to faulty design; which are defects in civil design, architectural defects in design and design defects in maintenance practicality and adequacy. The study concluded that the effect of faulty design on building maintenance range from moderately severe to most severe from owners and contractors' point of view.

1.2.1.2 Inaccuracy or Unavailability of As Built Drawings

The contractor is obliged to submit a complete set of as built drawings to the client upon completion of the project. As built drawings shall reflect the actual status of implemented works including the correct dimensions, locations of building elements and amendments and modifications to the shop drawings. For example, the as built drawings shall indicate the actual size of rooms and corridors and the exact location of conduits, drainage and sewer pipes, water supply connections and other relevant services and utilities.

The failure of maintaining an accurate as built drawings will result in confusion to maintenance team and additional works and time to perform the required task. If the contractor during maintenance was asked to replace the pipes which are embedded in the walls and the as built drawings are not reflecting the correct location of pipes, then it will result in demolition the wrong wall and eventually will require more budget and time to complete the work (Mahmoud, 1994).

1.2.2 Contractor

1.2.2.1 Shortages of Specialized Maintenance Contractors

The building maintenance works require specialized and experienced contractors to be performed effectively. The contractor who suit to undertake the building maintenance projects shall possess "know-how" and own the sufficient resources i.e. skilled labors, material and finance to execute the maintenance activities (Ramly, 2002)

Feilden, (2003) stated that there is a lack of expert performers to undertake the repair works of heritage buildings in particular. Ismail, A. Mutalib and Hamzah (2016) highlighted the shortages of competent contractor as one problem facing the maintenance of high-rise building in Malaysia.

In Bahrain, only five contractors were awarded by MoW to execute maintenance works for governmental buildings through MTC (2016-2018). This issue had a negative impact on quality of works since the five contractors will be overloaded with work requests and there will be tendency to use outsource (low-grade) manpower to complete the works.

1.2.2.2 Poor Communication Between Contractor and Client

Contractor shall maintain a proper communication with client and end users to ensure that the works are implemented in accordance with predetermined conditions and specification and to ensure the fulfillment of their requirements and needs. Moreover, sufficient communication improves contractor response rate to client's requests (Al-Khatam, 2003). Poor communication with end users is one of the problems facing maintenance team during execution of works. As a result of poor communication, the contractor may work in areas which are not the exact source of the detected defects which will incur more works at site and influences the quality and timely completion of projects (Hua et al., 2005).

1.2.2.3 Communication Difficulties Between Contractor and Labors

Considering the Middle East region, most of labors are hired from East Asian countries and they do not speak English or Arabic at all. In addition, there is no common Asian language that can be used to communicate with labors. These problems considered as a communication barrier between the contractors and their labors which result in misunderstanding by labors to contractors' instructions and eventually lead to rework and delay in the project (Al-Hammad, 1995).

1.2.2.4 Assignment of Unskilled Labors for Maintenance Projects

Most of maintenance contractors complain about low marginal profit earned from building maintenance projects. Therefore, the contractors seek to minimize the project's overhead costs by engaging unskilled and unqualified labors to complete the works since those workers get low wages compared with skilled and specialist's workers. The assignment of unskilled labors has a strong relationship with quality shortfalls and client's discontent (Al-Hammad, 1995). Adejimi (2005) opined that the level of labors skills required for maintaining building should be decided during design stage. Waziri and Vanduhe (2013) recognized that the shortages of skilled labors has significant effect on building maintenance projects in Nigeria. The aforementioned findings were echoed by (Ofori et al., 2015; Okosun & Olagunju, 2017).

1.2.2.5 Poor Quality Control

The contractor has to establish a solid quality control system during construction stage and maintenance stage. It shall cover step-by-step execution of each activity at site by obtaining all requisite inspection, testing and commissioning records to ensure that the works are implemented in compliance with contract documents and client's requirements.

Undoubtedly, building that subjected to an effective quality control system during construction phase has less defects and faults and consequently needs less maintenance than the building with poor or no quality control system. The quality control system is very important as well during the execution of maintenance works to guarantee that the rectification works have followed the correct procedures which shall reduce likelihood of reoccurrence of defects and faults (Mahmoud, 1994)

1.2.3 Client/Owner

1.2.3.1 Unawareness of Importance of Maintenance Works by Owner

Many of building owners leave their property without maintenance until the failures or breakdowns occur. They consider periodic maintenance as a minor issue which does not worth that much of attention (Al-Khatam, 2003).

The building owners must understand that the role of maintenance works begin immediately after completion of construction. The ignorance of maintenance works adversely affects the functionality, appearance, life span, services and market value of building. It further causes increase of maintenance cost since it coverts minor repair works to major failures and defects which may lead to stop the whole system and requires partial or full replacement to fix the problem (Olagunju, 2012).

1.2.3.2 Executing Maintenance Works Only for Emergency Situations

With passage of time, the building elements tend to deteriorate gradually due to many reasons such as physical and chemical properties of material, aging, climate, etc. The building therefore needs a persistence care and regular checking to detect any problems instantly and work to solve them. As stated earlier, the minor problems if ignored might grow, expand and become a serious problem which cannot be avoided (Al-Khatam, 2003).

The above scenario shed the light on the necessity of performing preventive and routine maintenance. This includes periodic inspection, testing, cleaning, etc. to mechanical and electrical installations and drainage pipes to prevent or postpone major rectification and restoration (Al-Khatam, 2003).

1.2.3.3 Misuse of Building by Owner/Occupants

Each part of building and its services is designed to perform a specific function. This part could be offices, shops, corridors, store, toiles, etc. The occupants shall pay more attention and care to each element in the building and use it in proper way.

The occupants in some circumstances intend to change the use of certain part of building which may requires minor modification or alteration. This is called as “Permissible Use” if these alterations do not affect capability of building, safety of occupants and abide by government legislation and restriction.

Changing the purposely designed use of building such as converting offices to stores and vice versa or using canopies as an access to roof may lead to structural problems due to overloading of certain elements, overcrowding the area which affect accessibility, increase risk of fire and electrical shocks or due to unauthorized changes the owner may be subjected to legal liability (Mahmoud, 1994).

1.2.3.4 Lack of Supervision by Client's Maintenance Team

It is well known that the supervision role is the secret behind the success of any maintenance works (Al-Hammad, 1995). Alshehri, Motawa & Ogunlana (2015) observed that the client's supervision staff especially in the governmental sector are weak in technical aspects and not qualified to perform complex supervisory tasks assigned to them due to insufficient training program provided by governmental bodies. Accordingly, maintenance team regularly rely on contractor to manage the execution of maintenance projects without proper supervision and control at site. This will give opportunity to contractors to manipulate with workmanship and quality of material.

1.2.4 Administrative and Management

1.2.4.1 Poor Management of Maintenance Group

Maintenance management is one of key success tools for maintenance projects. It includes the administration, direction, control and evaluation of the available resources i.e. staff, material, equipment and budget (Mahmoud, 1994).

