



---

# DEVELOPING OF BUILDING MAINTENANCE MANAGEMENT BY USING BIM

**Noor Sabah Omar**

Postgraduate Student, Department of Civil Engineering, University of Diyala, Baquba,  
Diyala, Iraq

**Wadhah Ameer Hatem**

Assistant Professor, Baquba Technical Institute, Middle Technical University, Baquba,  
Diyala, Iraq

**Hafid Ibrahim Najy**

Professor, Department of Civil Engineering, University of Diyala, Baquba, Diyala, Iraq

## ABSTRACT

*Buildings maintenance is a process that takes a great attention all over the worlds. The managing maintenance properly helps maintain capital and ensure health and safety in the use of the building. Frequently, there are many available systems to manage building maintenance data. Though, the current practice based on recorded papers handwritten unformatted and dispersed data. This study aims to potential benefits investigation of the integration of Building Maintenance Management data of existing buildings in Building Information Modeling (BIM). To do so the data was collected from literature reviews, interviews, case study, and maintenance work orders were adopted to meet the research aim. The finding of this research was: Periodic maintenance program, Predicting of the required budget for maintenance and distributing it according to items priority, Illustrative schemes to clarify maintenance work, and Periodic maintenance program. Finally conclusion confirmed that the integration of building maintenance management in BIM can increase the efficiency of the maintenance and support maintenance decisions.*

**Keywords:** Maintenance, Buildings maintenance, Maintenance management, BIM.

**Cite this Article:** Noor Sabah Omar Wadhah Ameer Hatem and Hafid Ibrahim Najy, Developing of Building Maintenance Management by Using BIM, International Journal of Civil Engineering and Technology, 9(11), 2018, pp. 1371–1383.

<http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=9&IType=10>

---

## 1. INTRODUCTION

The buildings have a typical life-cycle, i.e., planning, design, implementation, Operation and Maintenance (O&M) phases. Through this period, the buildings performance is changed and performance and quality are degraded such as structural members, components, elements and equipment ...etc. is aging. This will effect on user's safety and convenience and if the buildings are inappropriately managed, it required enormous cost [1]. An anew constructed building, as well requires maintenance. Additionally, it is not possible to rebuild or replace all buildings at same time. The value of a building reduce unless carried out building maintenance [2][3].

According to Ali [4] maintenance can be defined as the integration of managerial and technical activities to confirm the building elements and objects in an adequate standard to obtain its required basis. Maintenance issue often arises when the building performance is not meeting the standards and quality of design. Maintenance of building follows particular series of objectives including repair, renewals, replacement, modification, protection that protects the existing materials (i.e. thin coating and external painting), decoration that protects of building's internal surface (i.e. painting and etc.), and cleaning for maintaining building's internal face [5].

An effective Building Maintenance Management must manage and integrate information such as drawings, inspections and manuals [6], checklists, and records maintenance reports [7]. Commonly, the information consist of 2D drawings, bar charts field reports, and spreadsheets which are commonly handed over from the design and construction phase of the building [8]. This information existing as text format and kept as record papers handwritten [6][9]. Furthermore, information are distributed to various locations and the maintenance procedure have to deal with the various variables that are available from different systems and large data managing information. Conventionally, these datasets have been analyzed and stored separately with one another. The lack of information integration makes it difficult for managers to make maintenance management decisions optimally [6] and creates the process of linking the information significantly time consuming and less conjectural [9].

There is a vast waste of money and time for information searching or to try to decisions taking with limited information [10]. The effectiveness of the maintenance practice is expected to be extremely increased with the integrated digital database availability [11]. There is an opportunity to develop the current use and practice of BIM as a tool of decision making [12]. Applications of BIM on maintenance process can offer an integrated historical record database of all building elements, equipment, providing information about the real components performance within the building and direct access provision to all data through an easy interface [13].

## 2. LITERATURE REVIEW

Lu [14] stated that the BIM is not only a 3-dimensional drawing instrument but a modern tool to wholly manage data relating to construction projects from preparative phase, to operation and maintenance phase. It is a new working approach, using new technology to aperients project execution and management, internal coordination, problem solving, external communication, cross-disciplinary collaboration, better construction process control, and risk management.

Akcamete et al. [15] point out that the main benefit gained by using BIM in building maintenance was visualization of spatial relationships of work orders for more effective reactive and preventive maintenance as well as BIM provides better documentation system, maintenance functions can cause (3 to 4) times double more than the similar repair activity if

it were to be executed as planned maintenance. With the purpose of support decision planning of maintenance, a dependable maintenance database that store record history of maintenance work and the related information change is required. The BIM repository allowed paperless surroundings and the data can be modified or taken using intelligent tools [16]. By employing BIM models as an alternative of paper sketch, maintenance team can compatibility between 3D models with real components identical and direct themselves through the system to immediately implement action plan [17]. Ahn and Cha [1] stated that it can be overcome the problems caused by the present maintenance work procedure by updating, storing and managing maintenance data in a more efficient way by using BIM. Grobler [18] researched the actual investment return for BIM and observed that the most savings of realized life cycle cost for BIM using in a construction project is the operation and maintenance phase. The maintenance and repair are the main activities during operations.

