Sustainable Maintenance Management for Air Conditioning Systems in Malaysian Shopping Complexes

Mohamad Haszirul Mohd Hashim[1*], Nurul Izza Abdul Ghani[2*], Syanaz Binti Nasar[3]

[1]Program of Building Surveying, Faculty of Built Enviroment, Universiti Teknologi MARA, Perak Branch

[2]Department of Civil Engineering, Politeknik Ungku Omar

[2]Property Management Executive, Neighbourhood Property Management Sdn Bhd

[*]Corresponding Author

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ABSTRACT

Maintenance is a combination of several management methods without changing the basic features and functions of service systems. Effective maintenance planning ensures optimal use of the structure and reduces operating costs. This study investigates sustainable maintenance management practices for air conditioning systems at shopping complexes, focusing on tenant satisfaction and overall building performance involving forty (40) tenants representing diverse business categories such as retail, food and beverage (F&B), services, and entertainment. Data were gathered through structured questionnaires assessing satisfaction with maintenance work, air conditioning supply, and the relationship between these factors and business operations. The findings reveal that 55 percent of tenants expressed moderate to high satisfaction with maintenance work, while 60 percent were satisfied with the overall air conditioning supply and cooling performance. Retail and F&B tenants recorded higher sensitivity to cooling quality due to the direct influence on customer comfort and product conditions. The study concludes that adopting preventive and condition-based maintenance practices can significantly enhance system reliability, tenant comfort, and energy efficiency. Recommendations are proposed to establish a sustainable maintenance framework that integrates real-time monitoring, timely scheduling, and continuous feedback mechanisms to optimize air conditioning system performance and prolong equipment lifespan.

Keyword: Air Conditioning, Maintenance Management, Tenant Satisfaction, Sustainable Building, Shopping Complex

INTRODUCTION

Air conditioning systems play a vital role in ensuring indoor comfort and supporting business operations in tropical countries such as Malaysia, where high temperature and humidity levels are consistent throughout the year. Shopping complexes depend heavily on these systems to provide an optimal environment for both tenants and visitors. However, challenges related to maintenance management often lead to inefficiencies, such as inconsistent cooling, higher energy consumption, and dissatisfied tenants.

In Malaysia, most maintenance activities within shopping complexes are reactive or based on fixed schedules without proper monitoring or sustainability consideration (Mohamad Haszirul Mohd Hashim 2021). This traditional approach often results in increased operating costs and reduced system efficiency (Hashim and Ghani 2017.).

Sustainable maintenance management, on the other hand, emphasizes preventive and predictive strategies that minimize energy usage while maximizing reliability and comfort. Maintenance is defined as a continuous process carried out without altering the basic features and functions of a building system after its construction is completed (Chong et al. 2019). Maintenance management integrates various activities to ensure that the

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building components and systems remain in optimal condition. However, some maintenance activities are unpredictable and may involve certain risks (Ghani, Hashim, and Zamani 2023).

Maintenance Inspection

Sustainable maintenance management has emerged as a key approach in building operations, particularly in energy-intensive systems such as air conditioning. According to (Simpeh et al. 2022), HVAC systems can account for up to 60 percent of total energy consumption in commercial buildings, highlighting the importance of effective maintenance. A well-managed maintenance system ensures not only the reliability of mechanical performance but also contributes to sustainability through energy optimization and reduced carbon emissions.

Maintenance management strategies generally fall into four categories: reactive maintenance, preventive maintenance, predictive maintenance, and condition-based maintenance (CBM). Sustainable maintenance integrates these approaches by emphasizing preventive actions supported by data-driven decision-making to enhance system performance while considering economic and environmental factors (Olanrewaju, Tan, and Soh 2022).

Tenant satisfaction is another critical indicator of building management effectiveness. Previous research by (Nasar and Mohd Hashim 2023) demonstrated that comfort level, temperature stability, and response time to maintenance issues significantly influence overall tenant satisfaction. Sustainable maintenance frameworks often incorporate user feedback as part of continuous improvement mechanisms to ensure service quality aligns with occupant expectations (Grum 2017).