Based on research of Alshehri et al. (2015), most of top management in the maintenance organization are only followers to the organization's president. Hence, the strategy and policy of execution of maintenance works is mainly drawn based on president's experience and background. As a result of that, the maintenance group is suffering with the neglected problems which do not fall within president's area of interest. The maintenance team also suffers from bureaucracy, as they are not involved in decision making process. Such type of management creates unhealthy environment for maintenance staff and reflects negatively on their productivity and loyalty which also affects the performance of maintenance projects.

1.2.4.2 Training and Motivation

The maintenance industry is suffering from shortages of institutions and lack of training and motivation of maintenance staff. As the maintenance receives low concern, focus and appreciation from top management, the professional staff are not encouraged to take the risk and enter this field (Alshehri et al., 2015). Although the number of graduated students increases from 152 to 4427 students between 1970 and 1990, the maintenance staff forms 0.8% from the total workforce of Saudi Arabia (Mahmoud, 1994). Many studies emphasized on the inadequate training provided to maintenance personnel (Ali et al., 2010; El-Haram &

Horner, 2002). Some of the employers ignore the provision of training to their staff due to high short-term costs. However, this is incomplete view since the long-term acquired costs are much higher than the training cost. Furthermore, the poor training results in unqualified staff which do not have the requisite skills to practice maintenance works efficiently. This has several implications like faulty works, poor quality outcomes and ultimately increasing maintenance costs (Colen & Lambrecht, 2012).

1.2.5 Material and Equipment

1.2.5.1 Poor Quality of Material and Spare Parts

The usage of substandard material and spare parts is a common practice in building maintenance projects. The remedy works carried out using inferior material and/or spare parts apparently influence the quality and cost of maintenance works. It is also expected that it would expedite the rate of deterioration which in turn requires more frequent maintenance to keep up the facility in acceptable serviceable condition (Alshehri, 2016).

1.2.5.2 Shortages of Material and Spare Parts

Some of the material and spare parts are not available in the local market. Hence, the client will be forced to procure the material from foreign markets. The lead time for delivery of new material could stop the whole process of maintenance activities which lead to delay of maintenance project. This issue has serious ramifications to building performance and functionality as the facility will be unmaintained until the arrival of new item. Furthermore, the shortages of material and spare parts will increase its price due to additional cost of shipment and eventually increase maintenance expenditure (Alshehri et al., 2015).

1.2.6 Financial Problems

Budget is one of significant factors in building maintenance projects. Without sufficient allocation of maintenance budget, the building will not be maintained properly which lead to vast range of problems to building's structures, elements, services, functionality, operation and end users.

From technical aspect, the anticipation of accurate maintenance cost is very difficult and complicated process. For more clarification, the execution of maintenance works always accompany with variations to the original scope of works due to client new requirements, unforeseen works and the new repair works appear upon preparation of scope of works. Additionally, the instability of material, labor and equipment prices result in higher maintenance cost than what was expected by owner. All these factors lead to cost overrun and underestimation of maintenance projects (Mahmoud, 1994; Al-Hammad, 1995).

On the other side, the lack of awareness of owners about importance of maintenance works pushes them toward poor financial support for maintaining their facilities (Idrus, 2011). El-Haram and Horner (2002) claimed that the maintenance organizations are allocating insufficient budget to carryout maintenance works. As repeated previously, the rate of deterioration of building elements increases with passage of time. Therefore, the allocation of inadequate budget would lead to improper maintenance practices which finally may cause severe damages to building (Akasah, Abdul & Zuraidi, 2011). Lateef et al. (2011) stated that unavailability of budget converts maintenance approach from proactive to reactive which increases maintenance costs. The study of Ogunmakinde et al. (2013) revealed that the lack of fund is the first ranked factors causing building maintenance problems.

The quality factors were identified through extensive review of previous related literatures and summarized in Table 3.

Table 3: Summary of quality factors of building maintenance projects

N	Factors	Ismail *et al.* (2015)	Zulkarnain *et al.* (2011)	Akasah & Alriwaimi (2015)	Ogunmakinde et al. (2013)	Abisuga et al. (2017)	Okosun & Olagunju (2017)	Idris (1998)	Akinsola *et al.* (2012)	Assaf *et al.* (1996)	Waziri & Vandune (2013)	Al-Hammad (1995)	Forster & Kayan (2009)	Akasah *et al.* (2011)	Che-Ghani, Myeda & Ali (2016)	Adejimi (2005)	Lam, Chan & Chan (2010b)	Alshehri *et al.* (2015)	Mahmoud (1994)	Al-Khatam (2003)	Alshehri (2016)
1	Faulty design	√					√			√	√									√	
2	Lack of designing buildings for maintenance considerations			√						√	√				√				√	√	
3	Design Complexity									√										√	
4	Designer field experience								√						√						

5	Designer technical background														√						
6	Age of buildings			√			√		√						√					√	
7	Scope of the project (type, size and nature)			√																	
8	Site access			√											√						
9	Project duration			√		√											√				
10	discrepancies in contract documents (drawings, specifications and scope of works)			√																	
11	Unclear scope/ Unclear specification														√		√				
12	Quality of equipment			√	√																
13	Changes in material types and specification during maintenance			√																	
14	Unavailability of spare parts in local market																	√	√		
15	Usage of Cheaper/ Sub-Standard Materials				√		√				√								√	√	
16	Poor materials handling storage						√								√						
17	Fluctuation of Materials Prices			√																√	
18	Shortage/Unavailability of skilled labors			√		√				√					√				√	√	
19	Lack of labor incentives											√									
20	Control of sub-contractors' work			√		√															

21	Unfamiliarity of the Foreign Labors to Culture						√													√	
22	Unavailability/ Lack of specialized experienced maintenance contractors			√		√			√										√	√	
23	Owner's quick response (no delays in making decisions)			√		√															
24	Owner's contribution to design								√												
25	Misuse of facilities after construction completion						√			√	√				√				√	√	
26	Changed orders by client during maintenance			√																	
27	Lack of understanding the importance of maintenance work						√			√	√								√	√	
28	Conformance to specification			√											√						
29	Client ability to participate in different phases of project			√																	
30	Poor quality control														√				√	√	
31	Unfamiliarity with Maintenance Methods																			√	
32	Poor workmanship						√		√						√						
33	Slowness of execution											√									
34	Budget constraint	√			√		√		√	√	√	√		√	√			√	√	√	√
35	Amount of contractor's cash flow			√		√															

36	No delay of interim payments			√																	
37	Inaccurate estimation of maintenance cost by contractor											√									
38	harsh environments and weather conditions			√			√	√	√						√					√	
39	Application of health and safety factors in site project			√																	
40	Unsafe acts and unsafe condition			√																	
41	Poor Management of Maintenance Group										√				√			√	√	√	
42	Stakeholders Communication										√				√		√	√		√	√
43	Failure of Preventive Maintenance									√	√							√		√	
44	Poor management decision system					√									√						
45	Poor technical updating or staff training			√		√						√		√	√			√	√	√	
46	The Tendency to Execute Work Only When It Becomes As Matter of Urgency																			√	
47	Skill and experience of Owner's Supervision staff	√													√			√			
48	Skill and experience of Contractor’s staff	√																			
49	Lack of direct supervision by contractor	√										√									

50	Lack of direct supervision by owner											√	√		√			√			
51	Failure to Identify the True Cause of Defect						√													√	
52	unforeseen circumstances															√					
53	Training and Motivation													√							

1.2 Quality Modeling for Building Projects

The previous research papers conducted for building maintenance projects are very limited. Only modest attempts were implemented to find out the main problems encounter maintenance projects. On the other hand, several studies were conducted to model the quality factors of construction projects.