Witicovski [19] studied the cooperation between traditional systems and BIM-based systems in cost estimation and forecasting maintenance budget and concluded that it is possible to make efficient planning and cost control of construction through using BIM technique.

Furthermore, there are number of authors looking at effects of using BIM on project management and project managers [6]. They found by using BIM, all maintenance actions can be recorded with the basic details of the components that subjected to maintenance. It provides an opportunity to develop the effectiveness of maintenance by linking the BIM model with maintenance information. Development of BIM has facilitated better design interoperability, collaboration, and planning and clash detection [20].

### **3. MATERIALS AND METHODS**

The researcher adopted case study approach to analyze existing problems and in order to be able to explain potential benefits provided by the BIM for integration of maintenance data. Field observation, interviews approach, as well as maintenance plans and other existing databases reviews were conducted for data collection of this research.

Many semi-structured interviews with maintenance engineers' staff were conducted. It started with simple general information such as the interview participant's name, specialization and work experience. The second part of interviews represented question-answer format about how the case study building is routinely operated and managed, are there any systems used to manage maintenance work, and if the current work orders provide the necessary information to complete the maintenance work. Finally, main architecture and structural maintenance problems.

Headquarters of the Ministry of Construction and Housing in Diyala province was adopted as a case study. This project considered one of the main buildings in the province. It is recently implemented and has a lot of building defects and various architectural and structural details. Total buildup area (1000) m<sup>2</sup>, It consist of three floors, (27) rooms in each one.

#### **3.1. Creating 3D Case Study Model**

In order to achieve the integration of the different types of data bases required to creation of the system. Based on 2D cad plans and field survey, 3D model of case study project has been created using Autodesk Revit software 2018. The researcher used Revit software instead of other software because of it has high quality graphics and for better project document management, Figure-1 shown 3D model of case study building.



**Figure 1** An external view of the 3D Revit model of case project

### 3.2. Divisions the Case Study Building into Components and Elements

Because of the case study building includes many elements (columns, beams, walls, ceilings .etc.) and in order to easy control and reorganization of these elements, based on literature reviews and Global building maintenance guides [21] the researcher divided the building in to elements. The building division helps easier and better understand the maintenance items as well as for easy maintenance database creation using BIM.

Olagunju [22] pointed out that the buildings can be functionally divided into elements, all these elements can be linking with many defects that need repair and maintenance. Additionally, there are four type of building components (architectural and structural components, electrical components, mechanical components, and sanitary components) this study only considered architectural and structural building components maintenance. Maintenance defects was identified throughout interviews with engineers maintenance staff, case study defects, review of maintenance work that carried out in some government buildings.

Additionally, elements associated with architectural and structural components are (walls and ceilings, roofs isolation, doors and windows, structural, and floors, ceilings and stairs) elements. Each element has number of maintenance defects as shown in Table 1.

**Table 1** Condition rating scale of asset situation and definitions.

No.	Building Elements	Building Defects
1	Walls and ceilings element	Bricks efflorescence and wall dampness.
		Plastering partially falling, plaster crack, delamination or plaster dampness.
		Walls crack.
		Paint peeling, paint crack, blistering, discoloration.
		The roof is cracked or has a localized depression.
		Break and cracking Aluminum partitions joints
2	Roof isolation element	Cracks appeared on roof concrete tiles (Craze cracks, hairlines cracks).
		Expansion joints damage.
		Water leakage from the final surface and expansion joints
3	Structural elements	Deep crack on concrete surface.

		Dampness areas performed on structural elements (Roofs, columns).
		Steel bars corrosion in the structure elements.
		Spalling of concrete cover on structure elements.
4	Floors, ceiling and stairs coating element	Efflorescence and grout failure appeared between tiles.
		Chipped, scratched dislodgement and grout spalling stairs tiles.
		Move or loss the false ceiling elements.
5	Doors and windows element	Windows Defects (opening or closing Difficulty, screeching sound during the open or close, Fractured joint, lock and knob damage and broken glass).
		Doors defects (rotting wood, opening or closing difficulty, Erosion and decay frames of the doors, lock and knob damage).

### 3.3. Create 3D Model in Scope of Maintenance

In this research, it will be benefit from the possibilities offers by BIM to develop a system that helps in manage the various aspects of buildings maintenance. To achieve this goal, the following steps have to be taken:

1. Three dimensional model of case study project was created by using one of the BIM software (Revit).
2. The necessary investigation of building elements was conducted. The researcher adopted a paper approved by (Australasian Association of Higher Education Facilities Officers, 2000) [23] by giving grades from (1) to (5) for different maintenance items as shown in Table2. Then, the resources required maintaining this item and the expected cost also identified.

