

Examining Relationship between Maintenance Management and Sustainability in Buildings: Literature Review

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Abstract

Maintenance is defined as the combination of all technical and associated administrative actions intended to retain an item in, or restore it to, a state in which it can perform its required function. Whereas Sustainability is considered as an appropriate framework to gather all efforts aimed at improving the built environment through the development of social, economic and environmental aspects. The problem this paper has to deal with is the inefficiency of current maintenance management practices of sustainable buildings. The purpose of the study is to examine the relationship between maintenance and sustainability in buildings. This study counts upon a literature review to investigate the importance of maintenance, approaches to sustainable building maintenance, relation between maintenance and sustainability, sustainability-related trends of maintenance management, building maintenance management and frameworks for maintenance and sustainability processes. Upon examining the previous discussed topics, a number of focal points and gaps have been found ,these include; the elements of sustainable agenda to be taken into consideration for New buildings; the detailed factors of sustainability that have an effect on maintenance, the impact of maintenance on sustainable buildings; meaning how far sustainable strategy has an effect on maintenance and explaining the correlation between maintenance and sustainability, other current and futuristic maintenance management trends that should be applied to sustainable buildings, in addition ,a gap has been detected in the analysis of case studies and international examples for using sustainable factors in maintenance management, the frameworks that are concerned with the relation between sustainability and maintenance in buildings.

Keywords

Sustainable building maintenance, maintenance management practices, Sustainability-related trends of maintenance, frameworks

1. Introduction

This is the first part of an ongoing study to achieve an assessment framework to evaluate sustainability elements that should be applied to preserve the buildings through current and futuristic maintenance management trends for sustainable buildings and this will be attained in this study by tracking the latest trends in research in the last ten years and exploring the relationship between sustainability and maintenance.

First the research will discuss the relation of maintenance towards sustainability then current and futuristic maintenance management trends towards sustainability will be mentioned, then approaches to sustainable building maintenance will be covered. Deeper more types of frameworks of maintenance and sustainability created will be studied. Maintenance of different types of Sustainable buildings will not be left out from the study that in addition to special types of buildings maintenance and building maintenance overviewed with case studies of office buildings. Finally, maintenance importance will be highlighted to end this part of extensive literature review and some common problems of maintenance will be covered as well.

The relation between maintenance and sustainability was discussed through literature, and the discussed topics and characteristics that were focused on. These findings were based upon reviewing a number of literature sources that were published in the period between 1996 and 2017, following Table (1) of topics of literature that discussed sustainability and maintenance show literature that discussed maintenance and sustainability. Research contributions mainly were focused on building maintenance management with percentage 46% and then the importance of maintenance comes second in the focus of research with percentage of 16% and this puts a small weight of study on sustainable building maintenance what does this mean there is no concentration on approaches to sustainable building maintenance with percentage 5%.

Table (1): Topics of Literature that discussed sustainability and maintenance

Discussed Topics of Literature	Sources
Importance of Maintenance	(6)
Approaches to Sustainable Building Maintenance	(3)
Relation between Maintenance and Sustainability	(5)
Sustainability-related trends of Maintenance Management	(4)
Building Maintenance Management	(17)
Frameworks for Maintenance and Sustainability Processes	(4)

2. Timeline of the Developing of Maintenance Management in Literature Sources

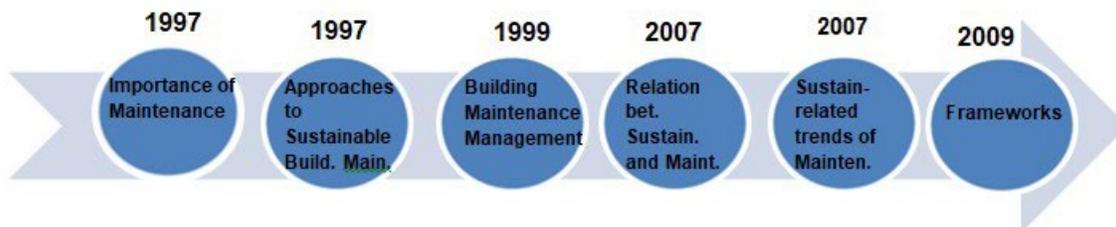


Figure (1). Timeline of the appearance of Discussed Topics from the oldest to newest topics tackled. (Researcher, 2018)