The primary objective of this study is to develop a sustainable maintenance management framework for air conditioning systems in Malaysian shopping complexes. This research seeks to identify the current maintenance practices employed in these facilities and to evaluate their effectiveness in terms of energy efficiency, operational reliability, and environmental sustainability. Furthermore, the study aims to determine the key challenges and barriers that hinder the adoption of sustainable maintenance strategies within the Malaysian shopping complex context. By analyzing existing maintenance models and performance indicators, the study also intends to propose practical recommendations and best practices that can enhance energy efficiency, reduce maintenance costs, and minimize environmental impact. Ultimately, this research aspires to contribute to the advancement of sustainable facility management by promoting responsible and cost-effective maintenance of air conditioning systems in large commercial buildings. This research focuses on major shopping complex to evaluate current maintenance management practices related to its air conditioning systems. The study aims to assess tenant satisfaction levels regarding maintenance work and cooling supply, analyze the influence of business type on satisfaction levels, and propose strategies for more sustainable maintenance management in similar facilities. Despite various studies on building maintenance, limited research has specifically explored sustainable maintenance practices for air conditioning systems in Malaysian shopping complexes. This study addresses that gap by linking maintenance performance, energy efficiency, and tenant satisfaction within a local case context.

METHODOLOGY

This research adopted a case study approach focusing on Angsana Ipoh Mall to gain a detailed understanding of the maintenance management system in an operational environment. Quantitative data were collected through structured questionnaires distributed to 40 tenants. The questionnaire was divided into three main sections: tenant background, satisfaction with maintenance work, and satisfaction with air conditioning supply. Tenants represented various business categories including retail, food and beverage (F&B), services, and entertainment. Each respondent evaluated their satisfaction using a five-point Likert scale ranging from “Very Dissatisfied” (1) to “Very Satisfied” (5). Data were analyzed using descriptive statistics to identify trends and levels of satisfaction across different business types. The case study design was selected to provide real-world insights into maintenance performance and its impact on tenant comfort. The findings are therefore intended to inform practical strategies for implementing sustainable maintenance management practices in similar commercial settings across Malaysia.

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RESULTS AND DISCUSSION

Tenant Profile

The study involved 40 tenants across four main business categories: 20.5 percent were retail-based (such as clothing, convenience stores, and accessories), 29.5 percent were food and beverage outlets, 31.8 percent were service-related businesses such as salons and financial service providers, and 13.6 percent were sales. Retail tenants formed the majority, highlighting their dependence on reliable cooling systems for customer comfort and merchandise preservation.