**Table 2** Condition rating scale of asset situation and definitions.

Building/element condition	General description (definition of rating/condition of building asset)	Condition rating
Very poor	<ul style="list-style-type: none"> <li>• Building has failed</li> <li>• Not operational</li> <li>• Unfit for occupancy</li> </ul>	1
poor	<ul style="list-style-type: none"> <li>• Badly deteriorated</li> <li>• Inferior appearance</li> <li>• Major defects</li> <li>• Components fail frequently</li> </ul>	2
Fair	<ul style="list-style-type: none"> <li>• Average condition</li> <li>• Significant defects are evident (e.g. non-structural cracks)</li> <li>• Deferred maintenance work</li> </ul>	3
Good	<ul style="list-style-type: none"> <li>• Minor defects</li> <li>• Major maintenance not required</li> </ul>	4
Excellent	<ul style="list-style-type: none"> <li>• Asset has no defects</li> <li>• As new condition and appearance</li> </ul>	5

- Investigation data was modeled through entering it into Revit database and linking it to the 3D model.

### 3.4. The Work Stages on Revit

In order to reach the aim study the researcher used the Revit software according to the following stages:

#### *Stage One: Spatial Division*

The researcher divided the spatial of all building floors (ground floor, repeated floor and roofs floor) according to the architectural divisions such as (meeting room, engineers rooms, documents rooms, Computer room, ... etc.) As shown in the following Figure 2, 3, 4.

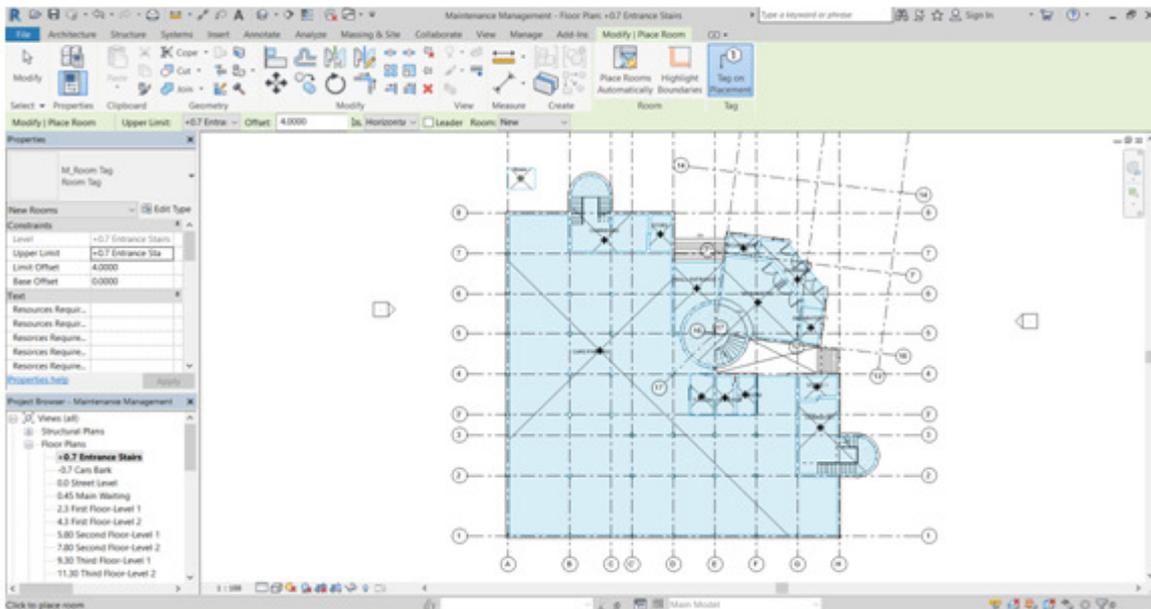


Figure2 The spatial division of the ground floor.

