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# The Adoption of Total Productive Maintenance (TPM) Concept for Maintenance Procurement of Green Buildings in Malaysia

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**Abstract:** Green building practices play an important role in achieving sustainability, especially in the construction industry. Green buildings are built to minimise the impact on the environment while reducing the impact of the building on the occupants. Unfortunately, the focus is on building green rather than its maintenance. Correspondingly, Total Productive Maintenance (TPM) is a tool that has been promoted for its simplicity and the advantages of maintaining a delivery system. It assures the maintenance effectiveness of each industry, such as improving project quality, reducing waste, reducing production costs, increasing hardware accessibility and enhancing organisational support conditions. Meanwhile, procurement is considered to be the key to strengthen the maintenance operation of the construction industry. This study adopts the TPM concept for the maintenance of green buildings in Malaysia and aims to present the TPM concept for the maintenance of green buildings, and to establish the best procurement to adopt TPM for the maintenance of green buildings in Malaysia. This study has employed a qualitative approach where face-to-face and telephone interviews have been adopted. Interviews have been conducted with seven prominent respondents who possess more than 5 years of experience in green building maintenance. Content and thematic analyses have been used to analyse the data that are collected from the interviews; findings show that most of the respondents agreed that TPM could be adopted in the maintenance of green buildings. It has also been identified that for a public project the most appropriate procurement method is the facilities management contract whereas for private project the most popular procurements for green building maintenance are the lump sum contract, out-tasking contract and term contract. The results of this study provide practitioners with a new insight into the impromptu creation of a total productive maintenance concept that could improve the current building maintenance sector.

**Keywords:** Total Productive Maintenance (TPM), maintenance procurement, green buildings

## 1. Introduction

In today's worldwide marketplace, there is an exceptionally focused, dynamic and rapid changing condition and rivalry among every sector (Jain, Bhatti, & Singh, 2014). Malaysia has also witnessed tremendous growth in many economic sectors, especially in the construction industry (Lateef, 2009). According to the Ninth Malaysian Plan by the Economic Planning Unit Malaysia (2006), building maintenance is becoming an important activity as the government is recognising the need for building maintenance and therefore requires significant resources. Thus, the buildings need maintenance to perform effectively and this might be the case throughout the next few years (Lateef, 2009).

In response to upkeep and bolster issues that are encountered in the manufacturing environment, the Total Productive Maintenance (TPM) is developed and introduced by the Japanese in 1971 (Chan, Lau, Chan, & Kong, 2005). TPM is an innovative Japanese concept for the maintenance of facilities and plants (Venkatesh, 2007a), which focuses on maximising equipment effectiveness in order to improve the overall efficiency. It initiates an integrated production and maintenance system covering the entire lifecycle of the facility, covering all relevant areas (i.e. performance, planning, maintenance, etc.) and maximising equipment efficiency (Mwanza & Mbohwa, 2015).

Accordingly, Malaysia has implemented TPM in the manufacturing industry about 16 years ago (Bakri et al., 2014), however, there is a lack of research on the adoption of the TPM concept in the Malaysian construction industry. This study suggests that TPM has great potential to be adopted for green buildings whereby the adoption of TPM concept for the maintenance of green buildings could improve the productivity of the works and plant efficiency, reduce waste during the maintenance periods, and reduce carbon emission (Peter, 2016; Bakri et al., 2014). Significantly, the implementation of TPM could make the system more structured and ensure that the works run smoothly, especially in the maintenance of green buildings.

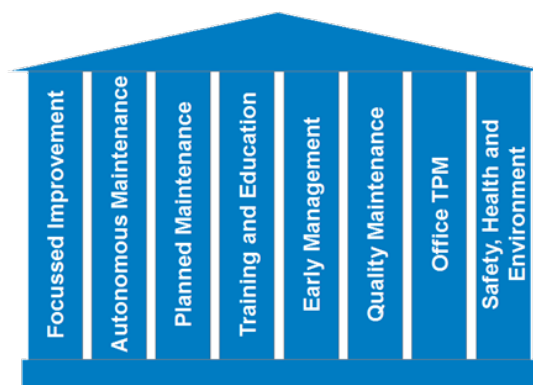
Research by Bakri et al. (2014) has shown that Malaysia has not yet adopted TPM in the construction industry, hence, there is no maintenance procurement for the TPM concept. Ghadamsi (2012) has said that the procurement method is an important process in the construction industry, which is to ensure project cost efficiency, contract management, and operational coordination. Therefore, the aim of this paper is two-fold: firstly, to present the TPM concept for the maintenance of green buildings in Malaysia; secondly, to establish the best procurement to adopt TPM for the maintenance of green buildings in Malaysia.

Even though there is no application of TPM in the construction industry, adopting TPM is a strategic decision in the maintenance of green building because it will improve the environmental sustainability (Peter, 2016; Bakri et al., 2014); however, the researchers have further added that the adoption of TPM is still weak. Therefore, by understanding the whole framework about the TPM concept for the maintenance of green buildings can actually help to solve the industry maintenance problem.

## 2. Literature Review

In 1951, TPM was the first preventive maintenance that was introduced in Japan. In 1971, Nippon Denso Co. Ltd. was initially introduced and had favourably implemented it in Japan. Their activities gained the TPM Excellence Factory Award from the Japan Institute of Plant Maintenance (JIPM). Hangad, Kumar and Siddiq (2013) have defined TPM as the best tool to make the maintenance industry competitive and efficient; JIPM defines TPM as Total (T), i.e. must involve all employees of the company; Productivity (P), i.e. making full use of all sources, and Maintenance (M) as keeping the Man-Machine-Material system in an ideal state (Forum, 2015). Adopted from the work by Hangad (2013), Mad-Lazim et al. (2008) and Hashim et al. (2012), their research have defined TPM in three definitions. First, total efficiency shows that TPM pursues economic benefits, such as cost, productiveness, standard, shipping, security, wellness, and circumstances. Second, the entire maintenance operation involves preventive maintenance, maintenance prevention, and maintainability improvements. Third, all participation of all workers includes self-maintenance by the operator through team exercises, e.g., ‘motivation management’.