According to the Figure (1) above of timeline of the Developing of Maintenance Management in Literature Sources and from 1997 researchers started to study importance of maintenance and the topic that was least tackled approaches to sustainable building maintenance shows the term was interesting to researchers by 1997 but few studies dealt with that topic. Whereas the studies around Building Maintenance Management which had the highest percentage showed the beginning of tackling this subject was by 1999. As to the relation between sustainability and maintenance, researchers dealt with it in 2007, also the sustainability-related trends of maintenance management. The most recent discussed topic was the frameworks in 2009.

3. Gaps in Research

Therefore, according to discussed topics of relation between maintenance and sustainability the five main gaps of the literature review are found to be in;

- the mentioned elements of sustainable agenda to be taken into consideration for new buildings,
- other current and futuristic maintenance management trends,
- analysis of international examples for using sustainable factors in maintenance management,
- frameworks,
- the impact of maintenance on sustainable buildings.

4. Examining the Relation between Maintenance and Sustainability

Due to the limited scope of the study and referring back to the studies made examining the relation between maintenance and sustainability, so the following areas should be covered to fill in the previous five gaps of the literature review are found to be;

4.1. Importance of Maintenance

This section discusses maintenance importance and some common problems of maintenance. Maintenance Importance rises from mentioning some common problems of maintenance building defects in traditional office buildings are and all of the problems are gathered from maintenance reports were mentioned in the study made by Suffian(2013) concerning the maintenance problems as; defective waterproofing system, typical cracks of buildings, critical consequences of soil settlements, poor workmanship in the finishes of façade, other staining problems in façades and lacks of knowledge and expertise on maintenance aspects due to poor and improper building maintenance will definitely cause more damages and costly repair works if left unattended. That's because failing to understand such fundamental, building maintenance would be unnecessarily costly. He added in his study that unfortunately the maintenance aspects of the building are still weak.

While in the study made by Lam(2005) , a commentary is provided on the ill-effect of inadequate maintenance of services in a 20-year hospital building. The author also offers his comments on the best management of design and maintenance that should be considered and pragmatic ways that can be used to improve building care and sustainability. Designers should improve whole life performance through either simple or innovative design solutions.

The consideration, during the procurement of built assets, of the influences of the factors discussed in this study is a necessity. The hospital building case clearly illustrates that maintenance was not probably strongly enough addressed by the designers in any great detail at the design stage, otherwise, normal maintenance problems can be tackled easily, and the building can be used at least for another 25 years. (Lam,2005):

The study focused on missing linkages between design, installation/construction, maintenance and sustainable buildings as shown the ability to control or modify maintenance diminishes from the earliest step in the following Table (2):

Table (2) Ability to control or modify maintenance diminishes from the earliest step (Lam,2005)

STAGE	CONTROL
Concept	Total control-building and services can be tailored to any maintenance philosophy; designing out maintenance will eliminate most problems.
Design	Total control-flexibility remains to select systems which have low maintenance requirements.
Construction	Very limited control-design is fixed; difficult to change design but still possible at high cost; inspection will identify maintenance problems (not ALL).
Building in use (a life of) 50 to 60 years	No control- maintenance problems will develop and appear. Repair – very limited control, minor corrections to maintenance are possible. Replacement- still limited control, but can reduce on-going problems. Improvement/Modification- control flexible is a little bit better, but may give good control (NOT TOTAL unless the whole system can be changed).

