

Occupant awareness towards the application of total productive maintenance in green office building

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Submitted : 27/08/2020

Revised : 06/07/2021

Accepted : 14/07/2021

ABSTRACT

Total productive maintenance (TPM) can be beneficial to be applied in green building. Successful TPM application requires total participation of the occupants in green building. However, lack of occupant awareness and involvement is among the barriers of TPM application in green building. Thus, this paper aims to examine the aspects of occupant awareness and occupant involvement in operation and maintenance of green building. A questionnaire survey was performed among the occupants of green office buildings in Malaysia with 417 valid responses. Descriptive analysis was used to identify the level of occupant awareness and involvement in the operation and maintenance activities. Then, Wilcoxon signed-rank test was run to examine the difference between occupant awareness and occupant involvement in the operation and maintenance activities. The results have demonstrated significant difference between the occupant awareness and occupant involvement, whereby the levels of occupant awareness aspects were above average, while the level of occupant involvement was below average. Since TPM concept in green building aims for total participation of occupants in operation and maintenance activities, the increase of occupant involvement is necessary. The occupants will be confident to take part in operation and maintenance activities if they are equipped with relevant competencies, skills, and knowledge. Therefore, comprehensive training and education programs are recommended to upskill the occupants' knowledge and skills.

Keywords: Total productive maintenance; Sustainable development; Green building; Occupant awareness; Occupant involvement.

INTRODUCTION

Total productive maintenance (TPM) is an improved maintenance strategy established to increase the equipment efficiency, minimize failures and encourage autonomous maintenance by involving all the employers and employees of the organization (Bhadury, 2000). Bartz et al. (2014) believes that the direction of TPM aims towards improving two main elements that are materials and human. The aspect of materials refers to machinery, equipment, tools, services and products. Human aspect looks at the improvement of skills related to personal traits such as knowledge, skills and attitudes. Interestingly, this concept was first initiated and implemented in the

automobile industry by M/s Nippon Denso Co. Ltd. of Japan in 1971 (Jain et al., 2014). It ensures that the organization is taking into account the maintenance planning as a part of overall organizational strategy (Weinstein et al., 2009). Ireland and Dale (2001) also signify the implementation of TPM in assisting business owners in their business decision-making, particularly in solving their business issues.

Jain et al. (2014) introduces five key characteristics of TPM that highlight its significant functions and contributions to business organizations:

- TPM aims to optimize equipment efficiency.
- TPM incorporates a strategy of preventive maintenance for the life cycle of equipment.
- TPM is cross-functional, implemented by various stakeholders.
- TPM involves every single employee in its execution through the motivation of management and autonomous small group activity.
- TPM emphasizes the role of teamwork, small group activities and the involvement of all employees to accomplish the equipment improvement objectives.

Typically, the application of TPM is more restrained in manufacturing industry (Weinstein et al., 2009, Bataineh et al., 2019). Nonetheless, its benefits are valuable to be practised in other industry, such as the construction industry (Andersson et al., 2015, Haddad, 2012, Jain et al., 2014, Kanta Patra et al., 2005). It is also noted that the development of green building is growing in the industry recently. Geng et al. (2019) believe that the green building research has grown extensively, in line with the rapid growth trend in various industries.

Rashid et al. (2012) prove that there is a correlation between green buildings and organization elements, which assists organizational leaders to link green buildings with the enhanced organizational values and benefits. Several similarities are determined between the TPM and green building. Thus, it could be beneficial to apply the TPM in green building.

According to Greenbuildingindex Sdn Bhd (2018), the main focus of green building is on the resource optimization use. It is believed that by optimizing the resources like energy, water, and materials, any building impacts foreseen on human health and the environment can be reduced. This can be achieved through the phases of building lifecycle starting from design, construction, operation and maintenance as well as removal. In fact, green buildings are in line with the norm of developing sustainable projects with the rising awareness of environmental issues and natural resource limitations (Al-Sulaihi et al., 2017). Cole (2019) believes that this concept matches with the overall idea of green practices' goals, which are to reduce the social and environmental impacts of the built environment while improving the quality of life for building occupants.