JIPM has also established an eight-pillars approach for TPM (Figure 1 and Table 1) with a focus on achieving zero break-downs, zero accidents and zero defects (Hashim et al., 2012; Forum, 2015; Dogra et al., 2011).



**Fig. 1 - Eight Pillars of TPM**  
**Source: Japan Institute of Plant Maintenance (JIPM)**

**Table 1 - Eight Pillars of TPM**

Types of Pillars	Explanations
Focussed Improvement	<ul style="list-style-type: none"> <li>To provide a team-based structured approach to eliminate the losses that are clearly identified in any process.</li> <li>It consists of a series of structured steps which are “<i>Plan, Do, Check and Act (PDCA) cycle</i>” that implements on any size or complexity improvement activity in any organisation (Singh, Gohil, Shah, &amp; Desai, 2013).</li> </ul>
Autonomous Maintenance (AM)	<ul style="list-style-type: none"> <li>To train operators to handle small maintenance task which is to provide operators with skill maintenance so that they can recognise, supervise and ameliorate their processes and facilities (Forum, 2015).</li> <li>It can be divided into three phrases such as to establish and maintain basic as well as enhance knowledge and optimal conditions.</li> </ul>
Planned Maintenance (PM)	<ul style="list-style-type: none"> <li>To achieve zero breakdowns (Forum, 2015)</li> <li>Assessing current maintenance performance and cost (Venkatesh, 2007c; Wakjira &amp; Singh, 2012)</li> <li>To produce non-trouble machines and equipment, to produce non-defect products in order to meet the overall needs of customers</li> </ul>
Training and Education	<ul style="list-style-type: none"> <li>To ensure that employees receive the identified skills training that is critical to the successful deployment and personal progress of the TPM, consistent with the organisation's goals</li> <li>To educate the employees to learn the two ‘Know’, i.e. ‘Know-How’ and ‘Know-Why’: ‘Know-How’ is allowing the employees to solve the problem based on their experiences, while ‘Know-Why’ allows the employees to know the reason why they are doing this (Venkatesh, 2007b; Wakjira &amp; Singh, 2012)</li> </ul>
Early Management (EM)	<ul style="list-style-type: none"> <li>To achieve different results and plans while achieving vertical upgrades and shortening the improvement cycle (Kumar, 2017)</li> <li>It will decrease the duration that is needed to introduce goods and methods, increase the overall equipment efficiency and deliver quantities at the right time at the start of production</li> </ul>
Quality Maintenance (QM)	<ul style="list-style-type: none"> <li>To achieve the highest quality of customer contentment through zero manufacturing failures (Wakjira &amp; Singh, 2012).</li> <li>To systematically reduce zero compliance and focus on improvement.</li> <li>To analyse defects, to eliminate the quality problem and ensuring quality continuity.</li> </ul>
Office TPM	<ul style="list-style-type: none"> <li>It focuses on all divisions of the company and is responsible for execution and assistance (Forum, 2015).</li> <li>To increase productivity, improve the efficiency of managerial functions, recognise and eliminate losses.</li> </ul>
Safety, Health, and Environments	<ul style="list-style-type: none"> <li>It is creating a safe workplace and surrounding areas that are unaffected by organisational processes or processes basis (Wakjira &amp; Singh, 2012).</li> <li>To achieve health, no accidents, no damage and no fire, which mean to provide a safe working place for the employees (Forum, 2015; Kumar, 2017; Venkatesh, 2007b)</li> </ul>

TPM is the best application for maintenance, where it can change the operation in the company. Additionally, it furnishes the promoting office with some approaches to enhance the nature of their work. Hence, the implementation of TPM brings various benefits to every sector involving maintenance (Forum, 2015; Kumar, 2017; Venkatesh, 2007b). TPM will assist in improving the effectiveness of production management and eliminates significant losses in the industry, and also helps the industry to reduce production management costs and optimise resource utilisation (Venkatesh, 2007b). Besides that, TPM helps in improving production quality by limiting losses and recognising issues in production management (Kumar, 2017). The staffs and workforces will self-maintain their machine while implementing TPM in the sector (Venkatesh, 2007b). Hence, this brings employee ownership and enables them to be fully improved in the organisation. The working area is also improved by adopting TPM (Forum, 2015, Kumar, 2017), where the indirect advantages are improving workers’ confidence, workers' ownership of the machine, having a clean, tidy and attractive work area, while the operator's attitude is beneficial to the company (e.g. sharing knowledge and experience among the employees). All the workers cooperate to accomplish the organisation’s goal and in creating new ideas in all areas of the organisation (Swanson, 2001).