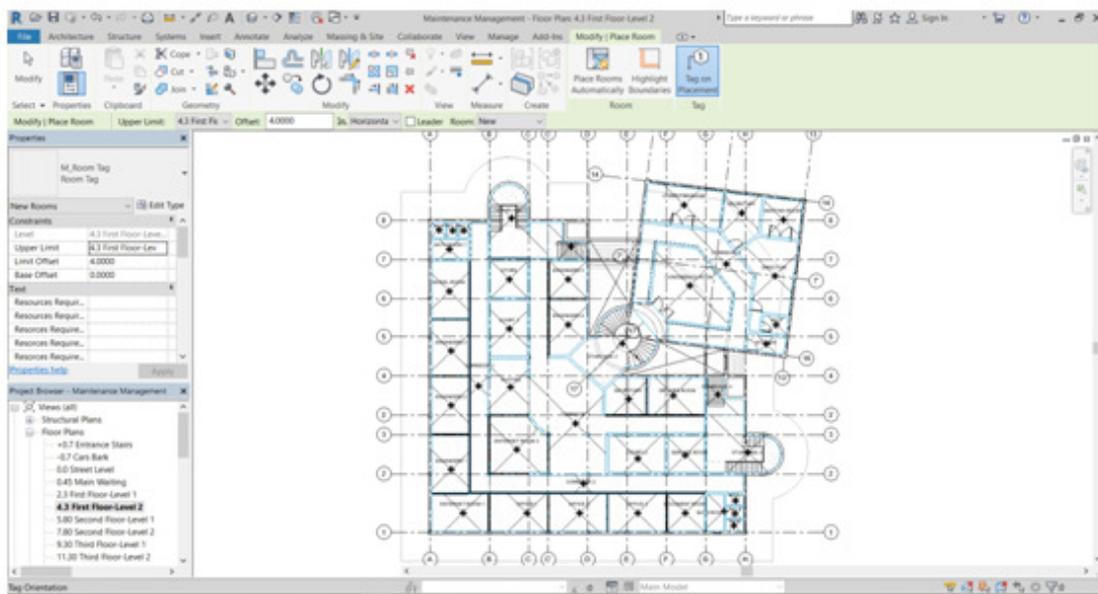
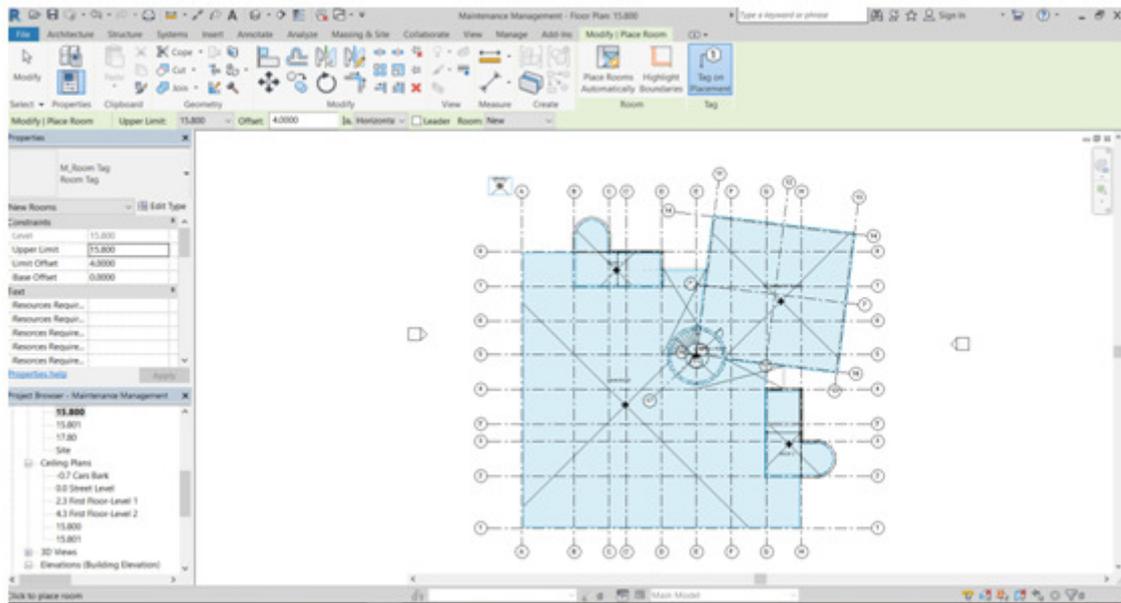


Figure 3 spatial divisions of repeated floors



**Figure 4** spatial divisions of roofs.

***Stage Two: Design of Maintenance Schedules and Linking Them with Spatial Divisions.***

After spatial division of all building elements has been done, the schedule was generated and the division depending on the room schedules.

After the rooms schedules were created, tables was generated which view all the sections that have been identified in the planner, then the parameters needed have been added, such as area which illustrates the space of each room, and level that determines the floor in which the room is located.

After that, all fields that related to maintenance have been entered, all architectural and structural elements as well as every architectural and structural maintenance defects have been introduced, and accordingly, each item included three fields:

1. Evaluations of the elements according to the evaluation system which was adopted.
2. Resources required for elements maintenance.
3. Expected cost of elements maintenance.

**4. RESULTS AND DISCUSSIONS**

**4.1 Periodic Maintenance Costs of Architectural and Structural Elements**

Fields were entered into the Revit table by (add parameter), and after entered all maintenance items for all building maintenance and resources required for maintenance work, the results showed the expected cost of periodic maintenance for all architectural and structural building elements and distribution of maintenance budget among these elements as shown in Figure 5.

