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The Application of Infrared Thermography for Enhancing Maintenance in Public University

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ABSTRACT

A university's main function is to produce quality graduates, and in doing so, university buildings do play significant roles and are vital assets and resources. Hence, to prolong a university building lifecycle to ensure all university activities to continue performing at an optimum level, building maintenance management is central. Eventhough previous studies have been conducted in this area, university buildings maintenance is still viewed as insignificant. The research about utilization of infrared thermography in term of maintenance in public universities is still lacking. The objective of this research was to provide recommendations for areas within the public universities that can benefit from the application of infrared thermography to enhance maintenance. The research method used in this research was a qualitative method. Three public universities that were established for more than 50 years were chosen as case studies. The data was collected through narrative review and then analyzed. The findings highlighted the benefits of implementing infrared thermography in older building maintenance within public universities, particularly in improving energy efficiency and identifying hidden issues such as moisture intrusion and structural defects. The study emphasized the importance of timely maintenance actions based on infrared thermography assessments to reduce energy consumption and apply predictive maintenance strategies. By conducting in-depth analyses at three established public universities in Malaysia, the researchers demonstrate the effectiveness of infrared thermography in enhancing maintenance practices and prolonging the lifecycle of university buildings.

1. Introduction

Maintenance practices are essential in every building to ensure the long-term durability and optimal performance of the building. Infrared thermography, which can also be referred to as thermal imaging, is non-invasive testing method that use infrared radiation to capture and analyze the thermal patterns of surfaces. It is involved the use of thermal cameras to capture radiation that emitted by materials and then translate the images into temperature color coded images [1]. The application of infrared thermography is significant for the improvement of maintenance practices in

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Malaysian buildings as a research stated that previous studies have highlight that maintenance practices in Malaysian building were inefficient and performed far below maintenance best practices with issues categorized into planning, management, staff, competency, technology and technical capabilities [2]. This research focused on infrared thermography and public universities since there was a lack of technology integration like infrared thermography in maintenance at public universities. Many research on the utilization of infrared thermography focused on heritage building as the case study so there is an insufficient research in regards the application of infrared thermography in public universities case studies.

2. Literature Review

2.1 Introduction

One of the innovative technologies that have been proven to be effective for the maintenance utilization is infrared thermography. Infrared thermography, also known as thermal imaging, is a non-invasive and non-destructive technology that uses infrared radiation to capture and analyze the thermal patterns of surfaces. Infrared thermography is categorized as a non-invasive testing method (NDT) according to the international standards [3]. To detect infrared radiation emitted by the structure surface and objects surface, it involves the use of infrared thermography to assess the variation in temperature. This process also includes measuring the release of energy, in the form of radiation, from an object and then converting that distribution into an image [4]. The historical development and evolution of infrared thermographic technology is due to the remarkable advancements of the technology in various fields such as medical and construction. The development of infrared thermography was initially for medical purposes but after much research revealed the versatility of that infrared thermography, it has been evolved into variety of valuable tool in fields such as material science and industrial maintenance.

Infrared thermography can be utilized for the assessment of building materials, identify and describe flaws in reinforced concrete and monitor the heating process during construction [5,6]. Structural monitoring such as the examination of constructive components in buildings and concrete bridges can be applied using infrared thermography [7]. Infrared thermography has become a popular instrument for a non-invasive inspection technique in building because it does not demand physical infiltration or damages to the building envelope. Infrared thermography is a non-intrusive testing technique that has the capability to swiftly and remotely identify issues in the building which make it prevalent acceptance in the construction industry [8].

2.2 The Application of Infrared Thermography

Infrared thermography has been applied widely across various fields for various purposes. Infrared thermography has become an essential non-destructive technique that is used in building inspection to detect any hidden defects [9]. It enables the identification of the potential issues since hidden defects typically cause a disturbance in the heat flow which then generates differences in temperature on the surface of the object [10]. If the object has a defect, the defect will have a periodic effect on the surface temperature distribution above it, even at low peaks. As a result, there will be a phase difference between the defective and non-defective areas [11]. Infrared thermography also relies on infrared sensors for detecting and measuring variations in thermal energy that objects emit. It is involved the use of thermal cameras to capture the radiation that emitted by materials and then translate the images into temperature color coded images [1]. The abnormal temperature changes in the images captured by the thermal cameras can indicate the

presence of cracks, humidity, heat and other surface damage [12]. One of the important applications of infrared thermography is in the field of maintenance practices which the public university infrastructure can benefit from the application of infrared thermography because it provides an accurate surface temperature and temperature contrast information which can be used to diagnose the mechanical and technical condition of the buildings.

2.3 The Maintenance Practices in Public Universities

To ensure the longevity and functionality of the public university's infrastructure, it is crucial to apply the maintenance strategies at the institution. There are several studies that have been focused on improving the maintenance management practices and the benefit to public education institutions. The application of infrared thermography is important for the improvement of maintenance practices in public universities as research stated that Malaysian building maintenance practices are inefficient and below best practices, with issues categorized into planning, management, staff, competency, technology and technical capabilities [2]. Study has emphasized that the overall maintenance costs can be reduced and the reliability and availability of equipment in the laboratory can be increased after the contribution of maintenance plans in public universities [13]. A systematic review of building maintenance practices has been conducted that highlights the need to address maintenance issues and their effects, to improve the professional maintenance practices. These studies highlight all the significance of comprehending maintenance practices and the maintenance issues which can be fundamental for improvement of maintenance in public universities [14].