Lam *et al.* (2010a) developed a project success index (PSI) represented by mathematical equation in their attempt to benchmark the success of building maintenance projects. The formulated equation consists of six main KPIs which were identified from previous literatures. The principal component analysis technique was utilized throughout formulation process. The following equation was developed to quantify the performance of building maintenance projects:

PSI-Mains = 0.397 (Time) + 0.452 (Cost) + 0.327 (Quality) + 0.281 (Functionality) + 0.398 (Safety) + 0.541 (Environmental friendliness)

The other research for building maintenance topic focus on identifying factors affecting performance of maintenance projects in general. Most of them use the same methodology which depends on extracting the factors from former studies and distributing questionnaires to the concern sample size thereafter. Finally, the factors are ranked using relative importance index method (Abisuga *et al.*, 2017; Ofori *et al.*, 2015; Ogunmakinde at el., 2013; Okosun and Olagunju, 2017; Waziri and Vanduhe, 2013). However, none of them provided a mathematical model to quantify the quality or performance of building maintenance projects.

Rustom and Amer (2006) provided three mathematical models for measuring quality of construction projects in Gaza strip using multiple regression analysis. Initially, the quality factors identified from previous studies and by conducting nominal group technique (NGT) session. Based on that, the questionnaire was designed and distributed over 65 contracting companies and 24 consulting offices. Then, the results were used for the development of quality model.Factor analysis method was utilized to reduce number of sub factors from 60 to 18 factors. These new factors were used in stepwise multiple regression analysis. However, the analysis showed that only 12 out of 18 factors have significance influence of quality.

Quality = (13.67 + 1.35 F1 + 1.21 F3 + 1.28 F4 + 1.02 F5 +1.18 F6 + 1.29 F8 + 0.75F9 + 1.09 F10 + 0.96 F14 + 1.14 F15 + 0.96 F17 + 1.06 F18) * (100/80.12)

Where;

F1, F3, F4, F5, F6, F8, F9, F10, F14, F15, F17, F18 are average weighted scores of:

F1: Characteristics of site layout.

F3: Characteristics of site staff.

F4: Characteristics design documents.

F5: Material Management System.

F6: Control Systems.

F8: Equipment Management System.

F9: Financial Management System.

F10: Political Environment.

F14: Integrated Management Execution System.

F15: Owner's Quick Response for Taking Decisions.

F17: Type of awarding system.

F18: Labor Management System.

80.12 = the summation of formula results if each factor gets the maximum score

100 = Maximum score of quality.

Another model developed by Ahmed and Yusuf (2016) in their study of factors affecting quality of construction phase in Iraqi government companies. The methodology adopted was based on questionnaire survey which includes the quality factors figured out through a comprehensive review of literatures. The factors were ranked based on degree of importance. Multiple regression analysis was applied throughout the formulation process of quality model.Quality in Construction Projects = β0 + 0.191 (Design) + 0.137 (Labor) + 0.217 (Materials) + 0.187(Equipment) + 0.177 (Site Staff) + 0.289 (Quality Systems) + 0.255 (Owner) – 0.006 (Contractor)

Where β0 is a constant value

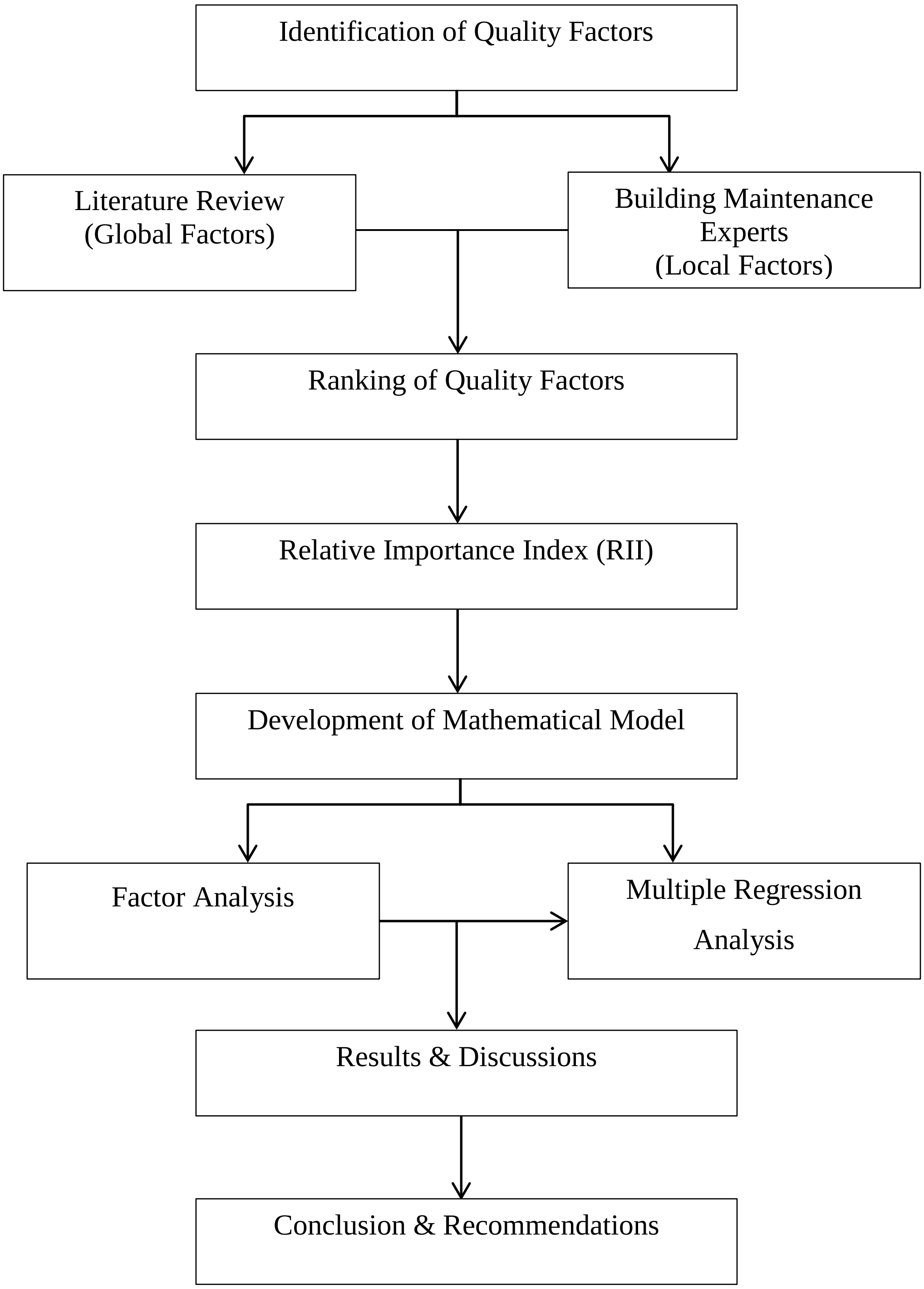

Fig. 1: Research's methodology scheme

2. Research Methodology

As shown in Figure 1, the study is implemented through four sequential phases. The study begins with identification of quality factors through extensive survey of previous literatures and experts in the maintenance field.