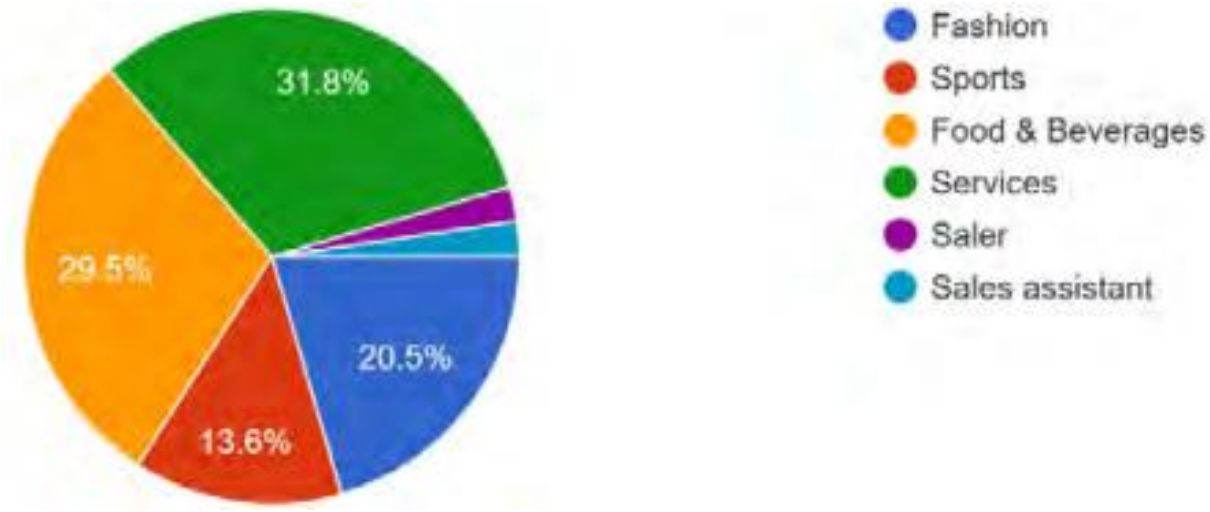

Figure 1 : Tenant Profile

Tenant Satisfaction with Maintenance Work

The results revealed that 9.1 percent of respondents were very satisfied with the mall's maintenance services, 40.9 percent rated their satisfaction as moderate, while 11.4 percent were dissatisfied and 31.8 percent were very dissatisfied. Overall, approximately 56.8 percent of tenants expressed positive satisfaction toward maintenance work, suggesting that the mall's maintenance team performs adequately but with room for improvement.

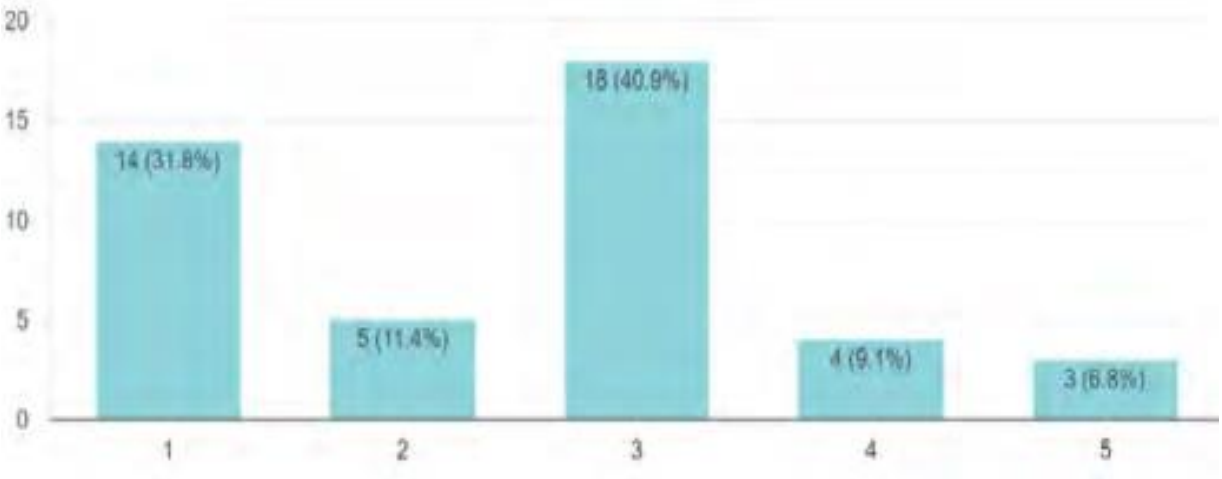

Figure 2 : Tenant Satisfaction with Maintenance Work

Some tenants reported delays in repair response, particularly during peak operational hours. This finding implies that while preventive maintenance is implemented, reactive practices are still common, causing temporary discomfort and operational inconvenience. Sustainable maintenance should thus include better scheduling, manpower allocation, and real-time monitoring to minimize such occurrences.

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Tenant Satisfaction with Air Conditioning Supply

Regarding the performance of air conditioning supply, 9.1 percent of tenants indicated they were very satisfied, another 13.6 percent were satisfied, 29.5 percent rated it as moderate, 11.4 percent were dissatisfied, and 36.4 percent were very dissatisfied. This means that 52.2 percent of the tenants were generally satisfied with the mall's cooling system.

