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Facility Management for Smart building Maintenance

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Abstract : Maintenance is a very important stage in buildings life cycle and many designers and contractors doesn't give it enough care and consider it as an unprofitable activity which make a lot of a very good designed and executed buildings after many years without maintenance in a very bad condition.

And as a researchers and first of all architect it's our mission to preserve and keep our buildings in a good condition and raise the awareness about the importance of building maintenance.

The new era of building construction, design and communication technologies make maintenance management easier and controllable due to the new technologies like BIM(Building information modeling), Io T (Internet of Things) and new branches like FM (Facility Management).

Another reason behind this paper is the absence of smart maintenance and facility management practices in the Middle East except in the United Arab Emirates (UAE) and recently in Saudi Arabia (KSA) and in Egypt there is no signs at all for smart maintenance in facility management practices.

The following research will discuss the new technologies and practices in facility management for smart buildings maintenance and how would it be applied with minimum expenses.

Keywords: Internet of things – Training – BIM – Maintenance – Monitoring – Smart Maintenance – Facility Management .

1. Research Problem:

- The term **smart maintenance**is mainly related to high cost infrastructure but no one focuses on the strategy and how to apply it on small and economic scale.
- Maintenance market only focus on the hardware (infrastructure) part not on the managerial part (software part).
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2. Research Goals:

- Emphasizing on the importance of modern maintenance software roles in managing maintenance tasks and assets tracking and controlling.
- Proving that adopting smart maintenance strategy doesn't have to be complicated or expensive(at least in the initial stages).

3. Research Methodology:

- Adopting the descriptive approach to describe the types and role of smart maintenance components.
- Adopting the comparative analytical approach to compare and analyze the case studies results.

- **Preface:**

Smartness concept nowadays is all about the applications and utilities, so the new era of smart maintenance market is related to how

can the user control his facility spaces and its condition and manage the assets of his facility.

But for the specialists the managerial part is a very important part, so this paper will discuss the new methods of managing and controlling facilities assets and elements.

The new applications in smart maintenance divided to two parts the first one is the managerial part and the second part is the hardware (infrastructure) part which the Building Automation System (BAS) is responsible for.The BAS definition is according to **The Association of German Engineers** "Building automation is the computerized measurement, control and management of building services. [2]

- **Building Automation System main functions are:**

1. Provide information about facilities functions like (current status – archived information – analysis).
2. Alarm management.
3. Diagnostic monitoring and reporting of system elements status.
4. Browsing between different building applications.

BAS changed from its classical to modern solution as shown in the following graphs:

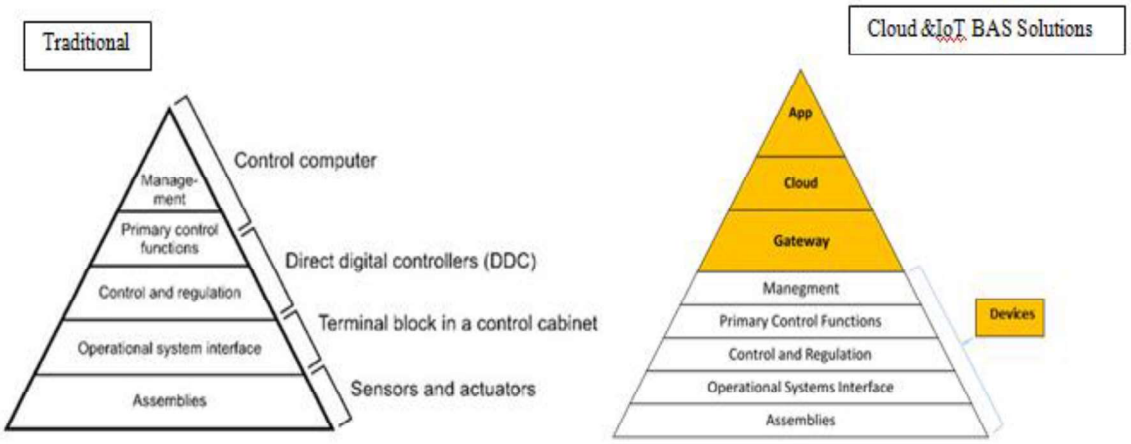


Fig 1 Traditional, Cloud &IoT BAS Solutions

IoT (Internet of Things) and cloud computing software and platforms made it possible to control building assets from any ware outside or inside the building, but first the internet of things definition have to be mentioned (is a network of sensors, meters, appliances and other devices that are capable of sending and receiving data).