Due to the urbanization, environment and energy issues that are alerting the global and human being, the promotion of green building concept increases drastically as the concept is recognized to develop buildings that are healthy, safe, comfortable, and environmental friendly (Ding et al., 2018).

Generally, the characteristics of green building are highlighted as follows (Greenbuildingindex Sdn Bhd, 2018):

- Optimize energy and resources, recycle materials, and reduce the emission of toxic substances throughout its life cycle.
- Utilize resources, have substantial operational savings and escalate workplace productivity.
- Correspond with the local climate, traditions, culture, and the surrounding environment.

- Sustain and enhance the quality of human life whilst maintaining the capacity of the ecosystem at local and global levels.

The suggested characteristics of green building indicate the life-cycle processes within the building functions that are anticipated to be able to contribute significantly to the business and environment, but at the same time mitigating or reducing the impacts to humans and natural environment.

It is obvious that both TPM and green building share the similar concept, which is maximizing the equipment or building efficiency with optimized resources to increase the productivity of organization (Hooi and Leong, 2017). In order to apply TPM in green building, involvement of all individuals in the organization is compulsory, especially the employees (Bataneh et al., 2019). Under the philosophy of TPM, the employees must transform their mentality toward the scope of works and be able to initiate the operation and maintenance actions when necessary (Kanta Patra et al., 2005). Interestingly, in their study, Kato et al. (2009) claim that organization or management perceived more advantages of green workplace compared to employees. This is also linked with the effects of quality working environment with the sense of positive job satisfaction among them. Che-Ghani et al. (2018)'s study suggests that the maintenance culture among the building users is important in improving the overall building performance, and this can be initiated with skill improvement and continuous knowledge.

In the operation stage, the occupant behavior and expectation have significant impacts on the performance of the building (Hong et al., 2017). Unfortunately, lack of awareness on the importance of building maintenance and lack of involvement of building occupants in operation and maintenance activities are common (Au-Yong et al., 2017). Meanwhile, occupant attitudes such as unconcern towards maintenance efforts and vandalisms often lead to the maintenance inefficiency (Jandali and Sweis, 2019).

Hassanain et al. (2019) also highlighted one of the occupant awareness issues affecting the maintenance effectiveness, which is lack of reporting of maintenance defects. In green building, sustaining green certification is a big challenge mainly due to inadequate maintenance practices and lack of occupant awareness about green and sustainability concept (Bandara et al., 2018). In fact, it is vital to increase the occupant awareness of non-negligible effects of maintenance on sustainability (Franciosi et al., 2020). It is also worth noting that the awareness is needed to demonstrate the linkage of green buildings and building maintenance towards improving the environmental factors and workplace behaviors of the occupants (Mulville et al., 2016).

Taking into cognizance the occupant awareness issues and importance of occupant involvement for TPM application in green building, this paper aims to examine the aspects of occupant awareness and occupant involvement in the operation and maintenance of green building. This way, this research seeks to check if there are any significant differences between occupant awareness and occupant involvement. The study is crucial to enhance the applicability of TPM in green building.

OPERATION AND MAINTENANCE IN GREEN BUILDING

Ohueri et al. (2018) stated that there are more than 300 certified green buildings and mainly dominated by commercial buildings in Malaysia. Typically, a green building can save over 55% of the energy compared to conventional buildings (Holmgren et al., 2017). Hence, it is always expressed in the form of sustainable development, whereby it employs best practice, clean and resource efficient from the exploitation of raw materials with more environmentally, socially and economically sustainable (Huo et al., 2019, Zhang et al., 2019). Meanwhile, Hewitt et al. (2019) suggested green building as a practice of creating and using healthier and more efficient resource of construction, maintenance, operation, renovation and demolition.

The rising demand of green buildings causes the researchers to start thinking about the maintainability of green buildings (Asmone et al., 2019). In order to ensure the good operational performance of green buildings, several indicators need to be measured in operation and maintenance stage, including energy, water, resources, pollutions, health, and management (Geng et al., 2019). Thus, appropriate operation and maintenance is essential to fulfil the operational performance indicators the green buildings (Nilashi et al., 2015).