The second phase encompasses ranking of quality factors using relative importance index from consultant and contractors' point of view. Also, the combined ranking will be generated to evaluate overall ranking of quality factors.

Based on the final list of quality factors generated from the first phase, a mathematical model was developed in order to measure quality performance of building maintenance projects. The development of model involves two statistical analysis methods; factor analysis is adopted to reduce the number of factors. After that, these new factors will be used in stepwise multiple regression analysis which will facilitate the establishment of model.

Finally, in the last phase of this study, an in-depth discussion for the all the findings and outcomes is carried out.

2.1 Derivation of Quality Factors of Building Maintenance Projects in Bahrain

The process of generation of quality factors list for building maintenance projects consists of two phases.

The primary data related to quality factors identified through a thorough and in-depth review of previous literatures. This includes an extensive study of several journal articles, conference proceeding and textbooks which cover period from 1994 to 2017. An initial list was established which involves 53 factors as shown in Table Ⅲ.

Then the initial quality factors list was distributed over seven of experts and maintenance project practitioners. They were requested to perform two tasks. Refinement of the global factors which were defined in the first phase; by discarding the factors that are inapplicable to maintenance project in Bahrain and retain the others. Secondly, they were asked to supplement the list with local factors that are associated to Bahraini projects in particular.

After several discussions and interviews, there was a consensus agreement among experts to include 36 factors to quality factors list and to omit 14 factors since they are not related to maintenance projects in Bahrain. In addition, there was a conflict about three factors namely “Changes in existence material type and specification during maintenance”, “Poor materials handling storage” and “Amount of contractor’s cash flow” as some of experts eliminated them from the list whereas the majority of experts opined that these factors must be included. The final decision was to include these factors to the list since identified repeatedly in the previous studies. There are two new factors proposed by experts which are the unavailability of building's history record and non-submission of method statements prior execution of maintenance works. The first one only agreed by experts to be located under project category in the list.

As shown in Table 4, the final list includes 40 factors represent quality model for building maintenance projects in Bahrain.

Table 4: Quality factors of building maintenance projects in Bahrain

No.	Category	Factors
1.	Project (C1)	Age of building (F1)
		Site access (F2)
		Unrealistic project duration (F3)
		Harsh environments and weather conditions (F4)
		Unforeseen circumstances/Unforeseen works (F5)
		Unavailability of accurate record of building history (F6)
2.	Design/Planning (C2)	Non consideration of future maintenance during building design phase (F7)
		Designer/Planner experience and technical background (F8)
		Failure to identify the true cause of defect (F9)

		Unavailability or Inaccuracy of as built drawings (F10)
3.	Contract (C3)	Discrepancies in contract documents (drawings, specifications, bill of quantities, etc.) (F11) Unclear or Wrong scope and specification (F12)
4.	Client/Owner (C4)	Client's quick response (delays in making decision) (F13) Client's contribution to design/planning phase to identify exact needs and requirements (F14) Change orders requested by client during maintenance (Scope creep) (F15) Lack of understanding about importance of maintenance work (F16) Failure of implementing the preventive maintenance (F17) Lack of direct supervision by client representatives during execution of maintenance works (F18)
5.	Contractor (C5)	Lack of specialized experienced maintenance contractors (F19) Poor control of sub-contractors work by main contractor (F20) Non-conformance to specification (F21) Poor quality control at site (F22) Poor workmanship for the delivered works (F23) Slowness of execution (F24) Skill and experience of contractor supervision staff (F25) Lack of direct supervision by contractor during execution of works (F26) Poor communication and coordination among project participants (F27) Poor technical updating and staff training (F28)

6.	Labor (C6)	Shortage/Unavailability of skilled labor (F29) Lack of motivation and incentive for labor (F30)
7.	Material (C7)	Changes in existence material type and specification during maintenance (F31) Unavailability of material in local market (F32) Usage of Sub-Standard Materials (F33) Poor materials handling storage (F34)
8.	Financial (C8)	Budget constrains (Poor financial support to maintenance works) (F35) Amount of contractor's cash flow (F36) Delay of interim payments (F37) Low marginal profit in maintenance projects (F38)
9.	Health & Safety (C9)	Failure of contractor to implement health and safety regulations at site (F39) Unavailability of safety officer during execution of maintenance works (F40)

2.2 Ranking of Quality Factors Using Relative Importance Index (RII)

The method used to rank the quality factors is RII. It depicts the consultant (MoW) and contractor's perception of the degree of importance for each quality factor of building maintenance projects for the governmental buildings in Bahrain. The information collected from questionnaires was used for calculation of relative importance of each factor with respect to quality of building maintenance projects.

The RII can be determined using the following formula (Waziri & Vanduhe, 2013):

$$\mathbf{RII} = \frac{\sum \mathbf{W}}{\mathbf{A} \times \mathbf{N}}$$

Where;

W: weight given to each factor.

A: highest weight.

N: total number of respondents.

In this study, since the 5point Likert scale will be adopted in the questionnaire, the RII can be expressed as:

$$\mathrm{RII} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N}$$

Where;

n_5: number of responses for very important.

n_4: number of responses for important.

n_3: number of responses for medium important.

n_2: number of responses for low important.

n_1: number of responses for very low important.

N: total number of respondents.

Table 5 shows the summary of ranking the quality factors by MoW employees, contractors and combined ranking.