- **Facility management:**

IFMA: (FM) is a profession that encompasses multiple disciplines to ensure functionality, comfort, safety and efficiency of the built environment by integrating people, place, process and technology.[12]

In the late 1980 FM became a profession in the construction industry at first it was just a managerial activity to manage "hardware" such as buildings, furniture and equipment and "software" such as people,process, environment, health and safety now facilities Management is responsible for planning, development, maintenance, and operations of County owned and leased buildings, infrastructure, and property.

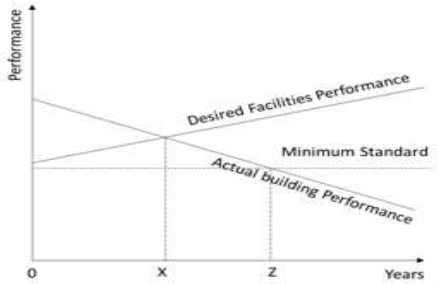
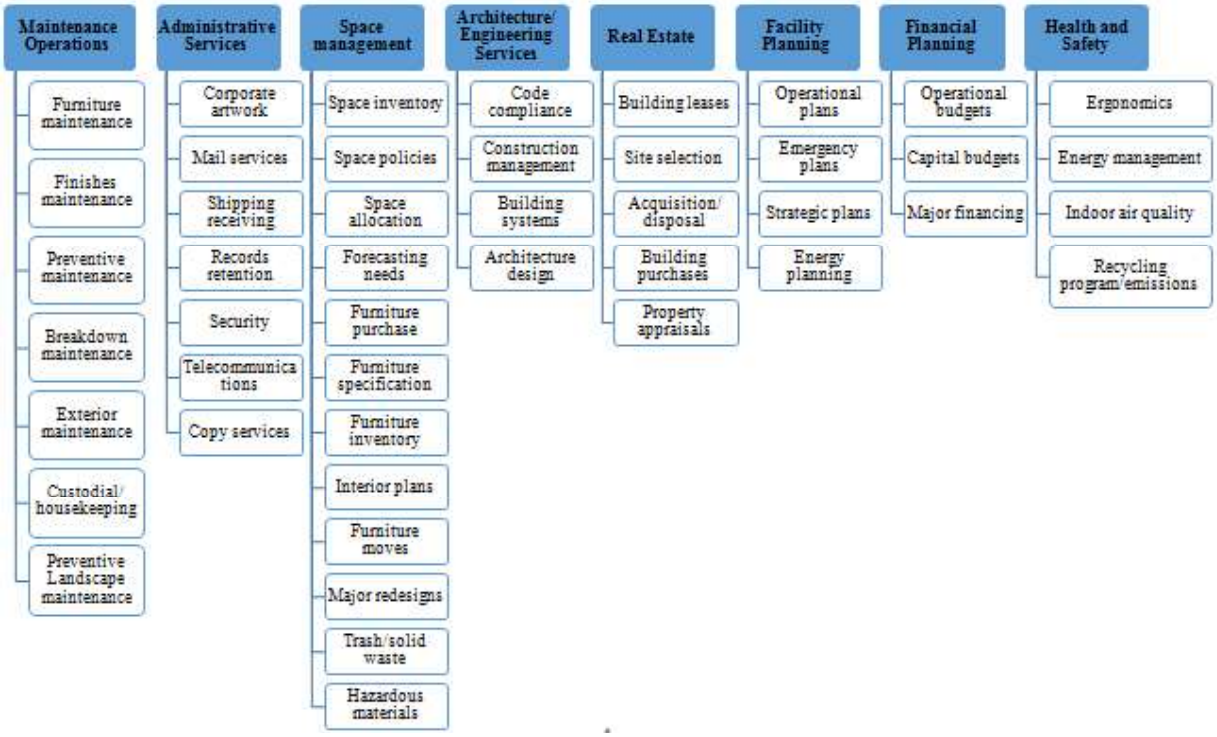


Fig 2 Relationship between building performance and facility management (Douglas, 1996, p. 26).[6]