Fenner et al. (2018) claims that building operational stage is the highest environmental impact attributor. From the lens of operation and maintenance, Fowler et al. (2008)'s study suggests that green buildings perform better than conventional buildings in terms of energy efficiency, water efficiency and also cost efficiency. Li et al. (2019) also emphasized the importance of operation and maintenance by indicating the critical success factors of green buildings in the operation and maintenance stage as follows:

- Communication and cooperation between stakeholders
- Effective maintenance planning and control
- Owner's involvement and commitment
- Clear goals and objectives
- Top management support
- Knowledge management
- Trust among stakeholders
- Occupant involvement
- Dedicated department for sustainability
- Skilled facilities management team
- Construction of sustainable culture.

Unfortunately, the existing research mostly focuses on design and construction of green building. The research on strategy to sustain the green certification is limited (Bandara et al., 2018). Bandara et al. (2018) also mentioned that building maintenance and management issues are the challenges in sustaining green certification. The reason being is that poor maintenance implementation implicates additional cost expenses and ineffective maintenance management practices upsets the functionality of green building. Similarly, Chew et al. (2017) claimed that the disregard of operation and maintenance of the green building caused lifelong resource ineffectiveness and emissions. Therefore, sustainable development must also take into consideration the green building operation and maintenance.

Proposing an effective maintenance strategy is seen as a constructive way to expand the sustainability of green building (Bandara et al., 2018). Based on the operation and maintenance challenges revealed in the green building, the involvement of all occupants in operation and maintenance is deemed important (Ohueri et al., 2018). This coincides with suggestion by Mulville et al. (2016) that an active management of the workplace via environmental monitoring and behavior change campaigns may result in positive changes in improving the workplace culture.

Coincidentally, TPM concept is coherent with the green building maintenance concept. It is a rational strategy that increases equipment effectiveness, reducing failures, and stimulates autonomous maintenance via the participation of all employees within an organization (Ahuja and Khamba, 2008). Basically, TPM necessitates all individuals in the organization from top management to floor staff be dedicated to the TPM program (Bataneh et al., 2019). Generally, the philosophy of TPM embeds the following (Kanta Patra et al., 2005):

- Total commitment to the strategy by top management is compulsory.
- Employees must be allowed to initiate corrective action.
- A long-range benefit must be recognized as TPM may take longer time to execute and is a long-run process.
- Transformation in employees' mentality toward their scope of works are mandatory.

In order to initiate the application of TPM, several steps need to be done accordingly in the preparatory stage (Venkatesh, 2007):

- i) Declaration by top management about the introduction of TPM in the organization (Ahuja and Khamba, 2008) – In this step, appropriate understanding and commitment of the top management is essential. The top management's direct involvement strengthens the TPM implementation in the organization (Hooi and Leong, 2017). Meanwhile, the senior management should take part in the awareness program too. Then, all the employees of the organization must be notified about the decision.
- ii) Initial education and propaganda for TPM – In this step, training programs are to be conducted based on the need. The employees must be made aware of what is TPM and its benefits (Poduval et al., 2015). Meanwhile, Hooi and Leong (2017) argued that a plan cannot be implemented without creating awareness to the relevant parties. Hence, the programs usually begin with some awareness trainings and then the intensive trainings to upgrade the skill and knowledge of employees with regard to the TPM.
- iii) Setting up TPM committees – The committees are set up to look after the needs of TPM. Poduval et al. (2015) stated that it is necessary to have a coordinator and an office set-up with dedicated work force for the coordination of TPM implementation.
- iv) Establishing the TPM working system and target – In this step, the total productive master plans are aligned with the organizational goals (Hooi and Leong, 2017). Then, the basic TPM policies and objectives are formulated (Ahuja and Khamba, 2008). Then, each area or workstation is benchmarked, and target is assigned for achievement.