While in the study made by Shohet et al. in which the main objective is to develop a methodology for the establishment of databases listing deterioration patterns of building and systems components based upon their actual condition monitored in-situ. The methodology aims at predicting the Life Cycle Expectancy of exterior claddings on the strength of an in-depth review of the faults, defects, and failures in exterior cladding components. A review of the causes of failure identified seven of the most frequent sources of premature deterioration in exterior cladding systems under study: (1) Faulty design; (2) Poor quality of implementation; (3) Poor quality of materials; (4)

Adverse climatic or atmospheric conditions (air pollution or intensive UV); (5) Adverse atmospheric conditions caused by air pollution; (6) Poor maintenance; (7) Intensive use. (Shohet et al., 1999)

The approach that investigated the impact of ISO 9000 as a solution for the building defects and it was for Low, it shows how ISO 9000 certification for contractors can affect the amount of defects occurring in their building projects. Building defects arise from the failings in the systems that control human activities. To prevent it and thus reduce its occurrence, effective measures must be in place to tackle each of its possible causes. The study seeks to show that for each cause of defect, there exists a reduction strategy that can be translated into a practical and effective program (as observed from the case study) which can then be accordingly subsumed into the requirements of the ISO 9000 standards. (Low, 2001)

This research made by Al-Hammad et al. is concerned with the increase in the cost of maintenance which according to the authors can be attributed to faulty designs. Many problems arise where design is satisfactory in principle but has a low probability of achievement in practice. These are not to be regarded as defects in workmanship but rather as too high an expectation in design. (Al-Hammad et al.,2009)

That it addition to another proposal made by the Governor of Sacramento, USA which confirmed that the budget needed for traditional maintenance of office buildings is high ;as the Governor’s budget proposes to create a new State Office Infrastructure Fund (SOIF) to support the construction and renovation of state office buildings in the Sacramento area. The Governor’s budget further proposes to deposit \$1.5 billion from the General Fund on a one-time basis into the SOIF in 2016-17 (Sacramento, The Governor’s State Office Building Proposal, the 2016-17 Budget)

4.2. Approaches to Sustainable Building Maintenance

The following studies discuss the various approaches to sustainable building maintenance where we find in the approach made by Chiang et al. which provides a computational framework to find the optimal solution for sustainable building maintenance through two main objectives are; First, the authors evaluate the life-cycle carbon emission, cost, and labor requirements of a project, which embody important environmental, economic, and social aspects of sustainable building maintenance. Second, the authors develop an optimization model to identify the optimal portfolio of materials that would minimize three sustainability objectives including carbon emission, cost, and labor deployment in their respective turns one at a time. (Chiang et al., 2014)

Also another approach made by Chiang et al. with Hong Kong as the case study, illustrates how existing residential buildings can be repaired and maintained using alternative materials, in order to minimize life-cycle labor inputs, costs, or carbon emissions. With different combinations of repair and maintenance materials, two of the three objectives can be achieved at any one time, when labor inputs, costs, and carbon emissions are set as separate constraints. (Chiang et al.,2014,pp.109-117)

In this paper, the authors focused on the maintenance sector in the demonstration of the methodology for simplicity. Maintenance works on existing residential buildings presents opportunities for reducing carbon footprints while gaining economic and social benefits. According to the results, it is identified that the most cost-effective materials that emit minimum carbon, and require the right levels of labor resources in relation to residential building maintenance. These materials also support the adoption of existing green technologies that suit the socio-economic and physical environment of Hong Kong. (Chiang et al.,2014,pp.109-117)

Another approach by Horner et al. aims to select a suitable maintenance strategy for each individual item in a building where they mentioned a current research project at the University of Dundee which is paying particular attention to the development of a new maintenance management approach aimed at reducing the maintenance costs of existing building stock. The goal of the new approach is to carry out as little maintenance as possible as infrequently as possible while at the same time preserving the availability of the services facilities, the building elements and the whole building. (Horner et al., 1997)

Approach and Author	Provides	Methodology	Conclusion
Approach 1 by Chiang et al. (2014)	Computational framework	Evaluating the life-cycle carbon emission, cost and labor requirements of a project= environmental, economic and social aspects	Optimizations model to identify optimal portfolio of materials that minimize 3 sustainability obj.
Approach 2 by Chiang et al. (2014)	Adoption of existing green technologies	Different combinations of repair and maintenance using alternative materials	Minimize life-cycle labor inputs, costs or carbon emissions.