2.4 Advantages of Infrared Thermography

Infrared thermography has shown variable benefits and advantages after the implementation of it. The first obvious advantage and the role of infrared thermography is that infrared thermography can detect hidden defects within a building without the need to damage and penetrate the building structure. Infrared thermography is advantages for building investigations because it can detect an early defect related to building insulation such as air leakage and moisture that is not visible and cannot be seen with naked eyes which make it difficult to localize. This can allow for timely measures and action to be taken to reduce energy consumption and apply predictive maintenance. The study stated that infrared thermography is effective to identify cracks and defects in building envelopes which can allow for assessment of damage levels and indicated the necessary maintenance strategies [15]. Infrared thermography has proven effective and has a lot of advantages and potential for wide applications in various fields. It is worthy and novel to use infrared thermography for the preventative maintenance at public university. Infrared thermography enables preventive maintenance and promotes sustainability in public universities by detecting any anomalies in the mechanical and electrical systems that could lead to larger system breakdowns. Other than that, infrared thermography also contributes to the sustainable public university buildings design as it detects thermal bridges and insulation discontinuities which plays an important role in energy consumption of a building.

2.5 Challenges and Limitations of Infrared Thermography

Despite the numerous advantages of infrared thermography, it does possess some challenges and limitations that should be considered when utilizing it. The first limitations that all researchers

have been considering when conducting an experiment using infrared thermography are the environmental factors. The accuracy and reliability of the result from infrared thermography can be manipulated by environmental factors. The actual temperature of the fault area can be affected by environmental factors such as wind speed and ambient temperature of the areas [16]. Another challenge lies in the fact that the accuracy of surface temperature measurements can be influenced by sources of error that thermographers do not fully comprehend. These errors can lead to inconsistency between stationary and dynamic thermography observations [17]. In addition, when the operators of infrared thermography lack experience, the interpretation of the result from the thermal images can be prone to significant errors [18]. There are also limitations in the existing infrared thermography techniques used for measuring resistance that might hinder their practical application [19]. Infrared thermography has shown some advance potential in assessing building condition, detecting building flaws and defects despite all the challenges and limitations. In order to address this limitation of infrared thermography, researchers have proposed a variety of advancements. For example, to overcome certain limitations, an extension of the differential infrared thermography (DIT) method has been considered [20]. The use of infrared thermography in buildings is promising with potential applications in predictive maintenance and energy efficiency.

3. Methodology

3.1 Data Collection Methods

The research objective was to provide recommendations for area within the public universities that can benefit from the application of infrared thermography to enhance maintenance. The type of data collection method that was used for this research objective was qualitative method which is narrative review. The results obtained from the data was analyzed and summarized into the specific topic that will support the data of this research.

3.1.1 Case study

A case study is a type of qualitative research approach that entails an inquiry into specific person, group, organization, event or phenomenon to conduct an in-depth analysis of the subject. There is total of three public universities in Malaysia that have been chosen as the case studies. The reason for the selection of case study that was all three case studies were established for more than 50 years which can indicate the public university is an old building.

3.1.2 Narrative review

The data collection method for research was a narrative review. The narrative review highlights the significant role of infrared thermography in building maintenance, especially in preventive maintenance. It outlines various applications and benefits of infrared thermography emphasizing its utility in identifying hidden issues like moisture intrusion and assessing the condition of aging structures. The review references multiple studies to underscore the versatility and effectiveness of infrared thermography in maintenance practices.

4. Data Analysis

The data from collected literature was categorized into different potential application areas of infrared thermography within public universities. Each category was analyzed to determine the benefits that is associated with the implementation of infrared thermography in public universities.

4.1 Older Building Maintenance

All three public universities which are the public university A, B and C can implement infrared thermography for the maintenance in older building within the public universities. The public universities can enhance its maintenance by improving energy efficiency in older building. Infrared thermography can be utilized for the inspection of historical buildings and cultural heritage sites which enables the study of building structures, identification of hidden element and the assessment of damages cause by aging or environmental factors. All three public universities were established for more than 50 years which can be indicated as an old building. Many of the buildings at the three public universities were established in the 1960s and 1970s and this was the reason why the building faced significant wear and tear. It needs proper maintenance because the lack of maintenance strategy combined with natural aging accelerates the deterioration of building structure [1].