In this regard, the occupants of the building that mainly consist of the organization's employees are the majority individuals to be involved in the preparatory stage. In other words, more emphasis is needed on the awareness trainings of occupants in the implementation of TPM. As such, the aspects of occupant awareness shall be investigated in the research. The rationale and need is further seconded by Agyekum et al. (2019), through their findings which list the inadequate awareness of the benefits of green certification of buildings and inadequate human resources as among the key barriers to the adoption of green certification of buildings.

OCCUPANT AWARENESS AND INVOLVEMENT IN TPM APPLICATION

The success of the green building practices and performance depend on the occupant awareness and involvement (Rashid et al., 2012). In order to sustain green building certification, one of the strategies is to ensure optimal operational performance (Geng et al., 2019). Whereas in TPM application, it is vital to assure that the occupants are aware of the relevant importance and how they support in the operation and maintenance activities (Sivaram et al., 2014). Hence, the important aspects on application of TPM are reviewed as follows:

- Importance of green building certification
- Importance of maintenance to secure green building certification
- Importance of occupant involvement in operation and maintenance activities
- Occupant involvement in operation and maintenance activities

It is crucial to recognize the importance of green building certification by the occupants. According to Mokhtar Azizi and Wilkinson (2015), the occupant's energy saving behavior is often stimulated by the green building certification and passionate to success the building performance. They added that occupants in the green buildings are more environmentally concerned, more energy saver and loyal than occupants in non-green buildings. It was also noted that the occupants of green certified building have greater satisfaction with indoor environment compared to the occupants of conventional buildings (Altomonte et al., 2019, Liu and Hu, 2019), which indirectly increases occupant productivity (Holmgren et al., 2017). Hence, raising occupant awareness on green building certification may improve the energy saving behavior practice (Mokhtar Azizi et al., 2015).

Moreover, maintenance activities carried out in green building is vital. It ensures the sustaining of green certification for the building. Nilashi et al. (2015) stated that the effective operation and maintenance of green building features is necessary to accomplish the sustainable operational benefits. Bandara et al. (2018) further explained that inappropriate maintenance implementation leads to additional cost expenditures and ineffective maintenance management practices results poor building functionality in green building. Thus, the importance of putting in place an effective maintenance system with adequate maintenance implementation is in urgent need for optimal sustainability (Emovon and Mgbemena, 2019).

Besides that, the occupants must realize the importance of their involvement in operation and maintenance activities in green building as in accordance with the TPM concept. The sustainability of green building cannot be guaranteed if the green building is not supported with environmental-friendly practices due to the low involvement of occupants in operation and maintenance (Rashid et al., 2012). Wickramasinghe and Perera (2016) revealed that one of the key success factors of TPM is the involvement of the building occupants. It is essential to encourage the occupants carrying out operation and maintenance activities upon adequate training (Sinha, 2015). In other words, it is vital to encourage more occupant involvement to achieve the aim of green building (Ohueri et al., 2018).

In order to increase the involvement of occupants in operation and maintenance activities, the occupants must be made aware of what is green building certification, TPM and their benefits (Agyekum et al., 2019, Poduval et al., 2015). As such, the awareness program can be conducted to convince the occupants about the importance of green building certification and TPM (Kanta Patra et al., 2005). Additionally, the organization shall make sure that the occupants are conscious of the significance of their activities and how they support to the successful implementation of TPM in green building (Sivaram et al., 2014).

RESEARCH METHODOLOGY

Since the research aimed to examine if there was any differences between occupant awareness and occupant involvement in green building maintenance, it adopted the research methodology done by Au-Yong et al. (2019), that is a questionnaire survey. Sets of questionnaires were randomly distributed to the occupants of green buildings. Nevertheless, the type of buildings was limited to green office buildings rated under the Green Building Index (GBI) Malaysia only.