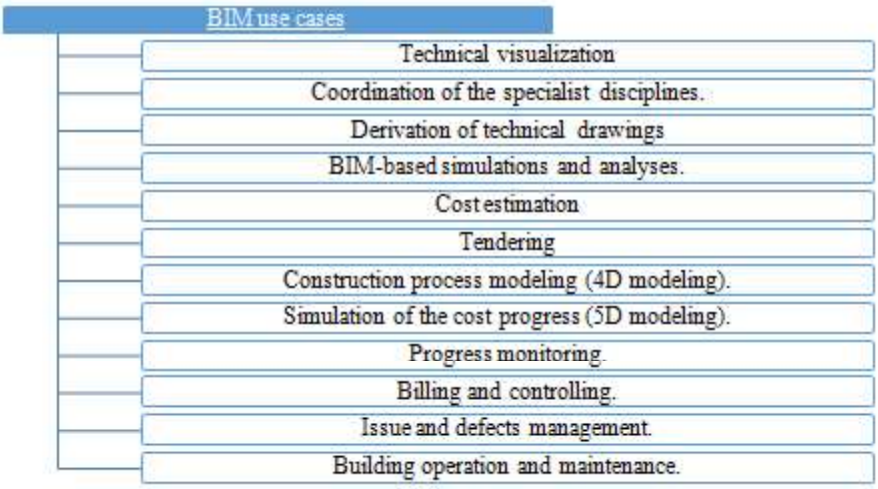
It implies simply that the higher performance of facilities, the better performance of the whole building. Throughout the lifespan of the building and decrease the operation and breakdown maintenance costs.

- **Facility Management Responsibilities and Roles:**



- **BIM:**

Building Information Modeling (BIM) is a process that begins with the creation of an intelligent 3D model and enables document management, coordination and simulation during the entire lifecycle of a project (plan, design, build, operation and maintenance).[11]



- **Why BIM:**

The BIM technology has a lot of advantages to help facility mangers and maintenance staff to control and track facility assets and elements due to the ability of containing families (e.g. Door family). BIM model is not like CAD file because CAD file only have the information about lines and layers and how to manage them it's like a drawing doesn't understand the difference between doors and flooring tiles or windowsbut BIM model is way different it got families and every family got the information about the element (e.g. Doors) will have (door type, dimensions, materials, manufacture, ….. Etc.). There is some parameters you can add like (installation date, statues, last inspection date, inspection notes …… Etc.) And any other parameters you want to add. BIM models are

combatable with a lot of software like (M.S. EXCEL …. Autodesk and other software providers).

According to study done by MEFMA (Middle East Facility Management Association)and CREDO mentioned that BIM is one of the FM and (Building management Systems) tools for asset management data, and according to the interviews with FM providers they mentioned that mobility and IoT is the next step in mobile monitoring in FM. [9]

The main feature of BIM and which make it easy for it to collaborate with other software and to include model families is the ability to export IFC files and the following part will review the history and the main features of IFC files.

There was a missing link in the process of linking BIM model to BAS to include the facility documents and parameters and all the building assets data and analytical models for structure and energy analysis, this link was the **IFC file.**

Autodesk decided to collaborate with (IAI) International Alliance for Interoperability to complete the process of standardization in 1995 this organization get a new name in 2005 is (Building Smart) and its now has 19 branches and more than 800 companies, organizations and institutes. A first version 1.0 of these standards was issued in 1997 as the "Industry Foundation Classes – IFC"

- **The main features of BIM:**

1. Make services cost estimation much more easer due to automated quantities calculations from the model.
2. Provide a detailed description for different spaces and its status (occupied or not), (hot or cold) by association with other software.
3. Provide a reliable assessment due to the sheets and tables generated by the model.
4. Provide a surveying tool to locate building assets for maintenance and administrative purposes.
5. Managing maintenance and operation tasks archiving.

- **Case studies:**

The following 3 case studies will show thenew approaches in smart maintenance to enhance facility management.

1. **The first case study will be fromCalifornia State University- USA:**[10]

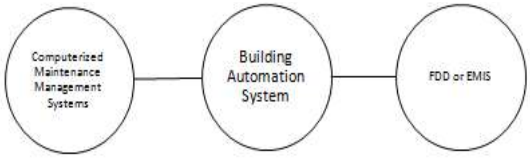


Fig 3 California State University System architecture

FDD:Fault Detection and Diagnostic (FDD) software identifies buildings with suboptimal performance by analyzing building automation system (BAS) data. **FDD is one type of energy management and information system (EMIS).**

Target:

1-Reduce power consumption.