4.3. Relation between Maintenance and Sustainability

In their research, Khamidi et al. had an objective to provide an overview of sustainability issues and building maintenance through literature and theory reviews and a second objective to analyze building defects in the Malaysian university campuses and for those objectives, a questionnaire survey and questionnaires were administered on 50 university maintenance organizations where it was concluded that lift failure, faulty electrical systems and roof damages were the defects that respondents considered extremely urgent to maintain and accordingly resources should be directed to those more urgent ones while the less urgent ones could be included in planned maintenance .(Khamidi et al.,2010)

While another researcher Othuman Mydin aimed to review and discuss some of the major elements and types of building maintenance towards achieving sustainable buildings and through the study it was found that types of maintenance to be; corrective, preventive and condition-based and through the research many factors were mentioned that influence the decision to perform maintenance on a building but the major intention of maintenance is to protect a building in its preliminary stage and to retain the value of investments in the property. (Othuman Mydin, 2014)

As for Saniuk et al. where the research dealt with presenting the role of maintenance in the realization of sustainable developing practices in a foundry industry where they proved that there are actions to be taken to strive for more efficient resources management and energy efficiency.(Saniuk et al.,2015)

Another attempt made by Azizi et al. who aimed from their study to identify energy management strategies that could be implemented in the Malaysian Green Building Index tool to improve energy efficiency performance. Accordingly, results were obtained from case studies that show that in practice, certified green buildings achieved a better energy management score, compared to a noncertified green building and a conventional building. (Azizi et al.,2013)

Jones and Cooper on the other hand addressed the sustainability agenda and in their research they presented the extent to which routine maintenance (both planned and responsive) can be used as a vehicle to improve the quality of social housing. The paper concludes that, whilst sustainability is generally perceived of strategic importance to their organizations there is little evidence that it is influencing operational maintenance decisions. To address this issue the paper argues that a change in the theoretical basis against which maintenance decisions are made is required. The paper outlines a new maintenance model that places sustainability issues clearly in the maintenance decision making process (Jones and Cooper, 2007)

4.4. Sustainability-related trends of Maintenance Management

There was a need in this section of the study to track the current maintenance management trends especially in the last ten years 2008-2018.

In their study, Mohammad et al. focused on the green maintenance management trend as one of the current trends and it was suggested in this study that there are problems related to this trend where the aim of the research is to determine the factors that lead to green buildings operations and maintenance problems in Malaysia .The criticality of the factors were then determined and the result indicates that design problems in technical defects aspect is the most critical factor that leads to green building operations and maintenance problems and this followed by construction related defects; building characteristics defects; and maintenance related defects. (Mohammad et al., 2014)

Another study made by Fawaz sought to understand how maintenance management is carried out in green buildings in Nairobi County, Kenya as a current trend.(Fawaz, 2013)

The major research findings revealed that green buildings in Nairobi were seen to be rated based on how well they met criteria set by the Leadership in Energy and Environmental Design Rating System.The study sought to have a holistic understanding of maintenance works in green buildings at the design stage, construction and the post construction stages. It was found that from the current maintenance management trends while the maintenance team might actually use corrective and conditioned based maintenance, it is preventive maintenance that is mostly adopted by green buildings in Nairobi. (Fawaz, 2013)

Other current Maintenance management trends were mentioned by Zulkarnain et al. in the study to be; planned and unplanned maintenance including preventive which is scheduled and condition based and corrective including emergency. (Zulkarnain et al., 2011)

Also in this study made by Zulkarnain et al., the researchers reviewed the critical success factor in building maintenance management practice for university sectors. For best maintenance management practice in the

University, the Critical Success Factors must be applied effectively to all activities as to ensure the standard of service provided to the public is excellent. (Zulkarnain et al., 2011)