Table 5: Ranking of quality factors by consultant (MoW), contractors and combined ranking

No.	Category	Factors	Consultant (MoW)	Contractors			Combined Ranking	
			RII	RII	Rank	Rank	RII	Rank
1.	C1	F1	0.924	0.879	1	1	0.892	1
		F2	0.710	0.709	39	39	0.709	39
		F3	0.805	0.745	35	25	0.763	34
		F4	0.695	0.717	38	40	0.711	38
		F5	0.729	0.681	40	38	0.695	40
		F6	0.762	0.735	36	33	0.743	37
2.	C2	F7	0.748	0.830	10	36	0.806	23

		F8	0.829	0.826	12	14	0.827	14
		F9	0.824	0.832	8	15	0.830	12
		F10	0.810	0.816	18	23	0.814	19
3.	C3	F11	0.848	0.861	3	12	0.857	4
		F12	0.876	0.865	2	8	0.868	2
4.	C4	F13	0.795	0.802	25	27	0.800	26
		F14	0.805	0.768	32	26	0.779	31
		F15	0.819	0.786	30	20	0.796	29
		F16	0.795	0.802	26	28	0.800	27
		F17	0.795	0.832	9	29	0.821	16
		F18	0.738	0.749	34	37	0.746	36
5.	C5	F19	0.881	0.810	22	6	0.831	10
		F20	0.824	0.802	27	16	0.809	21
		F21	0.852	0.816	19	11	0.827	15
		F22	0.876	0.844	4	9	0.854	5
		F23	0.890	0.838	7	5	0.854	6
		F24	0.824	0.735	37	17	0.762	35
		F25	0.905	0.828	11	3	0.851	8
		F26	0.910	0.844	5	2	0.864	3
		F27	0.857	0.818	15	10	0.830	13
		F28	0.814	0.818	16	22	0.817	18
6.	C6	F29	0.895	0.820	14	4	0.843	9
		F30	0.776	0.762	33	30	0.766	33

7.	C7	F31	0.762	0.784	31	34	0.777	32
		F32	0.824	0.792	29	18	0.801	24
		F33	0.848	0.824	13	13	0.831	11
		F34	0.819	0.818	17	21	0.818	17
8.	C8	F35	0.881	0.840	6	7	0.852	7
		F36	0.776	0.812	21	31	0.801	25
		F37	0.776	0.810	23	32	0.800	28
		F38	0.762	0.804	24	35	0.791	30
9.	C9	F39	0.824	0.802	28	19	0.809	22
		F40	0.810	0.814	20	24	0.813	20

From consultant (MoW) point of view, the most important factor affecting quality of building maintenance project is “Age of building” under category “Project” with RII value of 0.924. However, ranking the “Age of building” at the top of quality factor list is a debatable topic. Okosun & Olagunju (2017) ranked “Age of building” in 26th place among 31 factors contributing to maintenance problems. On the other hand, Akinsola *et al.* (2012) found that “Age of building” is most influencing factor affecting execution of maintenance works. These conflicts between studies can be justified that each country has different projects’ conditions, circumstances, environments and so forth, which consequently lead to different prioritization of quality factors. The second most significant factor goes for “Lack of direct supervision by contractor during execution of works” under category “Contractor” with RII value of 0.910. Al-Hammad (1995), ranked “Lack of direct supervision by contractor” in the 1st place among 30 factors for in the study of maintenance problems in Saudi Arabia which affirmed the importance of this factor in the Middle East region for building maintenance projects. “Skill and experience of contractor supervision staff” was ranked in the 3rd place among all factors which also categorized under “Contractor” group with RII value of 0.905. With RII value of 0.895, “Shortage/Unavailability of skilled labor” under “Labor” category was ranked as the fourth most significant factor affecting quality of maintenance projects. In the study of Assaf *et al.* (1996) of effect of faulty design and construction on maintenance works, the factor was ranked in the 1st place and 4th place from contractors and owner’s perspective respectively whereas the factor was ranked in 7^{th} place among 30 maintenance problems. The “Poor workmanship for the delivered works” factor under “Contractor” category was ranked in the 5^{th} place with RII value of 0.890. Many studies in both construction and maintenance field have highlighted the importance of this factor with respect to quality of works. According to Okosun and Olagunju (2017), “Poor workmanship” placed 7^{th} among 31 factors contributing in maintenance problems in Nigeria.

It can be noticed that the consultant (MoW) ranking is biased against contractor. There are seven out of top ten most affecting factors are related to contractor. Consultant (MoW) staff believes that the contractors bear the responsibility to achieve the quality of building maintenance projects as they are the real executor of the works. Only one factor from the top ten is related to consultant (MoW) which is “Unclear or Wrong scope and specification” ranked in the 8^{th} place with RII value of 0.876. The bias of consultant (MoW) for ranking quality factors could lead to misleading results and inaccurate factors’ priority list. Thus, the contractor view is discussed in the following paragraph to validate and confirm the consultant (MoW) ranking.

The contractors reiterated the result of consultant (MoW) by ranking the “Age of building” in the 1^{st} place among other 40 factors with RII value of 0.879. This confirms with no doubt the importance of obsolescence rate for exiting building’s structures and facilities. Many buildings within Kingdom of Bahrain – especially schools – have already exceeded the designed lifespan which makes maintaining quality of original building is impossible and the maintenance costs become unaffordable. Moreover, contractors corroborated the consultant (MoW) by ranking the “Lack of direct supervision by contractor during execution of works” among top five quality factors of building maintenance projects. The factor was ranked in the 5^{th} place with RII value 0.844. The “Unclear or Wrong scope and specification” under “Contract” category was ranked in the 2^{nd} place by the contractors with RII value of 0.865. The “Discrepancies in contract documents (drawings, specifications, bill of quantities, etc.)” under “Contract” was ranked as the third most affecting quality factor for building maintenance projects with RII value of 0.86. The 4^{th} place in the ranking of quality factors went for “Poor quality control at site” under “Contractor” category with RII value of 0.844. The importance of this factor has been affirmed by some studies such as the research conducted by Mahmoud (1994) where the “Poor quality control at site” ranked in 8^{th} place among 24 problems facing maintenance projects in Saudi Arabia.

One of the observations on contractors ranking is that it includes three factors related to contractor responsibility which gives it more credibility over the consultant (MoW) ranking where only one factor was related to consultant (MoW) responsibility in the top ten factors affecting quality of building maintenance projects. However, there are six common factors between both rankings in the top ten factors which enhance the overall credibility of RII ranking approach.

2.3 Development of Quality Model

*2.3.1 **Factor Analysis Method***

Factor analysis is a method used to re-formulate the independent variables; by eliminating some of variables which have negligible effect on the explanatory (dependent) variable and merging some of variables together to end up with new more meaningful number of independent variables. These new variables are representing the model in more powerful manner than the original ones. The method consists of two main processes which are factors extraction and factors rotation.

Prior to execution of factor analysis method, the sample size must verify using criteria proposed by Kaiser-Meyer-Olkin and Bartlett's (KMO and Bartlett's) sampling tests. SSPS was used in order to perform the tests as shown in Table 6.

Table 6: Kaiser-Meyer-Olkin and Bartlett's (KMO and Bartlett's) tests results

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.803
Bartlett's Test of Sphericity	Approx. Chi-Square	2669.044
	Degree of Freedom (df)	780
	Sig.	.000

- The criteria stated that, the Kaiser-Meyer-Olkin value should be equal to or greater than 0.5 (Tabachnick & Fidell, 2001) which already fulfilled with value of 0.803.
- Bartlett's test of Sphericity is statistically significance at 0.005 which means that the data is suitable and can be used for factor analysis.