2-Improve energy and performance effectiveness.

3-improve work orders flow.

Solutions:

1. Reduce energy usage by tracking errors from FDD software.
2. The FDD software enable the maintenance team to identify performance degradation.
3. FDD Software send email alerts and reports to the maintenance team to enable them to be updated about the buildings status.

Data collection:

Fault detection and diagnostic (FDD) software on 22 buildings across campus, tracking data from 183 energy meters and over 9,000 points from their building automation system (BAS).

The California State University decided to track assets performance like HVAC fans so the maintenance team installed FDD system consists of BAS and FDD software the FDD analyze the data in sky foundry cloud and then it can be transferred among the engineers and the facility management team shows the fault in the fan speed and how the system mange to enhance fans performance.

The FDD software monitors system performance during and after a demand response event to ensure that systems turn down as intended and subsequently return to normal operation.

Results:

1. In the first year the university saved **200,000$** of energy costs.
2. FDD give facility staff time on optimizing systems and proactive maintenance rather than random inspections and responding to system breakdowns.
3. The HVAC system performance improved very much before installing the FDD.

2. The second case study will be from Aalto University, Espoo, Finland:[4]

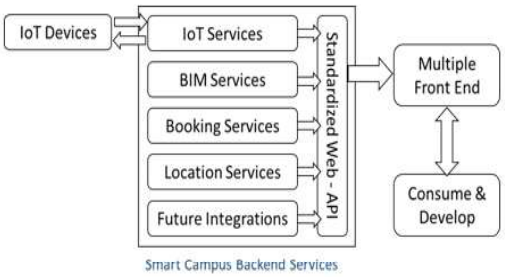


Fig 4 Aalto University System architecture

Targets:

Connect spaces/buildings with the data they generate through IoT devices with people living/working in those spaces.

Solutions:

By managing the relationship between spaces/buildings (described using IFC) and IoT data, in particular the translation of static IFC files into interactive web documents.

Data collection:

Sensors connected to the building automation and IFC file include the building information.

Results:

1. Enhancing facility management by integrating IoT sensors to provide real-time control and information availability for better decision making.
2. Managing maintenance events.
3. By integrating real-time controls with the Aalto Space app and integrating these with sensors, there is a potential to improve user comfort and spaceutilization**.**
4. Energy savings.

In this case study a team of researchers in the department of **computer science in Aalto University**, Finland integrate the IoT application in university campus with BIM because BIM include the building information and spaces information as well so they proposed an architecture to apply this model started with the implementation of sensors and connect them to the building automation and to the cloud. This was the first part and by creating BIM model for the campus and exported as IFC File format to link it to the data collected by the sensors so the data in the IFC model so a new concept of data collection and management is created which enable us to link the data from the existing model and real time data.

3. The third case study will be from University of Manitoba, Winnipeg Canada:

This case study will have 3 approaches: [5]

Targets:

1. Visualize CO2 & temperature data.
2. Compare between different approaches and select the ideal.
3. Liking elements status to the management system for maintenance and asset management purposes.

<u>The first approach (Sensor-Revit integration):</u>

Revit is used to visualize CO2 & temperature data by using **Dynamo visual scripting** to create 2 attributes to import CO2 and temperature to Revit model. The first Dynamo script, Revit model room element attributes like CO2 & temperature and room number and ID exported to data base template in **Microsoft Excel**. In the second script the parameters with value are imported to Revit and then it can be visualized in Revit.

Limitations:

1. Data can be only visualized in 2D.
2. This approach doesn't allow visualization of the historical data.
3. Revit direct integration allow high probability to delete or move any element unintentionally.
4. Revit operates slowly with large files.

<u>The second approach (Sensor-Revit- Navisworks integration):</u>

1. Two new shared parameters were created for temperature and CO2 levels.
2. The two parameters were loaded toroom elements in the model.
3. Revit models were exported and saved as the cache files (NWC file) to be imported to Navisworks.
4. Data Tools which is the function of Autodesk Navisworks software, is used to create and manage links between model file and the

sensor database with temperature and CO2 data for each room.

5. Open database connectivity driver was used within the "Data Tools" function to access the sensor database. Standard query language (SQL) string is created for the integration of the model elements in the software and the sensor database.