Numerous organisations are prepared to transform their perspective and become accustomed to the current methods and cultural shifts that are required to successfully implement TPM. The organisation has been unsuccessful in adapting

the TPM into practice again and again because they do not understand the seriousness of the circumstance and the implementation provisions. Thus, there are various disadvantages of TPM. Firstly, top management does not give a commitment (Poduval, Pramod, & Jagathy Raj, 2015); the program is effective only if the top management is fully involved in the TPM program. Secondly, the organisation's resistant (Poduval et al., 2015): organisations need to have courage in adapting and changing the dynamic environment in the complex ideologies. Notably, most organisations believe that changing their route is dangerous, so adopting TPM is challenging. Companies must change to stay ahead of their competitors. The reason for the failure of TPM implementation in many organisations is that employees cannot understand the TPM correctly. As a result, the employees do not have enough motivation to implement the TPM. Employees must understand what TPM is, why organisations start using TPM drives, and the benefits of TPM implementation. Only then, will the workers be ready to adopt TPM in the future. Since several researchers have mentioned that TPM is the best application for maintenance purposes, therefore this paper is focusing on its application to green building maintenance.

## 2.1 Green Building

Green building has become a global key consideration, as an effective way to respond to environmental changes (Chang & Lu, 2017). Buildings can contain many green features, but if they don't use energy efficiently, it is very hard to prove that they are truly green. The Environmental Protection Agency (EPA) has defined green buildings as "In the life cycle of the entire structure, from site selection to planning, construction, implementation, preservation, refurbishment and deconstruction, organisational structure and the use of environmentally responsible and resource efficient processes". Green buildings can also be defined as buildings that are built and maintained to ensure the healthiest environment while maximising the use of natural resources and minimising disruption.

The implementation of green buildings requires the use of more green techniques for the expansion and use of equipment, goods, and systems that protect the natural environment and resources. The performance of the buildings (e.g. environment, people and economy) can be enhanced by this technology (Silverman & Mydin, 2014). Green buildings not only have a real impact on common health and the environment but also minimise management costs, improve the marketability of buildings and organisations, enhance the productivity of the occupants and help generate sustainable communities (Fowler & Rauch, 2006).

Malaysia is a developing country that has an inspirational goal to join the ranks of developed countries. Therefore, the Malaysian government has taken initiatives in several fields to motivate energy-saving practices across the country (Pandey, 2015). One of the energy-saving practices is to construct green buildings where the Malaysian construction industry has been committed to building more sustainable green buildings over the years (Hashim, 2012). Mayor Thomas has said that "Green buildings are good for the environment, good for human and good in saving" (Turcotte, Villareal, & Bermingham, 2006). There are various benefits of green buildings and they are normally based on three basic pillars, e.g. environmentally, socially and economically beneficial (Weetas, 2018; Munshi, 2015; UK Essay, 2013; Abdel Shakour, 2011; Turcotte et al., 2006).

Environmental benefits include reducing emission, protecting natural resources, reducing waste, improving air and water quality. Green buildings have a huge advantage of reducing energy consumption and operating energy consumption. They are very effective due to the use of super-insulated, high-performance windows and passive solar designs window in operating energy. Consumption of water is another goal of green buildings. Water can be saved by recycling rainwater and collecting the greywater, and using it to flush toilets or for gardening (Munshi, 2015); consequently the risk of flooding will become lower by having proper rainwater management (UK Essay, 2013). Reducing the materials is also another consideration of green buildings which can be constructed by renewable, recyclable, reusable and non-toxic materials such as straw, recycled metal, concrete, wool, compressed clods, wood and bamboo (Weetas, 2018; Munshi, 2015). Through the use of these materials the amount of waste that needs to be disposed of in landfills will be reduced (UK Essay, 2013). As such, green design and improved workers' productivity that are related to the use of green materials can improve health benefits. The working environment or living space will affect the occupants' health in the green building, where people who work or live in a comfortable area will increase their effectiveness.

Although green buildings have various advantages, there are still some shortcomings such as cost, the time that is taken and the availability of materials. Cost is known as the most common disadvantage of green building. The improved quality of the construction methods and materials that are used will increase additional funding as the construction of green buildings needs special materials. Moreover, many environmentally friendly materials are not easy to find. Thus because of the difficulty in finding these materials, the costs of materials can be much higher than the normal price. The time that is required to complete a green building is also seen as a disadvantage (Hermans, 2014). Green building projects encourage the use of recycled materials and in the attempt to purchase them increases the completion time in the construction phase (Zainol et al., 2015).

On the other hand, green buildings can reduce the negative impacts of traditional buildings on the environment and the economy through the use of green materials and technologies. Therefore, the government should promote the construction of green buildings and overcome all the shortcomings because green buildings will bring many benefits in protecting the environment and enhance the quality of the people's lifestyle.

Mohd Faris Khamidi (2010) has defined maintenance of a green building as a maintenance process that satisfies the current user's value system without affecting the ability to meet future generations profits. It can also be defined as a building that is sustained by sustainable progress. There are three ways to achieve sustainable progress such as integrated life cycle approach, decrease energy consumption, and to enhance the quality of products and facilities (Hermans, 2014). From an environmental point of view, the earnestness of expanding the life of building components depends on the environmental impact of their life cycle. A Life Cycle Analysis will show the environmental impact data and the environmental impact of a product or activity at the different stages of its life cycle (Hermans, 2014). Energy savings do not meet the definition of maintenance because they mean improving energy performance rather than maintaining 'old' performance (Lateef, 2009). But efficiency and effectiveness maintenance should be considered, i.e. to lower the energy consumption. It is also important to reduce the amount of activity. The design maintenance needs can be predictable in advance and facilitate design revisions (Hermans, 2014). Improving the quality of maintenance can be achieved by repairing building components rather than replacing them. Timely attention to repair possibilities will extend the life of the components. In this regard, consideration should also be given to the accessibility of components of maintenance activities.

In general, the maintenance of green buildings is very important today. It can decrease maintenance costs for machinery, is time saving in administrative contracts, and ensures the final-user maintenance procedures. The target of administration performance has decreased the rates, decrease harmful effects on the environment and reach sustainability in the construction industry (Aghili, Hakim, Mohammed, & Sheau-ting, 2016). Therefore, focus must be made to the procurement methods in ensuring the above savings can be made to the green buildings maintenance.