The sampling is focused on green office buildings as the application of TPM is more suitable in green office building, as most of the building users are long-term occupants, that are office employees. Therefore, involvement of the occupants in operation and maintenance activities is more realistic. Krejcie and Morgan (1970) stated that the sample size increased at diminishing rate as the population increased and it remained relatively constant at 384 cases when the population size was one million or above. Therefore, since the population size for the research could not be determined, the data collection was expected to obtain at least 384 samples. Towards the end of the data collection, the researchers managed to collect 417 returned questionnaires. It reflected no issues on generalization of data. The questionnaire was designed to prompt the respondents to rate the importance level of various occupant

awareness aspects with five-point Likert scale (1-very low to 5-very high). It also requests the respondents to rate their involvement level in the operation and maintenance activities. Upon the completion of data collection, data analysis was run using the Statistical Package for Social Sciences (SPSS) software. Firstly, descriptive analysis was done to compute the mean scores of the research variables. Next, Wilcoxon signed-rank test was conducted to check if there was any significant difference between the occupant awareness and occupant involvement in the operation and maintenance activities. These methods are appropriate for ordinal data analysis (Jolaoso et al., 2012, Ogungbile and Oke, 2015). The Z-score of Wilcoxon signed-rank test could be computed via Equation (1) to Equation (3) as follows:

$$\mu_T = \frac{n(n+1)}{4} \quad (1)$$

$$\sigma_T = \sqrt{\frac{n(n-1)(2n+1)}{24}} \quad (2)$$

$$Z = \frac{T - \mu_T}{\sigma_T} \quad (3)$$

where n = sample size

T = total ranks for either + or – differences, whichever is less

Additionally, reliability analysis was performed for the research variables to monitor the consistency of the scale of data and evaluate the reliability of the data (Leech et al., 2011). The Cronbach's alpha coefficient test showed that the coefficient for the variables was 0.910. Au-Yong et al. (2019) suggested that a coefficient of more than 0.70 indicates good reliability. In fact, Ursachi et al. (2015) suggested that Cronbach's alpha is deemed as the most used reliability estimator, with the accepted rule that coefficient of 0.6-0.7 indicates an acceptable level of reliability, and 0.8 or greater a very good level.

FINDINGS AND DISCUSSION

Three maintenance awareness aspects related to the application of TPM in green buildings were determined through literature review, namely:

- Importance of green building certification
- Importance of maintenance to secure green building certification
- Importance of occupant involvement in operation and maintenance activities.

Table 1. Average values of occupant awareness and occupant involvement in the operation and maintenance activities.

| Aspects | Mean (n=417) |
|---|--------------|
| Awareness on the importance of green building certification | 3.92 |
| Awareness on the importance of maintenance to secure green building certification | 4.07 |
| Awareness on the importance of occupant involvement in the operation and maintenance activities | 4.05 |
| Involvement in operation and maintenance activities | 2.86 |

The occupant awareness and occupant involvement in the operation and maintenance activities were investigated using mean score analysis as shown in Table 1. In the aspects of occupant awareness, the ratings were similar. It is also noted that the importance of maintenance to secure green building certification obtained highest mean score ($\bar{x} = 4.07$). The findings show that the occupants recognized the role of maintenance to secure the green building certification. The results might be also due to the direct effects of maintenance towards the occupants. This is as maintenance implementation may influence the cost expenditures, and ineffective maintenance management practices may result poor building functionality in green building (Bandara et al., 2018).

Then, the importance of occupant involvement in operation and maintenance activities was rated with the mean score of 4.05. The result reflected that the occupants did understand the need of involvement in operation and maintenance activities in green building. This is in accordance with the ideal scenario for both green building and TPM concepts, whereby they required occupant involvement in operation and maintenance to achieve their optimal efficiency (Ohueri et al., 2018, Wickramasinghe and Perera, 2016).

However, it is also noted that the importance of green building certification obtained lower mean score of 3.92. It is also observed that to certain extent, the occupants recognized the importance of green building certification. Nevertheless, some occupants still did not appreciate the green building certification mainly because they could not observe any direct benefits from the certification. Notwithstanding the results, it is generally agreed by scholars that a green certified building provides better indoor environment quality compared to the conventional buildings and it indirectly helps in the increasing occupant productivity (Altomonte et al., 2019, Liu and Hu, 2019, Holmgren et al., 2017).