Furthermore, the study made by Au-Yong et al. identified the significant characteristics of scheduled and condition-based maintenance in office buildings as well as the measures to enhance efficiency of the characteristics that influence the maintenance performance. The study concludes that these dominant characteristics should be considered in the implementation of maintenance strategies. (Au-Yong et al, 2014)

4.5. Building Maintenance Management

One of the studies made on Malaysian Universities by Abdul Lateef et al. to propose a schematic value maintenance management model for university maintenance organization. It could be interpreted that the older universities have over the years developed their maintenance organization. In other words, based on their experience, in-house maintenance is their preferred choice. The results revealed that the most common maintenance is condition-based. Maintenance should be positively planned, strategically organized, proactively led, holistically controlled and dynamically implemented if best value is critical. A 5×5 graphical model of value maintenance management was proposed. The model is the entire series of organizational processes that add 'value' at each stop, beginning with the process of resources to the finished services. (Abdul Lateef et al, 2011)

The same team of researchers Abdul Lateef et al. found in another study that maintenance management is not usually regarded as part of the top management functions or duties in most university organizations rather it often regarded as an operational function. The outcome of this research is to devise a prototype maintenance management model that can facilitate university institutions to carry out buildings maintenance management services that meet the expectations, needs and perceptions of the stakeholders with optimum use of resources. It involves the efficient and effective utilization of an organization's resources by planning, directing, and implementation, controlling and organizing in order to meet the maintenance needs of the building users since the ultimate essence of the building is to enable the users to perform their task effectively and efficiently. (Abdul Lateef et al., 2010)

A third study done on higher institutions in Nigeria by Olowoake proved that effective and efficient maintenance management of Higher Education Institutions (HEIs) built environments in Nigeria to an appropriate and acceptable standard requires the adoption and use of appropriate procurement strategies (that is, outsource or insource or combine the two strategies);-maintenance method (curative or condition survey or preventive or combine them). This study has content analysis of twelve Higher Education Institutions works and services showing that many of the HEIs do not have full complement of technical staff; most of the projects either small and simple or large and complex are outsourced in maintenance and , the most ideal maintenance method is planned preventive maintenance method, which helps in preventing failures, saves cost, and prolong the service years of the assets and many of the HEIs works and services prepare maintenance budget based on the previous year's budget plus a percentage increase. (Olowoake, 2017)

The study done by Myeda et al. has given an overview of the scenario of maintenance management of high-rise office buildings in Malaysia, particularly on the development of maintenance management systems and also performance measurement systems. The findings suggest that in general the common maintenance management systems applied for office building comprises of three major aspects namely functional, technical and image. This paper concludes that maintenance management guidelines should be established in Malaysia to standardize the practices of office building maintenance managers. In relation to this, a statutory act on the compliance of maintenance management system criteria and regulations should be established to improve the maintenance management performance and also to avoid any mismanagement that could result in corruption and/or abuse of power. (Myeda et al., 2011)

This brings us to the study done by Marinie et al. aims to present the personnel characteristics in the current practice of building maintenance management in Malaysia. Building maintenance management is a highly complex sphere of operations, involving the interaction between the technical, social, legal and fiscal determinants that govern the use of buildings. An excellent practice of maintenance management is greatly needed to increase the life cycle of the property and to minimize unexpected breakdowns or deterioration effects. In this respect, the maintenance personnel will have to rely as much on knowledge of the managerial and social sciences as on the traditional technique knowledge base of building construction and deterioration. (Marinie et al., 2009)

4.6. Maintenance Management of Sustainable Buildings

The study done concerned with housing maintenance by Abdullateef et al. aims to create awareness on the roles of housing maintenance towards sustainability by evaluating the sustainability credentials of current maintenance practices and to contextualize the Maslow's Hierarchy of need to motivate homeowners' towards sustainable maintenance practice. The results of the findings led to the conclusion that in order for the housing sector to be a

solution of sustainable development, the maintenance of the building required rethinking and sustainable building maintenance is driven by the market, ethics and legislation. (Abdullateef et al., 2015)