Limitations:

The lack of historical data.

The Third approach (Sensor-Revit- Navisworks - API integration):

The third approach involved development of the new add-in for Navisworks with four additional functions:

1. General information about model.
2. Search assets of the facility in 3D environment.
3. Visualization of the temperature and CO2 data of the selected level.
4. Graphical representation of the historical sensor data of a selected room for a specified time period.

The add-in is developed in Microsoft Visual Studio software for Autodesk Navisworks.Net application programming interface (.net API) furthermore, object linking and embedding database (OLeDB) connection that allows importing of the data from a variety of sources in a uniform manner is used for reading of the sensor data from the database.

Limitations:

This approach has no limitations.

Data visualization for sensors data can view the information about equipment status and performance & the degradation in the equipment performance (the historical data) this data can be used to increase the quality of the equipment performance or **even improving the indoor environmental quality**. By linking the model to **Autodesk 360** the third approach can be controlled by mobile phones.

Results:

1. The data in the 3 approaches can be visualized with several modes.
2. The 3 approaches comparison has been made and several limitations has been found.
3. The needed data has been provided in the BIM model.
4. The collected data can be used for several proposes (Energy management, enhancing air quality andmanaging maintenance tasks…. Etc.).

Items	California State University	Aalto University	University of Manitoba
Building Type	Educational	Educational	Educational
Study Date	2018	2018	2019
Country	USA	Finland	Canada
Applied Technologies	Fault Detection and Diagnostic (FDD) and BAS	Sensors & BIM &Cloude Computing	1. Sensors & BIM. 2. Sensors & BIM &Navis Works. 3. Sensors & BIM &Navis Works & API.
Aims	**1.** Reduce power consumption. **2.** Improve energy and performance effectiveness. **3.** Improve work orders flow.	Connect spaces/buildings with the data they generate through IoT devices with people living/working in those spaces.	**1.** Visualize CO2 & temperature data. **2.** Compare between different approaches and select the ideal. **3.** Liking elements status to the management system for maintenance and asset management purposes.
Results	**1.** In the first year the university saved 200,000$ of energy costs. **2.** FDD give facility staff time on optimizing systems and proactive maintenance rather than random inspections and responding to system breakdowns. **3.** The HVAC system performance improved very much before installing the FDD.	**1.** Enhancing facility management by integrating IoT sensors to provide real-time control and information availability for better decision making. **2.** Managing maintenance events. **3.** By integrating real-time controls with the Aalto Space app and integrating these with sensors, there is a potential to improve user comfort and space utilization. **4.** Energy savings.	**1.** The data in the 3 approaches can be visualized with several modes. **2.** The 3 approaches comparison has been made and several limitations has been found. **3.** The needed data has been provided in the BIM model. **4.** The collected data can be used for several proposes (Energy management, enhancing air quality and managing maintenance tasks…. Etc.).

5. Conclusion& Results:

This paper included the smart methods for managing building maintenance and assets through the integration of BIM and IoT technologies, also this paper review the traditional and modern (BAS) and show the effect of IoT technology on it.

The second part reviews the facility management, use casesof BIM software, functions,the importance of IFC files and its contents.

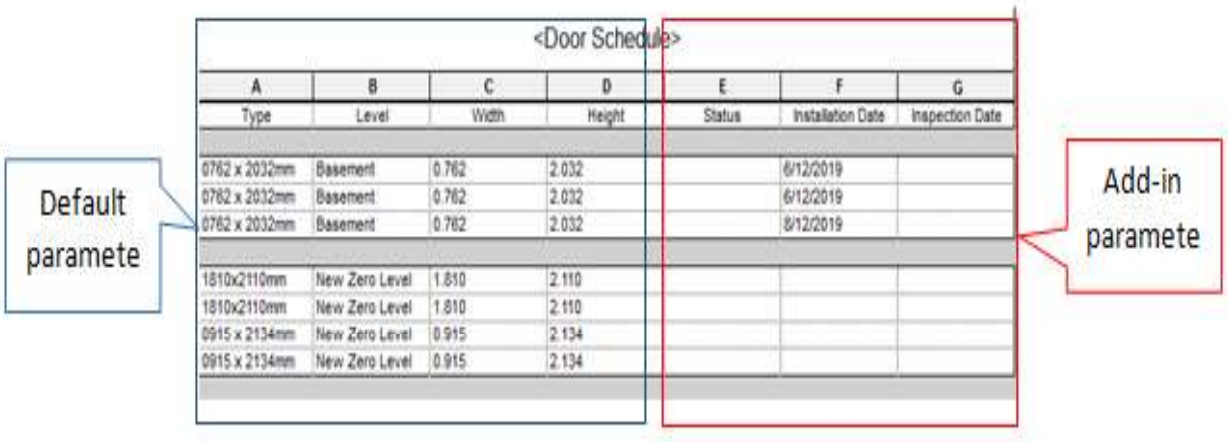
The third part show the case studies which adopted the traditional and modern approaches and the new software and technologies and its effect on the build environment, and finally the recommendation to know how to establish an economic initial management system and how to develop it to be full smart system.