## Developing of Building Maintenance Management by Using BIM

<Table (2) Expected Cost for All Building Elements Maintenance>							
A	B	C	D	E	F	G	H
Name	Area	Level	Expected Cost for Walls and Ceiling maintenance	Expected Cost for Floors, Ceiling and stairs coating maintenance	Expected cost for doors and windows and	Expected cost for Concrete components	Expected cost
SECRETARY 2	4 m <sup>2</sup>	+0.7 Entrance Stairs	05	0	5,000	0	0
SECRETARY1	5 m <sup>2</sup>	+0.7 Entrance Stairs	12,000	25,000	8,000	0	0
MAIN WAITING	61 m <sup>2</sup>	+0.7 Entrance Stairs	85,000	30,000	25,000	0	0
STORE 1	6 m <sup>2</sup>	+0.7 Entrance Stairs	0	21,000	10,000	0	0
STORE2	6 m <sup>2</sup>	+0.7 Entrance Stairs	0	0	10,000	0	0
CORRIDOR2	32 m <sup>2</sup>	+0.7 Entrance Stairs	65,000	5,000	25,000	0	0
CORRIDOR1	32 m <sup>2</sup>	+0.7 Entrance Stairs	0	40,000	15,000	0	0
T.ROOM	7 m <sup>2</sup>	+0.7 Entrance Stairs	0	15,000	0	0	0
ENTRANCE	15 m <sup>2</sup>	+0.7 Entrance Stairs	10,000	20,000	10,000	0	0
CARS PARKING	525 m <sup>2</sup>	+0.7 Entrance Stairs	0	0	0	0	0
SMALL ENTRANCE 1	17 m <sup>2</sup>	+0.7 Entrance Stairs	35,000	65,000	5,000	0	0
L.T ROOM	5 m <sup>2</sup>	+0.7 Entrance Stairs	0	0	0	0	0
R.T ROOM	5 m <sup>2</sup>	+0.7 Entrance Stairs	0	0	0	0	0
+0.7 Entrance Stairs: 11							
COMPUTER ROOM	24 m <sup>2</sup>	4.3 First Floor Level 2	65,000	60,000	25,000	0	0
SECRETARY	14 m <sup>2</sup>	4.3 First Floor Level 2	70,000	25,000	15,000	0	0
MEETING ROOM	12 m <sup>2</sup>	4.3 First Floor Level 2	75,000	30,000	15,000	0	0
DIRECTOR	29 m <sup>2</sup>	4.3 First Floor Level 2	20,000	45,000	35,000	0	0
WC ?	3 m <sup>2</sup>	4.3 First Floor Level 2	0	30,000	5,000	0	0
KITCHEN	6 m <sup>2</sup>	4.3 First Floor Level 2	8,000	25,000	8,000	0	0
CONFERENCE ROOM	42 m <sup>2</sup>	4.3 First Floor Level 2	75,000	40,000	45,000	0	0
circular staircase	32 m <sup>2</sup>	4.3 First Floor Level 2	0	35,000	35,000	0	0
DRIVERS ROOM	18 m <sup>2</sup>	4.3 First Floor Level 2	90,000	15,000	20,000	0	0
SECRETARY	12 m <sup>2</sup>	4.3 First Floor Level 2	0	20,000	15,000	0	0
SERVICE ROOM	11 m <sup>2</sup>	4.3 First Floor Level 2	10,000	0	0	0	0
COURT 2	17 m <sup>2</sup>	4.3 First Floor Level 2	0	25,000	12,000	0	0
ENTERTN ROOM 2	27 m <sup>2</sup>	4.3 First Floor Level 2	65,000	25,000	25,000	0	0
COURT 1	17 m <sup>2</sup>	4.3 First Floor Level 2	20,000	15,000	5,000	0	0
ENGINEERS 3	18 m <sup>2</sup>	4.3 First Floor Level 2	35,000	15,000	10,000	0	0
ENGINEERS 2	19 m <sup>2</sup>	4.3 First Floor Level 2	75,000	25,000	25,000	0	0
ENGINEERS 1	19 m <sup>2</sup>	4.3 First Floor Level 2	60,000	0	30,000	0	0
ENTERTN ROOM 1	18 m <sup>2</sup>	4.3 First Floor Level 2	0	0	10,000	0	0

**Figure 5** Budget required to carry out periodic maintenance

From the figure above we obtained:

Maintenance cost of walls and ceilings element is (10,045,000) DI.

Maintenance cost of structural element is (0) DI.

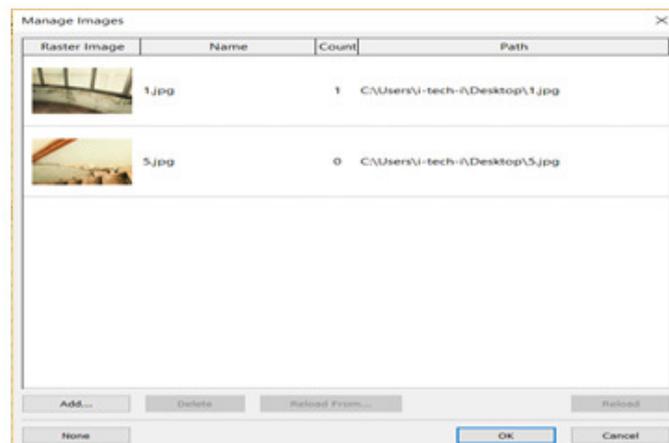
Maintenance cost of floors, ceilings and stairs coating element is (4,000,000) DI.

Maintenance cost of roof isolation element is (1,500,000) DI.

Maintenance cost of doors and windows element is (750,000) DI.