Another study done in the social housing by Jones and Cooper where routine maintenance (both planned and responsive) can be used as a vehicle to improve the quality of social housing in a way that addresses the sustainability agenda (environmental, social and economic impacts) is the main focus of this research so that the limitation of the current strategies could be identified; and a new theoretical basis for built asset management that integrates the sustainability principles into maintenance strategies (both responsive and planned) could be outlined. The paper outlines a new maintenance model that places sustainability issues clearly in the maintenance decision making process. (Jones and Cooper, 2007)

Whereas there is the study done concerned with the maintenance of higher education institutions by Adelaja Olowoake, and Wu who seek to assess and evaluate the works and service departments in higher education institutions in Nigeria by examining the effectiveness of maintenance works being carried out in connection with identifying the maintenance programme, maintenance schedules and jobs specifications (as maintenance control toolkit) have impacted the HEIs, and Proposing a framework to support key decision makers in Nigeria. The objectives of the study are to establish current theoretical approaches to assets maintenance management, to assess and evaluate works and services departments constraints in relation to procurement strategies, maintenance methods, budgets, effective maintenance management, and the influence of culture, to develop a theoretical asset maintenance strategic framework for HEIs in Nigeria and to validate the framework (through interviews and by attending workshops). (Olowoake, and Wu, 2015)

Two years later Olowoake made a study that reveals that, lack of use of the appropriate procurement strategy; maintenance method and budget; over reliance on letters of complaints from the assets users; absence of a quality control unit within works and services department; and lack of sustainable programme for the entire built environment have effects on the effective and efficient maintenance of the built environment of HEIs in Nigeria. Researcher agreed that, outsourcing should be used for large and complex maintenance projects, and insourcing could be used for simple and small projects. It is preferred the use of planned preventive maintenance method in order to reduce maintenance costs, prevent assets failures, prolong assets durability, and increase assets productivity levels. (Olowoake, 2017)

The other study made by Ridzuan and Ibrahim with the purpose to look at the implementation of the building maintenance policy in building maintenance management of high rise commercial buildings in Malaysia. This research aims to improve the value of buildings depends on the quality, safety and service of the maintenance practice in high rise office buildings through a proactive MM system that is based on the concept of building policy standard. This research establishes the need to develop a standard of building maintenance policy in high rise commercial building to be enforced legally in order to ensure the consistency of quality, safety and service to end users as well as publics all the time. (Ridzuan and Ibrahim, 2011)

4.7. Special Studies and Types of Building Maintenance

This section will highlight important studies concerned with special studies and types of building maintenance. The following study by AbdulLateef et al. explores the behaviours of homeowners and details household perceptions on how housing maintenance can contribute to the sustainability objectives. According to the study a conceptual maintenance behavioral model was presented to encourage sustainable maintenance practice among homeowners. With the model it was demonstrated that technical sustainability depends on non-technical sustainability to succeed. An important consideration in any sustainable maintenance is to initially clear the behavioural aspect without which the adoption and use of the technical sustainability is only possible if the users' behaviour is influence. The government needs to increase households' awareness of sustainability and the usage of reused / recycled materials for maintenance. For this to happen, the government directly or indirectly needs to create the market for these products. (AbdulLateef et al, 2016)

The next study is concerned with maintenance culture made by Sani et al. where the researchers explored, analyzed and presented some major factors affecting maintenance culture based on previous research to prove that changes the work culture towards a culture of maintenance requires a full commitment from all parties, especially the staff and management who are directly involved in the implementation of maintenance activities. If everyone understands the importance of maintenance the maintenance work can be improved and cost of will minimized. Based on the findings, it can be concluded that nine the determinant factors influence maintenance culture; leadership; communication; motivation, reward systems and recognition; empowerment; involvement; Policy System; Teamwork; Training and Education. In the study each factor has been discussed in context maintenance culture. (Sani et al. , 2012)