The research also reached to several results:

1. The performance of modern BAS is a lot better, faster, easier to use than the classical one.
2. The new approaches include ICT application which make it easier to control the building from anywhere from outside or inside the building.
3. The new software helped to make any BAS compatible with any service provider.

5. Recommendations:

The last 2 case studies are including BIM model which make it possible for individuals and facilities to review and access building assets,it helped to export schedules including assets data and status to make daily or weekly inspection report (**initial phase**) and postpone infrastructure as advanced phase, or install sensors infrastructure to the most vital spaces (**second phase**)to cut down initial costs, and as a (**final phase**) install sensors for the whole facility. Another case study done by(BasselAlhasn)[3] adopted the preventive approach by using **BIM**and **Micro Soft Access**to create **detonation models** for different elements to decide which element need maintenance and which don't.



<Door Schedule>

A	B	C	D	E	F	G
Type	Level	Width	Height	Status	Installation Date	Inspection Date
0762 x 2032mm	Basement	0.762	2.032		6/12/2019	
0762 x 2032mm	Basement	0.762	2.032		6/12/2019	
0762 x 2032mm	Basement	0.762	2.032		6/12/2019	
1810x2110mm	New Zero Level	1.810	2.110			
1810x2110mm	New Zero Level	1.810	2.110			
0915 x 2134mm	New Zero Level	0.915	2.134			
0915 x 2134mm	New Zero Level	0.915	2.134			

Fig 5 Schedule Sample from Revit Model

Maintenance categoriesin every building is broken down to the following categories:

1. Building envelop maintenance.
2. Interior systems maintenance. (Electrical systems, safety systems and alarms and remote monitoring, mechanical systems.
3. Roads and grounds maintenance.
4. Utility/central& treatment systems maintenance. (Electrical, mechanical, gas and waste water treatment).

Maintenance performance measurement is a very difficult task to manage because every facility has its own unique characteristics, activity (educational, industrial, and administrative ….. Etc.) And performance indicators so for this task benchmarking was used because it can be used to compare among different cases and a lot of standards from many institutes are used like BS (British Standards) & IFMA (International Facility Management Association).

The following part will review the benchmarks for maintenance Inspired by IBS (International British Standards) & IFMA (International Facility Management Association) and two other KPIs were added related to user satisfaction and green practices.

Table 1Maintenance Benchmarks[7]&[8]

*	Benchmark KPIs	Elements	Main Areas
1	Maintenance Expenses and Assets Management	Total maintenance cost, annual turnover & physical assets replacement value.	Financial & Asset management
2	Maintenance Monitoring	% Finished work orders	Management Software
		Preventive maintenance unfinished work orders.	
		Time range for work orders response.	
		Number of complaints.	
		Time to repair for each work order.	
		Cost per area.	
		Corrective maintenance unfinished work orders.	
		Equipment failure period.	
		Commitment to Planned Maintenance.	
		% Budget for unplanned maintenance.	
		Cost per full time maintenance personnels.	
3	Maintenance Team	Plumbers, electricians, carpenters, foremen & o&m directors.	Administration
4	Administration	Administrative assistant, help desk, other administrative support and planning sectors.	
5	User Satisfaction	Many studies showed that the ideal maintenance system is the one which provides user satisfaction.	User
6	Green Operations and Maintenance Practices	Certification Status, energy management and recycling.	Sustainability
7	Health & Safety	Maintenance team safety, risk analysis, laws and rules.	Health & Safety

6. References:

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