## 2.2 Procurement Methods

Ali and Shirley (2014) and Rwelamila and Edries (2007) have stated that procurement method has turned into a trendy and basic expression in the construction industry. Procurement methods act as a significant part in determining and defining the form of contractual methods and the relationship within the people in the project (Ghadamsi, 2016). Park et al. (2009) have described procurement methods as "relation and duties of project crew and the flow of project that is needed to develop capital projects". Rameezdeen and Ratnasabapathy (2006) have stated that it is the main tool for customers to create pre-requisites to achieve project-specific goals. Research that has been done by Masterman (1992), has defined contract procurement as an organisational structure in which a collection of characters is systematically organised and organised in terms of their obligation, liabilities, characters and their interrelationships. Ibbs and Chih (2011) have said that the success and efficiency of the project will be influenced by the chosen procurement method, therefore, the appropriate procurement method will achieve the best project performance (Chua, Ali, & Alias, 2014).

All types of construction procurement methods will affect project performance (Ghadamsi, 2012). The procurement method is an organisational system that allocates specific liabilities and authorities to people and organisations and defines the several parts of project construction" (Love, Skitmore & Earl, 2010). Procurement suggests appropriate contract strategies, bidding documents, selection of experts and contractors, contract organisations, and the avoidance of unnecessary discussions (Patil Chandrashekhar, 2017). Meanwhile, the procurement systems can be categorised into various types such as Traditional methods, Design and Build (D&B), Management Contracting (MC) and Construction Management (CM), as shown in Table 2 (Davis, Love, & Baccarini, 2008; Patil, 2017; Ghadamsi, 2016).

The advantage of traditional procurement is the certainty of procurement. The consultant is nominated by the client to prepare the project details and tender documents such as a bills of quantities, work schedules and drawings. Therefore, the contractor will have a clear understanding of the project and the contract amount. The advantage of design and build is a single point of obligation throughout the project (UK Essay, 2018). Clients only deal with one party so that the completed work can be done easily. The client can also work with contractors and their design teams or supply chains early in the design process to try to implement more functional or workable solutions when necessary (Designing Buildings Ltd., 2018c). The advantage of management contracts is to provide management skills. The contractor-designated design team can use their experience to improve the proposed development costs and buildability, as well as provide advice on packaging and interface risks (Designing Buildings Ltd., 2018c). The advantage of the construction management contract is the transformation of the planning, design, and construction processes into processes of creating value and maximising control.

Time management is considered to be one of the shortcomings of the traditional procurement methods (Trett, 2015; Bordoli, 2014; Kerzner, 2003), whereas the disadvantage of design and build is that the client loses control of the design (Greg Richards, 2006). Experience has shown that contractors will compromise on the design due to project costs, as this can be a client issue. The disadvantage of the management contract is that not all the clients can use this contract, although they can control the design and work before the project is implemented; it is only suitable for those who are experienced customers. Also, the disadvantage of the construction management contract is that a large portion of the total service that the building manager receives is not subject to bidding.

In short, those procurement methods have different advantages and disadvantages. Clients are required to choose carefully the appropriate procurement for their project. Table 2 shows several procurement methods that are used in

building maintenance, namely, Direct Labour or Inhouse, Outsourcing, Out-tasking, Lump Sum Contract, Public-Private Partnership (PPP), Partnering, and Total Facilities Management (TFM) (Wordsworth, 2001; Hui & Tsang, 2004; Ancarani & Capaldo, 2005; Atkin, B., & Brooks, 2005; RICS, 2009; Sheng, 2012).

**Table 2 - Types of procurement in maintenance work**

Types of Procurement in Description Maintenance Work	
Direct labour/ In-House	<ul style="list-style-type: none"> <li>- A way to directly execute construction projects for government clients using professionals and businessmen who are permanently or temporarily employed by the clients (Usman &amp; Sani, 2015).</li> <li>- An arrangement in which a customer or a building owner organises the various operations that are involved in the building and uses his materials and manpower to redesign an effective project.</li> <li>- It carries out work or project by the simple internal facilities such as unskilled labour, technicians, professionals, merchants and available equipment.</li> </ul>
Outsourcing	<ul style="list-style-type: none"> <li>- Outsourcing can be divided into several contracts such as Measured Term Contract (MTC), Specialist Term Contract, Tender Schedule Term Contract, and Repair and Maintenance Contract (RMC) (Chua et al., 2014; Sheng, 2012; Hui &amp; Tsang, 2004).</li> <li>- Measured Term Contract (MTC)                             <ul style="list-style-type: none"> <li>• A contract for providing construction works to single contractors within a certain period of time (3 years).</li> <li>• The client has his own construction team and is ready to tender.</li> <li>• The client entrusts the contractor to perform personal work, which may include written instructions, drawings, and assessments of the project agreed with the customer and the contractor.</li> </ul> </li> <li>- Specialist Term Contract                             <ul style="list-style-type: none"> <li>• Similar to Measured term contract</li> <li>• But it is defined as “specific tasks on a linear base, such as asbestos elimination, elevator preservation or a particular industry such as roofing, tarpaulin and refurbishment” (RICS, 2009).</li> </ul> </li> <li>- Tendered Schedule Term Contract                             <ul style="list-style-type: none"> <li>• As a lump sum contract, which is to ensure competitive prices and reduce the selection period of the entire contractor. Work is done in a traditional way, measuring, evaluating and certifying payments.</li> <li>• As a short-term contract where the design and tender phases will be reduced by an approximate quantity guide.</li> </ul> </li> <li>- Repair and Maintenance Contract (RMC)                             <ul style="list-style-type: none"> <li>• A contractual form of the JCT standard covering such work, the repair and maintenance contract.</li> <li>• Applies to the repair and maintenance of the building but not for regular maintenance or repairs of factories and residential resident.</li> <li>• It allows the client to estimate the prices based on fixed prices, date work or other rates, and allows flexible pricing and payment structures (Designing Buildings Ltd., 2018)</li> </ul> </li> </ul>
Out-Tasking	<ul style="list-style-type: none"> <li>- A management process for the contractor to perform a specific task, rather than the full set of support functions in the case of outsourcing (Encon Y.Y. Hui, 2004).</li> <li>- Often used in the area of facility management, and the number of outsourcing will usually exceed.</li> <li>- Outsourcing tasks keep the maintenance organisation lean; cost is an important factor in determining who will get a service contract or a retrofit project. The contractor should be respected.</li> <li>- There are 4 stages of implementation of out-tasking such as planning, service agreement, work transaction, and performance review.</li> </ul>
Public Private Partnership (PPP)	<ul style="list-style-type: none"> <li>- Widely used in large public projects through joint ventures between the government and the private sector.</li> <li>- An agreement between the public and private sectors to share resources, risks,</li> </ul>