2.3.1.1 ***Factors Extraction***

The factor extraction from its name includes identification of the new number of factors that forms the new model of quality of building maintenance projects. There are several methods followed by researchers in order to find out the new factors (independent variables) such as eigenvalue, Scree plot and parallel analysis. The eigenvalue approach was chosen in this research to determine the number of factors since its criteria is very clear and easy to adopt. In eigenvalue approach, retain the factors that have eigenvalue equal or greater than one, and eliminate the other factors (Rustom & Amer, 2006).

Principle component analysis was used for extraction of factors which is the recommended method when the purpose of factor analysis is to reduce the number of independent variables (Statistics solutions, n.d.b). Table 7 shows the result of factors extraction which obtained using SPSS; the total variance explained by each factor is represented by "Eigenvalue" column. From Table Ⅶ, the first 12 factors should be retained and represents the original 40 factors in the quality model since their eigenvalues are more than "one". These 7 factors have a cumulative percentage of variance of 69.117% while the other 28 factors express only 30.883%. Thus, the 12 factors considered sufficient to the represent the new quality model of building maintenance projects at current stage.

Table 7: Factor extraction results using principal component analysis

Component's Number	Eigenvalue	Percentage variance	Cumulative Percentage
1	10.848	27.121	27.121
2	2.505	6.262	33.383
3	2.072	5.180	38.563
4	1.923	4.807	43.370
5	1.683	4.208	47.578
6	1.526	3.816	51.393
7	1.383	3.458	54.852

8	1.273	3.182	58.033
9	1.213	3.031	61.065
10	1.165	2.912	63.977
11	1.053	2.632	66.609
12	1.003	2.508	69.117
13	0.971	2.427	71.544
14	0.899	2.249	73.792
15	0.848	2.120	75.912
16	0.793	1.981	77.894
17	0.749	1.872	79.766
18	0.631	1.578	81.344
19	0.604	1.509	82.853
20	0.590	1.474	84.327
21	0.559	1.396	85.723
22	0.536	1.341	87.064
23	0.488	1.221	88.285
24	0.473	1.184	89.469
25	0.453	1.133	90.601
26	0.394	0.985	91.586
27	0.389	0.972	92.559
28	0.370	0.924	93.483
29	0.335	0.837	94.320
30	0.325	0.813	95.133
31	0.294	0.734	95.867

32	0.269	0.672	96.538
33	0.236	0.591	97.129
34	0.226	0.566	97.695
35	0.206	0.515	98.209
36	0.193	0.483	98.693
37	0.181	0.454	99.146
38	0.124	0.311	99.457
39	0.121	0.303	99.761
40	0.096	0.239	100.000

2.3.1.2 ***Factors Rotation***

After the identification of new number of components in the quality model, the remaining question is how the original quality factors relate to the new 12 components? And which are the factors represented by each specific component? These questions can be answered using factor rotation; the varimax rotation.

The concept of the varimax rotation involves maximizing the variance over the two parameters of a component matrix, square loading and variables using the orthogonal rotation of the component axis. The effect of the aforementioned method would result in having a factor that is obtained by separating the original variables in the sense that it minimizes the number of variables, which have high loadings on any given factor. Individually, each factor will have set of high or, ironically, small loadings of variables on it.

In summary, the outcome of the varimax solution results in having set of results, which make it as easy as possible to identify each variable with a single factor, which makes it an attractive and a commonly used rotation option.

Table 8 shows the results of factors rotation. It shows each component and the set of factors represented by the component. It also indicates the correlation strength among component and factors.

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Table 8: Factor rotation results

Rotated Component Matrix												
	Component											
	1	2	3	4	5	6	7	8	9	10	11	12
Poor control of sub-contractors work by main contractor	0.794											
Poor workmanship for the delivered works	0.768											
Poor quality control at site	0.768											
Non-conformance to specification	0.705											
Lack of specialized experienced maintenance contractors	0.665											
Lack of direct supervision by contractor	0.636											
Shortage/Unavailability of skilled labors	0.621											
Skill and experience of Contractor supervision staff	0.560											
Poor communication and coordination among project participants	0.538											
Poor technical updating and staff training	0.517											
Delay of interim payments		0.782										
Low marginal profit in maintenance projects		0.720										

Amount of contractor’s cash flow		0.610										
Failure of contractor to implement health and safety regulations at site			0.804									
Unavailability of safety officer during execution of maintenance works			0.780									
Discrepancies in contract documents				0.776								
Unclear or Wrong scope and specification				0.658								
Failure to identify the true cause of defect					0.746							
Non-consideration of future maintenance during building design phase					0.597							
Lack of understanding about importance of maintenance work					0.540		0.531					
Client’s contribution to design/planning phase to identify exact needs and requirements						0.768						
Client’s quick response (delays in making decision)						0.619						
Failure of implementing the preventive maintenance							0.819					
Lack of direct supervision by client’s representatives							0.523					

during execution of maintenance works												
Unavailability of accurate record of building history								0.698				
Site access								0.624				
Unrealistic project duration								0.570				
Unforeseen circumstances/Unforeseen works									0.709			
Harsh environments and weather conditions									0.615			
Poor materials handling storage										0.618		
Unavailability of material in local market										0.542		
Lack of motivation and incentive for labor											0.734	
Age of building												0.813

As a result of factor analysis method, the 40 independent variables (factors) were reduced to 12 new factors which will represent the quality model (Figure 2). The names of new factors can be found in Table 9.