### 4.2. Most Important Parts That Need Maintenance

In order to take advantage of the recorded maintenance history and previous maintenance experiences to make the optimal decision based on interrelated information, especially in the buildings that are subjected to the same conditions, the image of damaged part can also be added as shown in Figure 6.



**Figure6** Images of the maintenance items.

It also shows the most important parts that need maintenance and resources required for repair, for example Figure-7 showed walls and ceilings element in addition to the resources required to maintain each of these parts and the expected cost of maintenance.

**Table 10 The Repair Required And Expected Cost For Walls and Ceiling Elements Maintenance**

J	K	L	M	N	O
Resources Required For Damaged or Separation Interior Wall	Resources Required For Wall Cracks Maint	Resources Required for Roof Cracks and Loc	Resources Required For Aluminium partite	Resources Required For Walls paint	Expected cost
--	--	epoxy glue	--	--	85
coating wall with plastic panel	--	--	--	--	12,000
--	--	--	--	--	85,000
--	--	--	--	--	0
re-whiteness the damaged walls	--	--	--	paint damaged wall	65,000
--	--	--	--	--	0
--	use adhesive	--	--	--	0
--	--	--	--	--	18,000
the whiteness of affected area up to bricks and then r	--	--	--	paint damaged wall	35,000
--	--	--	--	--	0
--	--	--	--	--	0
re-whiteness the wall	--	--	Replacement damaged part with new one	paint damaged walls	65,000
--	--	--	--	--	78,000
coating wall with plastic panel	--	--	Replacement damaged part with new one	paint dirty walls	75,000
--	--	--	--	--	28,000
--	--	--	--	--	0
re-whiteness of affected area up to bricks and then r	use adhesive	epoxy glue	--	paint damaged wall	8,000
--	--	--	--	--	75,000
re-whiteness the damaged walls	--	--	--	re-paint walls	98,000
--	--	--	--	--	0
coating wall with plastic panel	--	epoxy glue	--	--	18,000
--	--	--	--	--	0
re-whiteness the damaged walls	--	--	--	paint damaged wall	65,000
--	--	polymeric cement mortar	--	--	28,000
--	--	--	Replacement damaged part with new one	--	35,000
--	--	--	Replacement damaged part with new one	--	75,000
re-whiteness the wall	--	--	--	paint damaged wall	68,000
--	--	--	--	--	0

Figure 7 Tracking the maintenance work of the walls and ceilings element.

### 4.3. Illustrative Scheme for Maintenance Work

The main advantage of using Revit in maintenance work is the ability of this software to model the parameters that have been linked to each building element, all data which have been entered into the program such as resources required for maintenance and engineer’s evaluations of building elements can be linked to the 3D model and illustrated with color annotated scheme. This feature also helps in tracking maintenance by showing the parts that have been maintained in a different color than those do not want repair.

#### 4.3.1 Parts that need secondary ceiling element maintenance

As shown in Figure 8 bellow there were four rooms required secondary ceiling element maintenance and there were two rooms in blue color which has been maintained and two rooms in red has not been maintained yet.