		and rewards among partners.
		- PPP begins with joint risk acceptance, estimates the cost and expects a return as well as designing to achieve all construction goals through the collaboration between the two parties (Loosemore M, 2008).
Total Facilities Management (TFM)		- Development of management contractor prospects, FM suppliers will provide all or at least most of the FM services to customer organisations through strategic partnerships, joint ventures, subsidiaries or internal resources. - Provide a complete FM solution or " <i>one-stop service</i> ", managing multiple facility services is a time-consuming, complex, and costly commitment, especially for organisations with multiple attributes in different locations.
Partnering		- A concept that provides a framework for building common goals between teams, trying to reach a consistent dispute resolution process and encouraging the principles of continuous improvement. - The framework integrates trust, collaboration, and teamwork into a fragmented process that enables industry participants to work together and focus on project goals.

### 2.3 Factors that Affect the Success of Selecting the Maintenance Procurement

Chan et al. (2001) have stated that the poor performance of construction projects is due to improper use of procurement. Commonly, there are several factors that affect the selection of procurement methods such as time, quality, price certainty, risk, and others (Love et al., 1998). Basically, the time is determined from the initial phase to the maintenance phase. Therefore, the duration of the project evaluation needs to be determined early in the planning phase. This means they need a procurement method that is fully planned at the beginning of the construction period to achieve the required completion time. Another factor that influences the choice to maintain procurement success is the quality level. It is worth noting that the procurement arrangements that are used do not consider the quality level to be severely affected, but depend on the contractor's experience with the procurement method and the accuracy of the contract documents that are provided by the designer and consultant. Quality is a set of basic characteristics that meet the customer's requirements. Collier (1982) has said that "The quality of construction engineering is usually handled under contract conditions, especially in technical specifications." Price certainty is another factor that influences the success of choosing to maintain procurement. In the beginning, the total cost of the project must be confirmed. Price certainty will change throughout the project. By obtaining a fixed price before the project is established enables the surveyor to generate approximate estimates for the client so that the project cost is within the financial budget. Last but not least, risk avoidance is another factor that influences the success of choosing to maintain procurement. The project is complex to maintain, has a long production cycle and involves many participants and is therefore related to risks and uncertainties. Turner (1990) has pointed out that the client must understand the risks that are involved and consciously transfers the risk to another organisation, or the way risk is consciously passed to another organisation, or how to share the risk between him and another organisation in a certain proportion. Choosing a procurement method is a challenging task for the client due to various factors in managing the maintenance project. Different customers have various needs and specifications, and construction projects in various aspects vary greatly. There is no-one-size fits all approach in choosing a procurement method for maintenance project.

To sum up, green buildings construction brings many benefits in creating healthier environments and enhances the quality of people's lifestyle by maximising the use of natural resources and technologies which protect the environment and reduce energy consumption. However, maintenance issue should be given prior attention before decision is made to implement green buildings in any project. Maintenance is particularly important since construction of a green building usually needs special materials, e.g., green materials and cutting-edge technologies. This study suggests that the application of TPM could bring various benefits to every sector involving maintenance, including the construction sector. In achieving total efficiency of maintenance for a green building project, implementation of TPM necessitates a suitable procurement method. To recap what have been mentioned by Ibbs and Chih (2011) as well as Chua, Ali and Alias (2014), the success, efficiency and performance of a project is hugely influenced by the chosen procurement method. Hence, this study aims to present TPM as a concept for the maintenance of green buildings and establish the best procurement to adopt TPM for the maintenance of green buildings in Malaysia.