Next, the level of occupant involvement in operation and maintenance activities was below average, which accrued mean score of 2.86. The result was not encouraging, as the implementation of TPM requires total participation of occupants or employees in the operation and maintenance activities. So, it is essential to disclose to the occupants the importance and benefits of implementing TPM in green building via appropriate awareness programs (Kanta Patra et al., 2005, Poduval et al., 2015, Sivaram et al., 2014).

Table 2. Wilcoxon signed-rank test of occupant awareness towards involvement in operation and maintenance activities.

| Involvement in operation and maintenance activities – Awareness aspect | Z-score | p-value |
|---|----------------------|---------|
| Awareness on the importance of green building certification | -13.335 ^a | .000 |
| Awareness on the importance of maintenance to secure green building certification | -14.156 ^a | .000 |
| Awareness on the importance of occupant involvement in operation and maintenance activities | -13.841 ^a | .000 |
| a. Based on positive ranks. | | |

In order to confirm if there are any significant differences between the occupant awareness and occupant involvement, Wilcoxon signed-rank test was employed. Each aspect of occupant awareness was compared with the occupant involvement in operation and maintenance activities. The results are then tabulated in Table 2. Based on the results, all aspects of occupant awareness had significant differences with occupant involvement in operation and maintenance activities, with reference to the P-value that is $p < 0.05$. Moreover, the result revealed that the level of occupant involvement was lower than all the occupant awareness aspects, in which the mean score of occupant involvement was lower than the occupant awareness aspects.

Indeed, the level of occupant involvement was expected to be similar with the level of occupant awareness. The result poses a conflict with Poduval et al. (2015), who mentioned that letting the occupants aware of the important aspects of TPM in green building helped promote the occupant involvement in operation and maintenance activities. Hence, other possible factors influencing the occupant involvement needed to be explored.

Sufficient level of awareness might suffice the occupants to involve themselves in the operation of the green building for energy-saving practices. For example, some of the exemplary behavioral practices that may contribute significantly are when occupants in the office will shut down the computers when not in use and switch off the lights when not needed. However, in order to get involved in the maintenance of the green buildings, the occupants must pose relevant competencies, skills and knowledge before they can take part in the maintenance activities. Sinha (2015) highlighted that the organization can only allow the occupants to conduct maintenance activities after proper training. Ideally, organizations need to invest on the employees or occupants' knowledge and cooperation via appropriate and adequate training to cultivate a proactive and progressive maintenance culture (Hooi and Leong, 2017). In summary, training and education programs are recommended to upskill the occupants' knowledge as well as skills. Therefore, promoting the involvement of occupants in operation and maintenance activities in green building is of paramount importance. Interestingly, Jain et al. (2018) also noted that the return on investment of the training and education is higher than the cost incurred.

CONCLUSION

TPM that was initially applied in manufacturing industry is now widely applied in other industries due to its advantages, including the construction industry. Coincidentally, several similarities are determined between the TPM and green building. As such, it could be beneficial to apply the TPM in green building. Since TPM requires

total participation from the occupants when it is applied in green building operation and maintenance, it is compulsory to study the occupant awareness and involvement in operation and maintenance activities. The investigated aspects of occupant awareness include the importance of green building certification, importance of maintenance to secure green building certification, and importance of occupant involvement in operation and maintenance activities. The findings indicate that the levels of occupant awareness are above average. Nonetheless, they are found to be significantly different with the level of occupant involvement in operation and maintenance. The level of occupant involvement is below average, which is against the TPM concept. Therefore, in order to promote occupant involvement in operation and maintenance of green building, the occupants must be trained properly with relevant competencies, skills and knowledge. Consequently, training and education programs are recommended to upskill the occupants' knowledge as well as skills in promoting the occupant involvement in operation and maintenance activities of green building.

ACKNOWLEDGMENT

The author gratefully acknowledges the financial support of the University Malaya Faculty Research Grant (GPF), grant no. GPF006F-2018 established at the Faculty of Built Environment, Universiti Malaya.

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