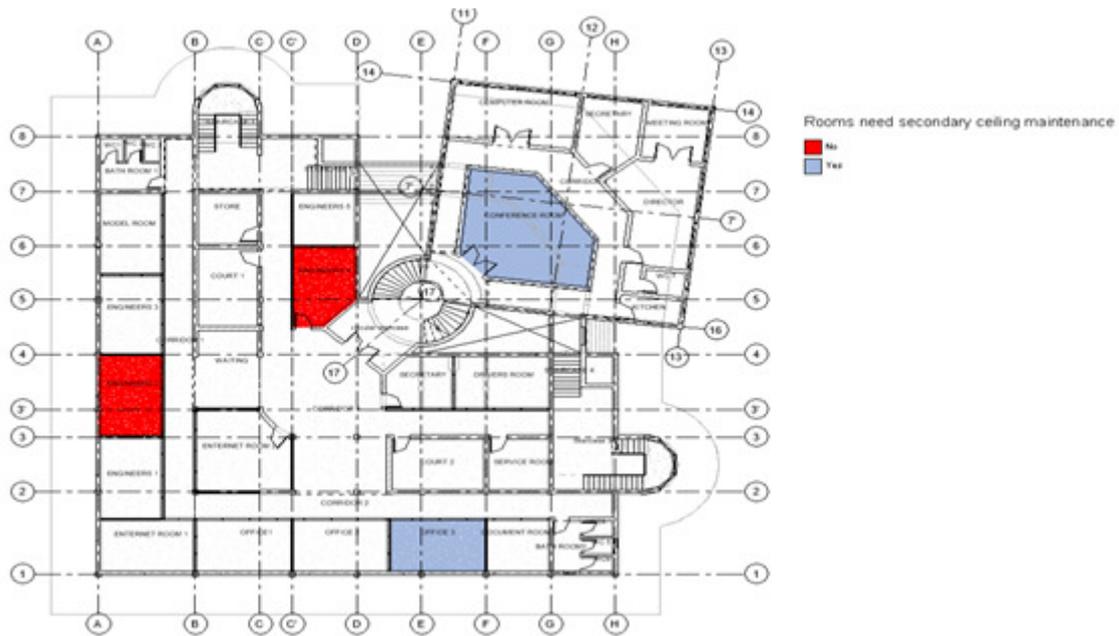


Figure 8 Rooms that need secondary ceiling element maintenance

#### 4.3.2 Rooms that need walls painting

The following Figure-9 shows the rooms that have been evaluated (1 to 5) by the maintenance staff engineers on the peeling paint item. As illustrated in following figure there were five rooms had (1 & 2) rating which had priority to paint and two rooms have (3) rating which their maintenance depends on the availability of the budget required for maintenance.



Figure9 Rooms that need walls paint

Therefore, we observe that it can be obtain a large number of illustrative schemes of all maintenance aspects in a simple way. These schemes change automatically as maintenance data changes. Therefore, the visual modeling provided by BIM applications have been employed for managing and tracking maintenance work.

It can be also know the condition of each parts of building in term of maintenance, once the section is selected, we have all the information related to this parts by (Properties Palette) list appear in the left side of the program interface such as engineers evaluations, the resources required, the expected costs and the tracking of maintenance activities. Any data can be added directly to this list instead of being entered into the tables as illustrated in Figure10.

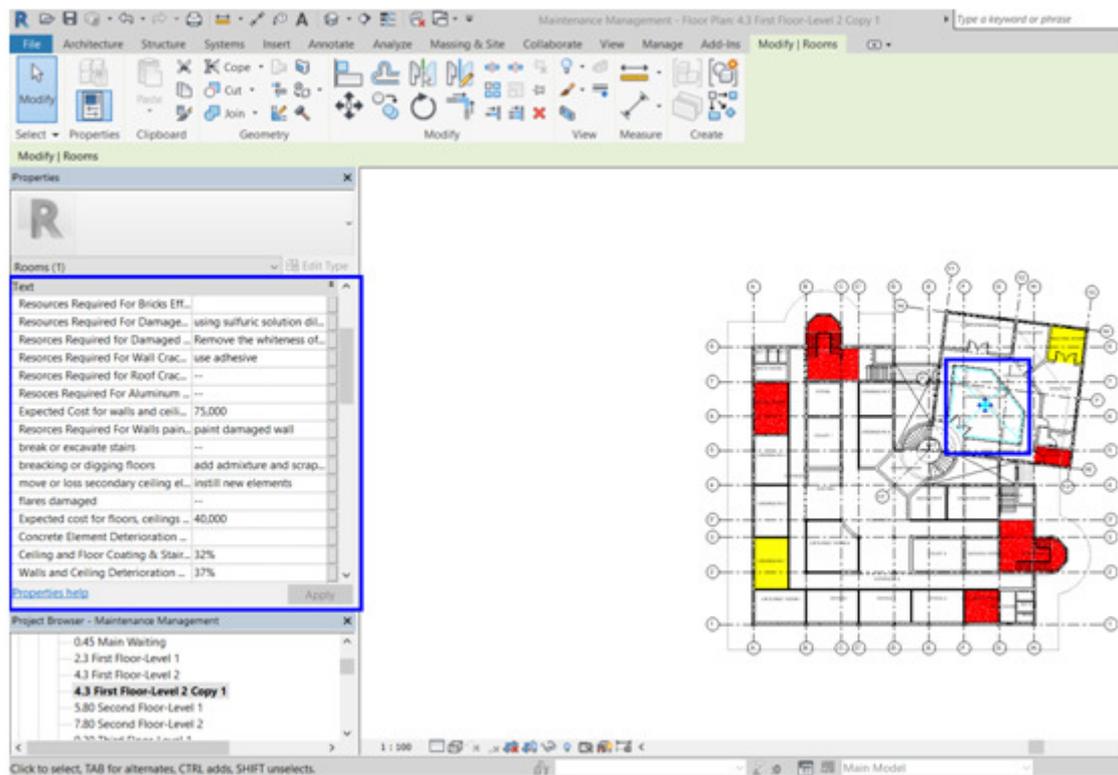


Figure 10 Data for maintenance cases in BIM application

## 5. CONCLUSION

In a traditional practice, the procedure of maintenance data updating needs a large amount of cost and time because of inconsistency in data management, which generally based on documents of human-oriented handwritten. But cost reduction and efficiency improvement of maintenance work are expected by information management integration using BIM applications.

The case study of the Headquarters of the Ministry of Construction and Housing in Diyala confirms that there is no practice of a seamless and continuous flow of information through maintenance processes. This study has shown many advantages provided by BIM in managing the various aspects of building maintenance.