### 3. Research Methodology

This study adopted a qualitative method where semi-structured interviews are used to collect the data that are needed for this study. This method enables the study to include extensive new knowledge and information on the topic of developing TPM procurement framework for the maintenance of green buildings in Malaysia. The interview method has used the face-to-face interview and telephone interview; the face-to-face interview is the core method that is used in this research. Farooq (2015) has said that the principal communication tool is body language, which ensures the correct delivery and understanding of information. Thus, it can gain further information and details through more in-depth

questions that are raised by researchers. Hay (2010) has said that the respondents could tell us if there is a misplaced problem through this kind of interview. If it is difficult to agree on face-to-face interviews date, a telephone interview will be used. Barriball, Christian, While, and Bergen (1996) say that the usual method of qualitative research is telephone interviews. The phone is known as the basic electronic tool for interpersonal communication and forms a new understanding of spoken language (Hopper, 1992). Since this study is focusing on the procurement methods in maintaining the green buildings, therefore the respondents who are being selected are facility managers, project managers, and surveyors. The respondents must have at least 5 years of experience in building maintenance works. Since the population of the respondents with good knowledge or practicing maintenance works is very small, Latham (2007) in his research has suggested that the researchers can rely on previously determined team members to identify other people who might have the same characteristics as the existing teams through snowballs sampling. Meanwhile, the recommendations of the potential respondents of the respondents will facilitate the process of collecting data and in obtaining the required sample size. A study by Ness (2015) has shown that in qualitative research, the number of interviews that are required to manage data saturation is an amount that cannot be quantified, but interviews will be carried out as much as possible. The identification tags that are used for interviewees are J01 to J07. The duration of each interview is 45 minutes to 1 hour. Interviews were conducted through face-to-face interviews, except for J03 and J05, which were conducted by telephone interviews. Due to the difficulty of reaching an agreement on the date of the meeting. A total of 8 open-ended questions have been designed for the interview questions. There are 4 questions regarding the TPM concept in Malaysia and the other 4 questions regarding the maintenance procurement of green buildings in Malaysia. All data were analysed using the thematic and content analysis.

#### 4. Result and Discussion

In this study, two facility managers, two project managers, and three surveyors were interviewed. Three of them were from the public sector and another four of them from the private sector.

**Table 3 - Background of the interviewees**

Interviewee	Gender	Job Title	Working Experiences (Years)	Sector	Mode of Interview
J01	Male	Facility Manager	7	Public	Face-to-Face
J02	Male	Facility Manager	16	Public	Face-to-Face
J03	Male	Project Manager	21	Private	Telephone
J04	Male	Project Manager	30	Private	Face-to-Face
J05	Male	Surveyor	18	Private	Telephone
J06	Male	Surveyor	6	Public	Face-to-Face
J07	Male	Surveyor	17	Private	Face-to-Face

All of the respondents are very experienced in green building maintenance. All information from the interviews have been transcribed into text. The ideas and opinions that are shared by respondents are highlighted and discussed as follows:

#### 4.1 Total Productive Maintenance (TPM) Concept in Malaysia

Interviewees were asked questions about the Malaysian TPM concept. First, whether they have heard about the concept of TPM and to determine their understanding of the concept. Next, the opinion of the interviewees on the construction industry’s implementation and adoption of the TPM concept. Finally, whether the eight pillars of TPM can effectively carry out building maintenance.

##### 4.1.1 Total Productive Maintenance Concept

The purpose of this section is to analyse the respondents understanding on the Total Productive Maintenance Concept. Based on the data in Table 4, 43% of the respondents, which are J02, J05, and J07, understand the TPM concept clearly. J02 and J05 that represent 29% of the respondents have said TPM is not new in the manufacturing field, but not in the construction sector. Therefore, it will have some differences in different fields. Interviewee J07



representing 14% of the respondents has said that the TPM concept is mainly practice in the manufacturing field. Based on the result it can be concluded that the TPM concept is not very popular in the construction industry. Among the four respondents, they interpret it as a new concept that can improve or ensure the sustainability of the building. This result compliment with the research finding that has been done by Bakri et al. (2014), “Malaysia had not yet adopted Total Productive Maintenance (TPM) in the construction industry.”

**Table 4 - The understanding or explanation TPM concept**

<b>Interviewees</b>	<b>Do You Know About the Total Productive Maintenance (TPM) Concept? If Yes, Can You Please Further Explain?</b>
J01	No. Has no idea what it is. It may be related to maintenance.
J02	Yes. TPM is not new in the manufacturing field, but not in the construction sector. Therefore, it will have some differences in different fields.
J03	No. It probably is a new concept. It may involve sustainability or life cycle to ensure the sustainability of buildings.
J04	No. It probably is a new thing. It may involve sustainability or life cycle or green building design. Perhaps sourcing appropriate materials or resources to ensure the sustainability of green buildings
J05	Yes. TPM was not actually new in the building and construction industry. Philosophically, it aims for optimisation. Practically, however, this concept might entail different scenarios and perspective as it normally highly influenced by regional context, including Malaysia
J06	No. Has no idea what it is. It may be related to maintenance.
J07	Yes. TPM practice much in manufacturing fields.

#### 4.1.1.1 Implementation of Total Productive Maintenance (TPM) in Construction Industry

Table 5 shows a result on the respondent opinion on TPM implementation in the construction industry. All respondents have agreed that TPM could be implemented in the construction industry. Respondent J05 further elaborates that modification needs to be done especially in the area of legal, technical, safety, risk and etc. Respondent J07 is of the opinion that TPM pillars can be used as policies and be incorporated into building maintenance contracts and maintenance supervision. It is being spun off from manufacturing and can be used for local maintenance operations. The most important part is the overall strategy of the top policy, how to incorporate it into the organisation and how to adopt the TPM concept in the maintenance field. This result agrees with Peter (2016) and Bakri et al., (2014) where they have clearly stated that the adopting of TPM is a strategic decision in the maintenance of green building because it will improve the environmental sustainability.