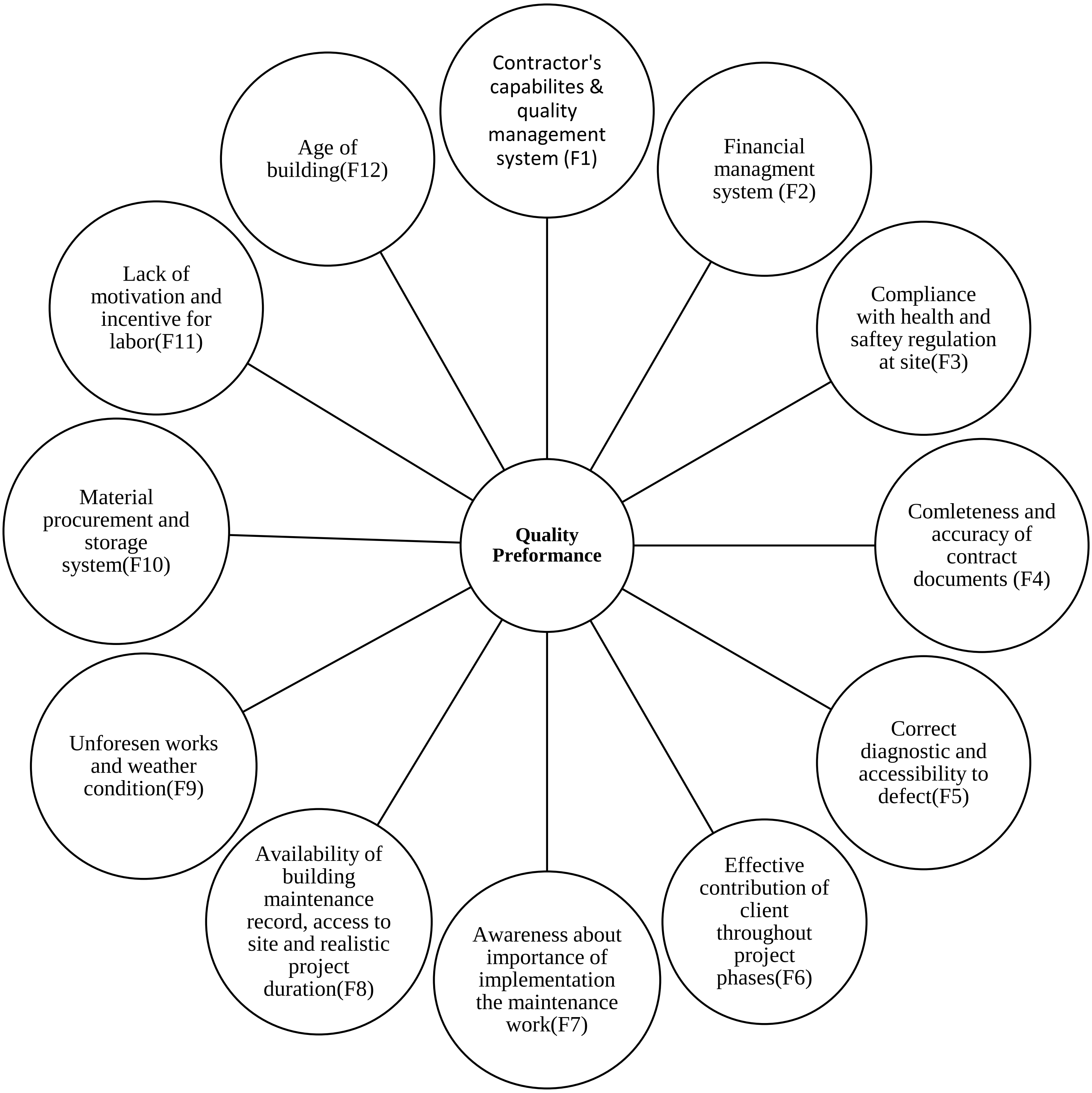

Fig. 2: New model for quality performance of building maintenance projects in Bahrain

Table 9: Names of 12 new factors of quality model

Code of Factor	Name of Factor
F1	Contractor's capabilities & quality management system
F2	Financial management system
F3	Compliance with health and safety regulations at site
F4	Completeness and accuracy of contract documents
F5	Correct diagnostic and accessibility to defect
F6	Effective contribution of client throughout project phases
F7	Awareness about importance of implementation the maintenance works
F8	Availability of building maintenance record, access to site and realistic project duration
F9	Unforeseen works and weather condition
F10	Material procurement and storage system
F11	Lack of motivation and incentive for labor
F12	Age of building

*2.3.2 **Multiple Regression Analysis***

The multiple regression is adopted in this study to explore the relationship between a dependent variable and two or more independent variables. The quality of building maintenance represents the dependent variable and the new 12 factors obtained from factor analysis method represent the independent variables (predictors) in the regression model.

2.3.2.1 **Development of MLR Equation**

The model equation will be built-up based on the general equation of multiple regression:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ldots + \beta_n X_n + \varepsilon$$

Where;

Y:	dependent variable (i.e. quality performance).
X_1 to X_n:	independent variables (i.e. factor contributing for predicting quality performance)
β_0:	constant value of model.
β_1 to β_n:	coefficient of independent variables (also represents the influence of each independent variables toward the dependent variable).
ε:	model error

The main aim of the analysis is to identify the number of predictor variables in the model and the coefficients' values of each variable. As stated earlier, using SPSS, the stepwise regression was applied on the 12 factors extracted from factor analysis to study the effect of each factor on quality performance of building maintenance projects. The F-to-enter and F-to-remove values were specified as 0.05 and 0.10 respectively and were used as the criteria to add and remove the factors in each step of the analysis. The summary of regression results is exhibited in Table 10.

Table 10: Summary of the models of the stepwise multiple regression analysis

Model	R	R Square	F-Value	P-Value (Significance Level)
1	0.559[a]	0.313	63.284	0.000*
2	0.652[b]	0.425	26.892	0.000*
3	0.715[c]	0.512	24.346	0.000*
4	0.767[d]	0.589	25.441	0.000*
5	0.813[e]	0.662	29.106	0.000*
6	0.851[f]	0.724	30.577	0.000*
7	0.887[g]	0.786	38.345	0.000*
8	0.921[h]	0.848	53.356	0.000*
9	0.951[i]	0.904	77.280	0.000*
10	0.979[j]	0.958	169.275	0.000*

11	0.991[k]	0.982	163.362	0.000*
12	1.000[l]	0.999	2327.428	0.000*

a. Predictors: (Constant), F1
b. Predictors: (Constant), F1, F2
c. Predictors: (Constant), F1, F2, F3
d. Predictors: (Constant), F1, F2, F3, F6
e. Predictors: (Constant), F1, F2, F3, F6, F4
f. Predictors: (Constant), F1, F2, F3, F6, F4, F5
g. Predictors: (Constant), F1, F2, F3, F6, F4, F5, F9
h. Predictors: (Constant), F1, F2, F3, F6, F4, F5, F9, F8
i. Predictors: (Constant), F1, F2, F3, F6, F4, F5, F9, F8, F10
j. Predictors: (Constant), F1, F2, F3, F6, F4, F5, F9, F8, F10, F7
k. Predictors: (Constant), F1, F2, F3, F6, F4, F5, F9, F8, F10, F7, F12
l. Predictors: (Constant), F1, F2, F3, F6, F4, F5, F9, F8, F10, F7, F12, F11
m. Dependent variable: Quality

Table 10 shows 12 different models that incorporate different subsets of independent variables. To select the most suitable model, the R^2 values shall be assessed. However, according to Nau (n.d.a), it is difficult to have a general rule to specify an optimum R^2 value in which the selection of the model can rely on. It depends on too many factors such as the unit of measurement, what is the purpose and type of the study and dependent variable and independent variables. For this study, the R^2 value with 0.980 or more seems to be sufficient to for the selection of appropriate model (Rustom & Amer, 2006). Therefore, model 11 (R^2 = 0.982) was selected for to represent quality performance of building maintenance projects. R^2 = 0.982 means that 98.2% of the variance of quality performance explained by overall regression model (Ghani and Ahmad, 2010). The model incorporates 11 factors out of the original 12 factors and statically significant at $\alpha = 0.001$.

After selection of model and identification of number of predictor variables, the remaining step is to determine the coefficients values for each variable. However, before proceeding with that, the hypothesis shall be examined.