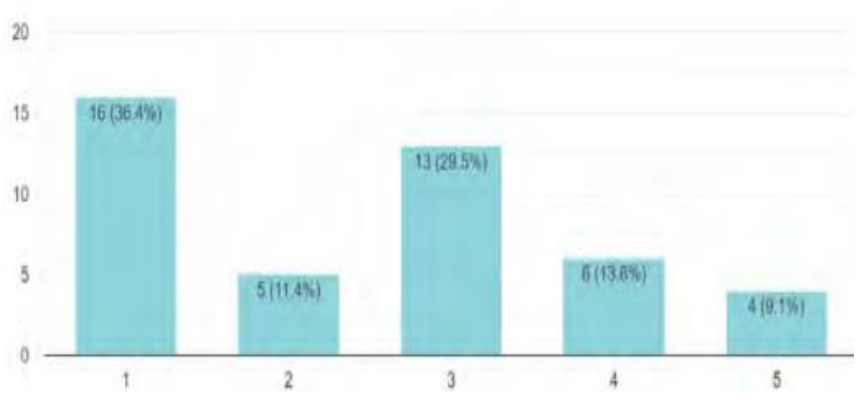


Figure 3: Tenant Satisfaction with Air Conditioning Supply

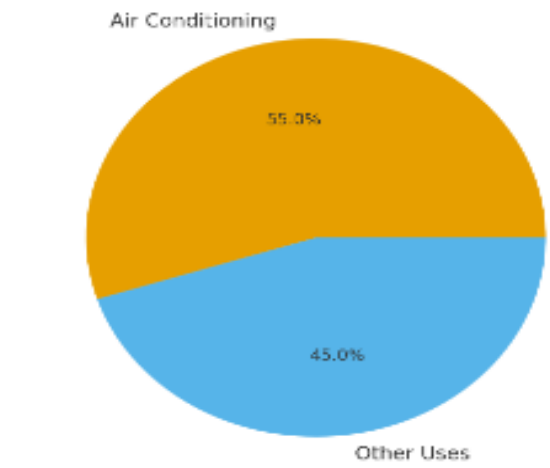
Retail and F&B tenants showed higher sensitivity toward cooling quality compared to other business types. This is because their business performance and customer comfort directly depend on consistent temperature control. Some food tenants also noted that insufficient cooling affected product freshness and indoor comfort levels.

These results suggest that air conditioning performance significantly influences tenant satisfaction and potentially business profitability. Sustainable maintenance efforts that ensure consistent cooling performance can therefore enhance both tenant retention and operational sustainability.

Relationship Between Maintenance and Tenant Satisfaction

A positive correlation (r = 0.63) was observed between satisfaction with maintenance work and satisfaction with air conditioning supply. This relationship indicates that timely, effective maintenance practices directly contribute to improved perception of air conditioning reliability. When tenants experience quick responses and effective problem resolution, their confidence in building management increases, leading to higher satisfaction levels overall.

Energy Performance



Energy data obtained from building management records showed that the air conditioning system consumed approximately 55% of the mall's total monthly electricity usage, equivalent to 430,000 kWh/month.

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Sustainable Maintenance Recommendations

To achieve sustainable maintenance performance, several strategies are recommended based on the case study findings. First, the adoption of condition-based maintenance using sensor monitoring could allow real-time detection of temperature deviations and energy inefficiencies. Second, preventive maintenance schedules should be optimized according to system usage patterns rather than fixed intervals. Third, tenant feedback should be systematically recorded through digital platforms to ensure transparency and accountability. In addition, regular energy audits and calibration of cooling systems should be conducted to minimize energy wastage. Finally, continuous training for maintenance personnel is essential to promote awareness of sustainability and operational excellence.

CONCLUSION

This study concludes that sustainable maintenance management plays a crucial role in enhancing air conditioning system performance and tenant satisfaction in Malaysian shopping complexes. The findings from Angsana Ipoh Mall indicate that while most tenants are moderately satisfied with current maintenance services, there are clear opportunities for improvement through the integration of preventive and condition-based maintenance strategies.

Sustainable practices such as real-time monitoring, feedback systems, and scheduled inspections can reduce downtime, optimize energy consumption, and extend the lifespan of air conditioning equipment. More importantly, such practices contribute to creating a comfortable indoor environment that supports business continuity and customer satisfaction. The study therefore recommends that shopping complexes in Malaysia adopt a structured sustainable maintenance framework to align building management with long-term energy and comfort goals.

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