**Table 5 - Opinion of the respondents on the construction industry implementation and adaptation of the TPM concept**

<b>Interviewees</b>	<b>Do You Think Total Productive Maintenance (TPM) Concept Can Be Implemented in the Construction Industry?</b>
J01	Possible, no doubt.
J02	This is theoretically feasible, but it actually requires modification of the construction industry. Therefore, if it is not very difficult, it is best to compare in the same field.
J03	Possible, no doubt.
J04	Possible, no doubt.
J05	Theoretically possible, yet practically need modifications with regards to the Malaysian construction industry. Many other factors to be considered prior to implementation: legal aspect, procedures, guidelines, technical, economic and social dimension (sustainable construction & development & planning), safety and risk aspects and etc. All of these will make the adoption is facing substantial issues and challenges, yet it is crucial.
J06	It is theoretically possible, but in practice, it may have problems.
J07	Yes, it is possible to integrate TPM's policies into building maintenance practices that have been completed or deployed in any building or asset that is currently practiced in Malaysia. These pillars can be used as policies and incorporated into building maintenance contracts and maintenance supervision. It is being spun off from manufacturing and can be used for local maintenance operations. The most important part is the overall strategy of the top policy, how to incorporate it into the organisation and how to adopt the TPM concept in the maintenance field.

#### 4.1.1.2 Eight Pillars of Total Productive Maintenance (TPM) can Effectively Carry Out Maintenance Operation

The effectiveness of the eight pillars of TPM that can effectively carry out building maintenance operation is shown in Table 6. All respondents have agreed that the most effective pillars are planned maintenance. 87.14% of the respondents have agreed that training and education, quality management, office TPM, and safety, health & environments are important. 57.14% of the respondents think that focused improvement is effective and 14.29% is of the opinion that autonomous maintenance is effective.

**Table 6 - Effectiveness of eight pillars of Total Productive Maintenance (TPM)**

	Focused improvement	Autonomous maintenance	Planned maintenance	Training and education	Early management	Quality management	Office TPM	Safety, Health and Environments
Disagree	0	4 (57.14%)	0	0	0	0	0	0
Undecided	3 (42.86%)	2 (28.58%)	0	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)
Agree	4 (57.14%)	1 (14.29%)	7 (100%)	6 (85.71%)	6 (85.71%)	6 (85.71%)	6 (85.71%)	6 (85.71%)

#### 4.1.2 Maintenance Procurement of Green Buildings in Malaysia

All respondents were asked questions regarding the maintenance procurement of green buildings in Malaysia. The questions are as follows:

1. The differences of the maintenance procurement between a normal building and the green building;
2. Types of maintenance procurement used in the construction fields;
3. Method that was used to select the procurement; and
4. The issues of selecting the maintenance procurement were asked to the respondents.

##### 4.1.2.1 Differences in the Maintenance Procurement between Normal Building and Green Building

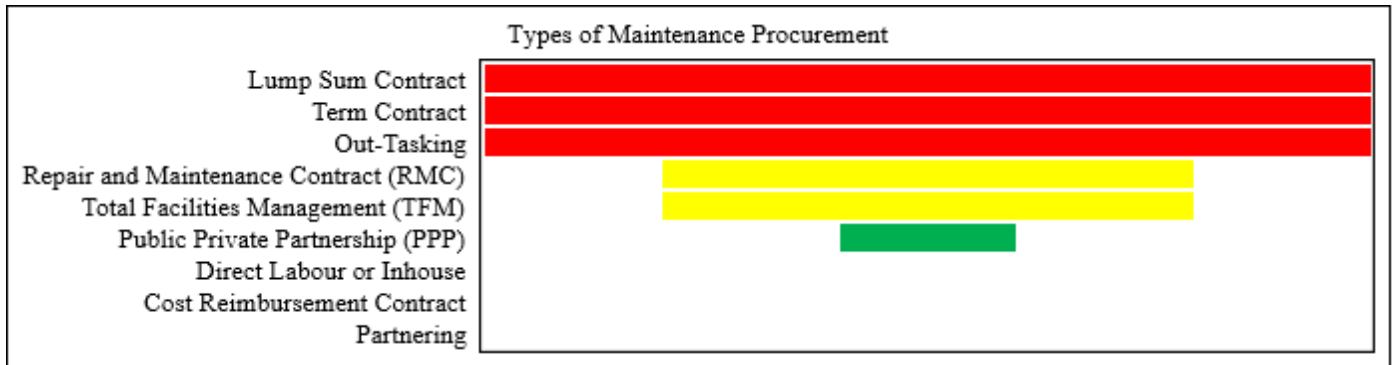
All respondents except J05 have responded that there are not much differences of maintenance procurement between the normal building and the green building. 57% of the respondents except J03, J05 and J07 is of the opinion that maintenance procurement differs only in the specification section and it should be modified to meet the green building maintenance requirements. They are also of the opinion that special provisions or requirements for the maintenance of green buildings should be added to the standard form of contract. Respondent J03 has mentioned that green building is a low carbon emission, and apart from the design, in order to implement TPM, procurement of material during construction stage is the key factor for the successful implementation of TPM. Respondent J05 has said that green building procurement needs to be aligned to the factories or theme or dimension domain in TPM. Respondent J07 has said that there is no difference between normal buildings or green buildings. It depends on the client's organisational leadership and maintenance strategy. Ibbs and Chih (2011) as well as Chua, Ali and Alias (2014), mentioned that, the success, efficiency and performance of a project is hugely influenced by the chosen procurement method

##### 4.1.2.2 Types of Maintenance Procurement used in the Property Management Sectors

Table 7 and Figure 2 show the analyses on the types of maintenance procurement. The top three procurement methods being ranked by the respondents are out-tasking, lump sum and term contract. And this is followed by repair and maintenance contract, total facilities management and public private partnership. The lowest ranked are cost reimbursement contract, partnering, in house and other. In general, it can be concluded that for the public project the most frequently used procurement is facilities management contract, whereas for private project the most popular procurements for green building maintenance are the lump sum contract, out-tasking contract and term contract.