While the study made by Yahya and Ibrahim aims to evaluate the health and safety performance of high rise office buildings, using a basic assessment method. An assessment method based on a hierarchy of building performance indicators concerning the quality of design factor and management factor with five attributes such as architectural design, building services design, the surrounding environment, operation and maintenance, and facilities management. Most of the variations in building health and safety conditions were attributed to differences in building management systems rather than building designs. Improvement of facilities management system particularly in operation and maintenance processes (e.g. planned and unplanned maintenance as well as building policy requirement) is necessary in order to sustain health and safety aspects in the building.(Yahya and Ibrahim, 2016)

Arditi and Nawakorawit focused on the extent to which maintenance issues are considered when designers specify the buildings' design, building materials and service equipment ; level of designers' knowledge in maintenance-related issues; the degree to which design personnel is exposed to training in maintenance-related matters; the extent to which designers consult property managers and maintenance consultants; the relative importance of maintenance issues to other design factors; the level of difficulty in cleaning, inspecting, repairing, and replacing various building components; and the magnitude and frequency of maintenance-related complaints that designers receive from clients and tenants. The performance of buildings is likely to be enhanced if designers are cognizant of maintenance-related matters.(Arditi and Nawakorawit, 1999)

Whereas Au-Yong et al. made findings in their study that reveal that the maintenance characteristics which influence occupants' satisfaction level towards the HVAC system are eight significant characteristics include the skill and knowledge of the manager, the skill and knowledge of the labourer, the quality of spare parts and materials, as well as the response level towards failure and downtime. The study concludes that an effective communication platform which involves all key participants in the maintenance activities should be developed by the management to improve the maintenance outcomes.(Au-Yong et al, 2014)

Sodangi et al. directed their study at identifying and ranking the criteria that support sustainable best practice criteria for sustainable maintenance management of heritage buildings in Malaysia based on the perceptions of the in-house experts, Academics and Consultants. It was found out that “maintenance staff training & expertise”; was the most important criteria that support sustainable best practice in the maintenance management of heritage buildings in Malaysia as agreed by the respondents.(Sodangi et al., 2013)

4.8. Frameworks for Maintenance and Sustainability Processes

The following part is concerned with related subjects where proposed frameworks for maintenance and sustainability.

In the study made by Thaheem and De Marco where a functional project risk management framework, to manage Repair and Maintenance risk and deal with the risks in a sustainable manner, is proposed. The framework is further tweaked keeping in account the conditions and challenges of developing countries where priorities can be drastically diverse and focus can be short sighted, where the expertise is mostly reserved for more complex and financially-stringent activities and where the ascertaining precision seems quite challenging. The authors discussed risk identification to precise analysis, and appropriate response planning to thorough monitoring and control, a tailored and specialized project risk management (PRM) framework-a combination of specific tools and techniques-will greatly help by considering how risky these undertakings are, dealing with apparent threats and converting them into real opportunities, beyond that, it does not offer the preventive or mitigating measures for handling such events owing to the fact that at such situation, every risk needs specific technical treatment, which is beyond the scope of this study. (Thaheem and De Marco, 2014)

The outcome of the research made by Abdul Lateef et al. is a framework created that can facilitate university institutions to carry out buildings maintenance management services that meet the expectations, needs and perceptions of the stakeholders with optimum use of resources. Maintenance management is not usually regarded as part of the top management functions or duties in most university organizations rather it often regarded as an operational function. It involves the efficient and effective utilization of an organization's resources by planning, directing, and implementation, controlling and organizing in order to meet the maintenance needs of the building.(Abdul Lateef et al, 2010)

Defining a process for maintenance management is the role chosen by Márquez, et al. in their study .The researchers present a generic model proposed for maintenance management which integrates other models found in the literature for built and in-use assets, and consists of eight sequential management building blocks. The different maintenance engineering techniques are playing a crucial role within each one of those eight management building blocks. Following this path we characterize the “maintenance management framework”.(Márquez, et al., 2009)