2.3.2.2 **Model Validation**

The quality model established in study needs to be verified in order to be used for measuring the quality of building maintenance projects. The validation is carried out to provide evidence about the reliability and accuracy of the model. Four of completed and ongoing building maintenance projects were used to check the validation of model. The project managers of those maintenance projects were asked to weigh the eleven factors included in the model with respect to quality.

First project:

- Project Title: Refurbishment of Special Investigation Unit offices at Public Prosecution.
- Status of Project: Completed.
- Type of Contract: Measured Term Contract.

Code of Factor	Name of Factor	Weight
F1	Contractor's capabilities & quality management system	2
F2	Financial management system	3
F3	Compliance with health and safety regulations at site	3
F4	Completeness and accuracy of contract documents	2
F5	Correct diagnostic and accessibility to defect	4
F6	Effective contribution of client throughout project phases	4
F7	Awareness about importance of implementation the maintenance works	5
F8	Availability of building maintenance record, access to site and realistic project duration	1
F9	Unforeseen works and weather condition	2
F10	Material procurement and storage system	4
F12	Age of building	2
Quality Performance (%)		71.8%
Contractor Appraisal (%)		70.0%

Variation (%)	2.57%

Second project:

- Project Title: Proposed Rehabilitation of Legal Affairs & Internal Auditing Building at Municipality Affairs & Urban Planning.
- Status of Project: Completed.
- Type of Contract: Measured Term Contract.

Code of Factor	Name of Factor	Weight
F1	Contractor's capabilities & quality management system	2
F2	Financial management system	4
F3	Compliance with health and safety regulations at site	2
F4	Completeness and accuracy of contract documents	4
F5	Correct diagnostic and accessibility to defect	5
F6	Effective contribution of client throughout project phases	5
F7	Awareness about importance of implementation the maintenance works	4
F8	Availability of building maintenance record, access to site and realistic project duration	2
F9	Unforeseen works and weather condition	2
F10	Material procurement and storage system	4
F12	Age of building	4
Quality Performance (%)		77.8%
Contractor Appraisal (%)		66.0%
Variation (%)		17.9%

Third project:

- Project Title: Full renovation to Ground floor server room and ITD second floor at Capital Municipality Council in Ministry of Works, Municipality Affairs and Urban Planning, Manama.

- Status of Project: Completed.
- Type of Contract: Measured Term Contract.

Code of Factor	Name of Factor	Weight
F1	Contractor's capabilities & quality management system	4
F2	Financial management system	4
F3	Compliance with health and safety regulations at site	2
F4	Completeness and accuracy of contract documents	4
F5	Correct diagnostic and accessibility to defect	4
F6	Effective contribution of client throughout project phases	4
F7	Awareness about importance of implementation the maintenance works	4
F8	Availability of building maintenance record, access to site and realistic project duration	2
F9	Unforeseen works and weather condition	2
F10	Material procurement and storage system	4
F12	Age of building	2
Quality Performance (%)		79.0%
Contractor Appraisal (%)		68.0%
Variation (%)		16.2%

Fourth project:

- Project Title: Construction of New Administrative Building, Fish Market, Guard Room and Toilet Including Upgrading works at Duraz Fishermen Port.
- Status of Project: Ongoing.
- Type of Contract: Lump Sum Contract.

Code of Factor	Name of Factor	Weight
F1	Contractor's capabilities & quality management system	2

F2	Financial management system	4
F3	Compliance with health and safety regulations at site	2
F4	Completeness and accuracy of contract documents	4
F5	Correct diagnostic and accessibility to defect	5
F6	Effective contribution of client throughout project phases	2
F7	Awareness about importance of implementation the maintenance works	4
F8	Availability of building maintenance record, access to site and realistic project duration	2
F9	Unforeseen works and weather condition	2
F10	Material procurement and storage system	4
F12	Age of building	4
Quality Performance (%)		74.3%
Contractor Appraisal (%)		Not Applicable
Variation (%)		Not Applicable

The above results show that the model is reliable and ready to be used for measuring the quality of building maintenance projects. Although there is variation between the outputs of the model and the figures obtained from the contractor appraisal, these variations can be justified due to the different objectives the two forms are measuring. The contractor appraisal form focuses on the determination of contractor performance only. Hence, some of the quality aspects associated with MoW which are not considered in this form. On the other side, the research model gives a broader view for the quality of projects. Therefore, it is logical to have some variances on the results but the closeness of the figures among them proves that the model is valid.

After verifying the validity of the model, the quality of building maintenance projects can be measured and assessed practically by project managers/engineers. Furthermore, a data base for quality of projects can be established by recording the quality of each maintenance projects which will allow to set a benchmark or an bottom line for the accepted quality value for the future projects. To clarify, if the client measure the quality of hundred maintenance projects and most of the values found to be around 75%, the client could consider this value as minimum acceptable value for any of the coming projects. This data base can be used to compare the ongoing projects with previous records which will make the picture clear for management about the quality performance of the maintenance projects.

In addition to, the quality model can reflect the causes of poor quality of works for project managers/engineers by knowing the amount of contribution of each factor in the model towards the quality. Another data can be obtained by identifying the most repeated factor(s) having the biggest effect on the quality of the projects. The organization can then study the possible solutions of that causes which would help significantly to improve the quality of maintenance projects.

3. Conclusions

The quality problems of building maintenance projects have been considered as a serious issue by top authorities of the government of Bahrain.

The research has identified the quality factors of building maintenance projects using the previous literatures and the opinion of maintenance experts. As a result of that, 40 factors have been established and categorized into nine groups. The quality factors were ranked using relative importance, the MoW and contractors ranking shows the dominance of "Age of building" over the other factors which prove the fact that many of governmental buildings which maintained by MoW are very old and dilapidated.

The research also provides a mathematical model for measuring the quality of building maintenance projects. The 40 quality factors were re-formulated using the factor analysis method where 12 factors were the new quality model representatives. The mathematical equation was developed using stepwise multiple regression and included 11 factors as follow:

$$\mathbf{Quality = 161.291 + 10.937F1 + 6.546F2 + 5.760F3 + 5.282F4 + 4.903F5 + 5.424F6 + 4.551F7 + 4.852F8 + 4.855F9 + 4.648F10 + 2.982F12}$$

To recap, it can be said that the level of quality of building maintenance projects mainly depends on the study of buildings condition and to what extent the maintenance will be useful for those buildings. Also, it depends on the experiences and skills of the labors and the overall contractor performance and quality management system at site.

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Alt Text

Fig. 1 Caption: Research's methodology scheme

Fig. 1 Alt Text: In this research first step was to identify the quality factors in building maintenance projects. The quality factors were ranked using relative index by contractors, consultants and combined ranking. The mathematical model was formulated using stepwise multiple regression technique.

Fig. 2 Caption: New model for quality performance of building maintenance projects in Bahrain

Fig. 2 Alt-Text: By making use of factor analysis method forty independent factors was reduced to twelve new factors as represented in the figure. The mathematical equation for measuring quality of building maintenance was developed in terms of these factors.