**Table 7 - Types of maintenance procurement**

Interviewees	Types of Maintenance Procurement
J01 and J06	- Out-Tasking contract and facilities management is been used for a public project. - The facilities management is part of total facilities management
J02	- Out-Tasking has mostly been used for previous public projects. - Facility Management has recently been used for public projects
J03 and J04	- Lump Sum contract or Term contract
J05	- Lump Sum contract, Out-tasking and Public-Private Partnership (PPP)
J07	- Term contract, Repair and Maintenance Contract (RMC) and Out-Tasking



**Fig. 2 - Types of maintenance procurement**

**4.1.2.3 The Issues in selecting the Green Building Maintenance Procurement**

Issues on selected maintenance procurement can be categorised based on the public and private sector. Respondent J01 and J06, both are of the opinion that there are no issues on selecting the maintenance procurement in public projects. They have further added that, the procurement in public green building projects will mostly adopt the facilities management contract. Respondent J02 has stated that problems may arise in choosing the maintenance procurement method, and elaborates that the project's scope of work and budget will affect the choice of procurement method. Besides that, time, cost, manpower, and material resources will also influence the procurement method. Respondent J03 and J04 share the same opinion where they have said that there are no issues in selecting the green building maintenance procurement; they elaborate that client’s needs are the most important factor in choosing the right procurement method. Respondent J05 has stated that legal, technical, economic, social, and environmental are among the factors that will influence the choice of green building maintenance procurement. Respondent J07 is of the opinion that due to the lack of knowledge and competitiveness, a consultant will normally be appointed to advise the appropriate procurement method for the maintenance of green buildings.

It can be concluded that there is no major problem in choosing the maintenance procurement for a green building, as different organisation has different objectives and goal in choosing the right procurement system for its maintenance. Procurement is one of the most important parameters for project success and customer satisfaction (Love, Mistry, & Peter Davis, 2010). Procurement methods act as a significant part in determining and defining the form of contractual methods and the relationship within the people in the project (Ghadamsi, 2016).

**4.1.3 Total Productive Maintenance (TPM) Procurement Framework for Maintenance of Green Building**

Based on this study, a TPM procurement framework for maintaining green buildings in Malaysia has been developed. The framework can be used to maintain green buildings and improve efficiency and effectiveness in Malaysia's maintenance sector. The TPM procurement framework is as shown in Figure 3.

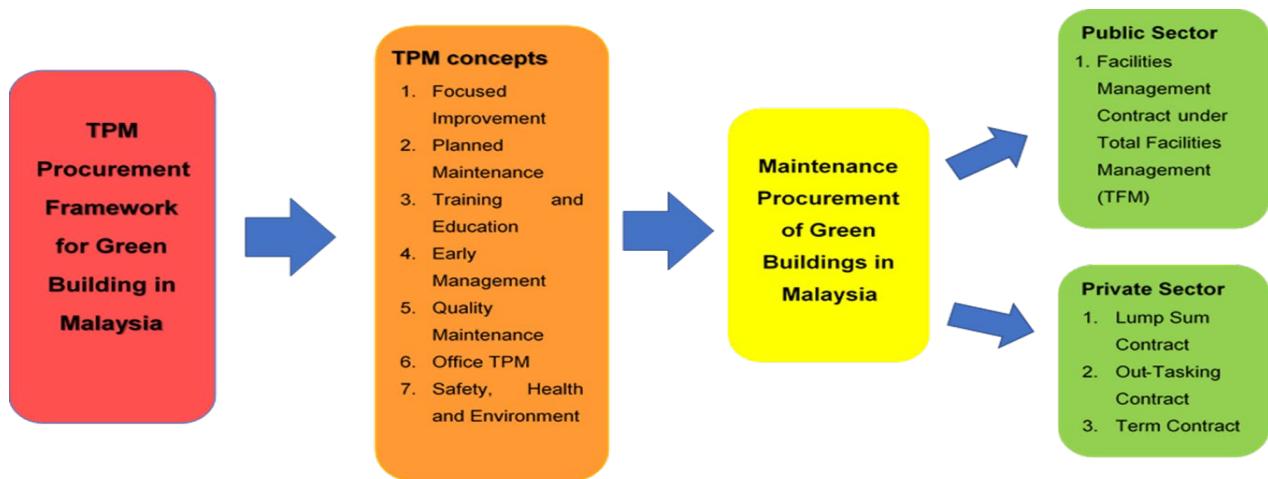


Fig. 3 - Total Production Maintenance (TPM) Procurement Framework

## 5.0 Conclusion

Throughout the study, it can be concluded that the maintenance sector is not ready to adopt the Total Productive Maintenance (TPM) concept. Result show that most of the respondents in the opinion that TPM is a new concept and not widely used in construction industry especially in the maintenance of green buildings. However most of the respondents do not have any objection to adopt TPM concept in maintenance of green buildings in Malaysia. The adoption of the TPM concept for the maintenance of green buildings could improve the productivity of the works and plant efficiency, reduce waste during the maintenance periods and reduce carbon emission. The implementation of TPM could make the system more structured and ensure that the works run smoothly especially in the maintenance of green buildings. In terms of the procurement method in Malaysia there is no specific procurement method that can be used for the Total Productive Maintenance concept implementation. It was identified that for public projects the most appropriate procurement method is Facilities Management Contract whereas for private projects there are the lump sum contract, out-tasking contract and term contract. The results of this study provide practitioners with a new insight into the impromptu creation of a TPM concept that could improve the current building maintenance sector. The policy maker should introduce and promote the importance of TPM to the construction industry in Malaysia.

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