Whereas Marinie et al. examine the process of building maintenance and management in Malaysia with the aim of identifying factors causing poor maintenance in various types of buildings, and delivering a new improved process including setting up organizations, policies and quality standards. The framework of the process was then developed based on the outcome of the surveys made. The process covers all major aspects such as management, staffing, training and regulation that are useful in managing maintenance sections. (Marinie et al., 2010)

5. Conclusions

In this paper the objective is tracking the latest trends in research in the last ten years and exploring the relationship between sustainability and maintenance through six discussed topics; importance of maintenance, approaches to sustainable building maintenance, relation between maintenance and sustainability, sustainability-related trends of maintenance management, building maintenance management and frameworks. Nearly half of the researches focused on building maintenance management whereas a small percentage of the studies focused on approaches to sustainable building maintenance which means there is a lack in the study of different approaches.

As it appeared in the timeline of the developing of efficient maintenance management of sustainable office buildings the topic approaches to sustainable building maintenance was tackled the earliest in 1997 but at the same time it was the least tackled ; this means that studies concerned with approaches to sustainable building maintenance are vague and not clear. There is an early start to tackling Building maintenance management in 1999 but it was the most tackled subject with nearly half of the studies covering it. Whereas the topic frameworks was covered most recently in 2009 but with a small percentage of studies.

In the six discussed topics, there were five gaps found ; elements of sustainable agenda to be taken into consideration for new buildings, other current and futuristic maintenance management trends, analysis of international examples for using sustainable factors in maintenance management, frameworks, the impact of maintenance on sustainable buildings.

In each of the six discussed topics, the percentages of the gaps differ from one topic to the other. In the first topic: importance of maintenance, all gaps were missing in all studies except frameworks were the focus of half of the studies. That means that some frameworks were explained in the studies that covered importance of maintenance. In the second topic: approaches to sustainable building maintenance, maintenance management trends were not covered at all in the studies , whereas two thirds of the studies did not cover frameworks and one third did not cover the three other gaps. That means trends that inspire the approaches are missing completely from the studies. In the third topic: relation of maintenance and sustainability, analysis of international examples was not covered at all. That means that the applications of relation between maintenance and sustainability is missing and not found. The gap of the impact of maintenance on sustainable buildings is least missing, that means it is of focus by 80% of the studies so it could be easily mentioned. In the fourth topic: sustainability-related trends of maintenance management, other current and futuristic maintenance management trends and analysis of international examples are not found at all in the studies covering this topic whereas 75 % offer this topic in the form of frameworks. In the fifth topic: building maintenance management, three gaps were missing completely ; sustainable agenda for new building, maintenance management trends, analysis of international examples whereas nearly 68 % of studies discussing building maintenance management lack the other two gaps . That means the gaps were not covered for this topic. In the sixth topic: frameworks of maintenance and sustainability , three gaps were missing completely ; sustainable agenda for new building, maintenance management trends, analysis of international examples whereas all the studies offered frameworks as it is the focus of this topic but it is not a gap so the studies will be useful meanwhile 75 % of the studies focus on the impact of maintenance on sustainable buildings.

Table (3): The table shows the key gaps in each topic.

Topic	Key Gaps
1 Importance of Maintenance	Sustainable agenda for new buildings, maintenance management trends, analysis of international examples, the impact of maintenance on sustainable buildings
2 Approaches to Sustainable Building Maintenance	Maintenance management trends
3 Relation of Maintenance and Sustainability	Sustainable agenda for new buildings ,analysis of international examples
4Sustainability-related trends of Maintenance Management	Maintenance management trends, analysis of international examples
5 Building Maintenance Management	Sustainable agenda for new buildings, maintenance

	management trends, analysis of international examples
6 Frameworks of Maintenance and Sustainability	Sustainable agenda for new buildings, maintenance management trends, analysis of international examples

As shown in the table (3) above that the most missing is sustainable agenda for new buildings , maintenance management trends and analysis of international examples whereas the impact of maintenance on sustainable buildings and frameworks of maintenance and sustainability are discussed more.

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Biography

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