One of the most important features demonstrated in this study is the modeling of the survey data and maintenance parameters then linking it to the 3D building model And realization the maintenance process more transparent which based on a clear scientific

approach. In addition the ability to enter maintenance data for an unlimited number of years. Furthermore, the maintenance staff can identify the maintenance history of any section of the building and compare the condition of the building between one year and another, as well as time saving and increase the maintenance effectiveness. Thus, this study will be useful in improving the BIM application in the maintenance phase by the BIM model integration in an effective way with the maintenance data.

## 6. REFERENCES

- [1] Ahn D, Cha H. Integration of Building Maintenance Data in Application of Building Information Modeling (BIM). *Journal of Building Construction and Planning Research*. 2014 Jun 9; 2(02):166.
- [2] Lateef OA, Khamidi MF, Idrus A. Appraisal of the building maintenance management practices of Malaysian universities. *Journal of Building Appraisal*. 2011 Jan 1; 6(3-4):261-75.
- [3] Shah Ali A. Cost decision making in building maintenance practice in Malaysia. *Journal of Facilities Management*. 2009 Sep 25;7(4):298-306.
- [4] Ali AS, Keong KC, Zakaria N, Zolkafli U, Akashah F. The effect of design on maintenance for school buildings in Penang, Malaysia. *Structural Survey*. 2013 Jul 5; 31(3):194-201.
- [5] Amani NA, Ali NM, Mohammed AH, Samat RA. A survey on the implementation of facilities maintenance management system of building in Iran. *Malaysian Journal of Civil Engineering*. 2012; 24(1).
- [6] Chen HM, Hou CC, Wang YH. A 3D visualized expert system for maintenance and management of existing building facilities using reliability-based method. *Expert Systems with Applications*. 2013 Jan 1; 40(1):287-99.
- [7] Lin YC, Su YC. Developing mobile-and BIM-based integrated visual facility maintenance management system. *The Scientific World Journal*. 2013; 2013.
- [8] Koch C, Neges M, König M, Abramovici M. Natural markers for augmented reality-based indoor navigation and facility maintenance. *Automation in Construction*. 2014 Dec 1; 48:18-30.
- [9] Motamedi A, Hammad A, Asen Y. Knowledge-assisted BIM-based visual analytics for failure root cause detection in facilities management. *Automation in construction*. 2014 Jul 1; 43:73-83.
- [10] Akinci B. Situational Awareness in Construction and Facility Management. *Frontiers of Engineering Management*. 2015 Feb 4;1(3):283-9.
- [11] Akcamete A, Liu X, Akinci B, Garrett JH. Integrating and visualizing maintenance and repair work orders in BIM: lessons learned from a prototype. In *Proceedings of the 11th International Conference on Construction Applications of Virtual Reality 2011* (pp. 639-649).
- [12] Carbonari G, Stravoravdis S, Gausden C. Building information model implementation for existing buildings for facilities management: a framework and two case studies. *Building Information Modelling (BIM) in Design, Construction and Operations*; WIT Press: Southampton, UK. 2015 Sep 1; 149:395-406.
- [13] Oskouie P, Gerber DJ, Alves T, Becerik-Gerber B. Extending the interaction of building information modeling and lean construction. In *IGLC 2012-20th Conference of the International Group for Lean Construction, the International Group for Lean Construction 2012 Jul*.

- [14] Lu W, Fung A, Peng Y, Liang C, Rowlinson S. Demystifying construction project time–effort distribution curves: BIM and non-BIM comparison. *Journal of Management in Engineering*. 2015 Mar 11;31(6):04015010.
- [15] Akcamete A, Akinci B, Garrett JH. Potential utilization of building information models for planning maintenance activities. In *Proceedings of the international conference on computing in civil and building engineering 2010 Jun 30* (pp. 151-157). June.
- [16] Whyte J, Stasis A, Lindkvist C. Managing change in the delivery of complex projects: Configuration management, asset information and ‘big data’. *International Journal of Project Management*. 2016 Feb 29; 34(2):339-51.
- [17] Golabchi A, Akula MV, Kamat VR. Leveraging BIM for automated fault detection in operational buildings. In *ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction 2013* (Vol. 30, p. 1). Vilnius Gediminas Technical University, Department of Construction Economics & Property.
- [18] Grobler F. Overview of building SMART International and BIM implementation in US. *InProc.*, Singapore BIM Conference 2011.
- [19] Witicovski, L. C., & Scheer, S. (2012). Some improvements for BIM based cost estimation.
- [20] Hatem WA, Kwan A, Miles J. comparing the effectiveness of face to face and computer mediated collaboration. *Advanced Engineering Informatics*. 2012 Apr 1;26(2):383-95.
- [21] BORNAND, E. *Le guide de maintenance*, Berne, 1991.147p
- [22] Olagunju RE. Predictive modelling for sustainable residential building maintenance in developing countries: A Nigerian case. *Interdisciplinary Journal of Contemporary Research in Business*. 2012;4(6):1273-4.
- [23] AAPPA - Australasian Association of Higher Education Facilities Officers. *Guideline for Strategic Asset Management, SAM – How to Undertake A Facility Audit* (2000), 1st Edition, ISBN.