4.2 Building Envelope

For building envelope application, infrared thermography is the most effective in detecting hidden defects such as moisture intrusion. Research has emphasized the role of infrared thermography in evaluating building envelope air leakage, showcasing its potential as a forensic tool for assessing the thermal performance of building envelopes [17]. Moisture cause 75 to 80 % of defects in building envelopes and it enables the identification of potential problems since defects typically cause a disturbance in the heat flow which generates temperature differences on the surface of the elements [10]. If the object has a defect, the defect will have a periodic effect on the surface temperature distribution above it, even at low peaks. As a result, there will be a phase difference between the defective and non-defective areas [11]. Infrared thermography works by detecting any temperature anomalies in the areas which can be used to detect moisture surface because it has different thermal conductivity compared to dry surface. The thermal conductivity of water is higher that the dry building materials and when there is water in the pores of these materials, the thermal conductivity will increase, and thermal resistance will be lower [10]. Based on the observation at each case studies, the most common defects that can be found was related to moisture intrusion. Defects caused by moisture intrusion can be seen at building envelope at public universities such as mould growth especially at the exterior wall of public universities restroom. Infrared thermography can detect moisture areas with precision, recall and accuracy around 83.5, 73.5 and 72.5 % respectively in concealed areas of building structures [5]. Infrared thermography enables quick and efficient scanning of large areas which can reduce the inspection time in comparison with traditional methods [11]. Infrared thermography also enables the detection of moisture intrusion that are not visible naked eye, making it a valuable tool for identifying hidden defects within the building envelopes [21].

4.3 Mechanical and Electrical Systems

Maintaining mechanical and electrical systems is important for the efficiency in operation and by implementing infrared thermography can offer significant advantages. Infrared thermography has shown positive results for non-destructive evaluation of composite bonding structures used in electrical insulation [22]. The application of infrared thermography can be utilized in early fault detection in the mechanical and electrical systems at public universities which can prevent costly breakdowns. Infrared thermography can also be utilized for solar panel systems. Infrared thermography, renowned for its non-destructive testing capabilities, can effectively detect anomalies and defects in solar panels by measuring temperature variations [23].

All the three cases have implemented several solar panel systems across its campuses to harness renewable energy, reduce carbon emissions and serves as a practical demonstration for students and researchers. These solar panels were installed on the rooftops of key buildings including the engineering faculties at each case study. For electric power systems, infrared thermography has become an effective tool due to its high precision and non-intrusiveness in the field of preventive maintenance [24]. By detecting potential hazards such as overheating components or electrical arcing, infrared thermography helps in enhancing safety measures for maintenance personnel and preventing accidents [1]. Infrared used to inspect solar panels by identifying hotspots and defective cells which ensures optimal performance of renewable energy systems installed at the case studies.

4.4 Energy Audits

Energy audits facilitated by infrared thermography can identify areas of heat loss and energy inefficiencies in public university buildings. Infrared thermography can aid in conducting energy audits by providing insights into heat losses through building envelope [25]. Infrared thermography can detect insulation leaks. The implementation of infrared thermography in building energy audits is to identify any thermal defects that happen such as the thermal bridging, insulation level and air leakage [26]. Any areas for improvement, to reduce the energy consumption in building, can be identified by conducting an energy audit.

The improvement of sustainability of HVAC systems can help in providing health and comfort for the occupants, improved energy efficiency and reduce the environmental impact which is significant for the building [27]. Infrared thermography can also evaluate variety of building material. This is effective in the detection of moisture in various building materials, which can help in identify the areas affected by moisture that can contribute to energy loss [5]. The role of infrared thermography is that it can detect thermal bridges and energy loss due to lack of insulation in building, which can use to evaluate the building envelope [28]. By implementing the use of infrared thermography in maintenance, it can ensure energy efficiency and better maintenance and sustainability practices in public universities.

Table 1 shows the primary areas where infrared thermography can be applied within public universities and highlighting its benefits with supporting references for each application.

Table 1
Summary area for the application of infrared thermography within public universities

Area of application	Benefits	References
Older building maintenance	Improves energy efficiency in older buildings	Cadelano *et al.,* [25]
	Enables inspection of historical and cultural heritage sites	

	Identifies hidden elements and assesses damage caused by aging or environmental factors	
Building envelope	Defects hidden defects such as moisture intrusion	Garrido *et al.,* [5]; Dafico *et al*., [10], Qu *et al.,* [11], Vazquez and Thomachot-Schneider [21]
	Identifies potential problems *via* temperature differences	
	Detects moisture areas with high precision, recall and accuracy	
	Reduces inspection time compared to traditional methods	
	Identifies hidden defects not visible to the naked eye	
Mechanical and electrical systems	Offers non-destructive evaluation of composite bonding structures in electrical insulation	Guo [22]
	Detects early faults in mechanical and electrical systems to prevent costly breakdowns	
	Monitors solar panel systems for anomalies and defects	
	Enhances safety measures by detecting overheating components or electrical arching	
Energy audits	Identifies areas of heat loss and energy inefficiencies	Garrido *et al.,* [5]; Cadelano *et al.,* [25]; Asim *et al.,* [27]
	Detects insulation leaks and thermal defects	
	Improves sustainability of HVAC systems	
	Evaluates thermal bridges and energy loss due to lack of insulation	
	Ensures energy efficiency and better maintenance and sustainability practices	

5. Results and Discussion

5.1 To Provide Recommendations for Area Within the Public Universities that Can Benefit from the Application of Infrared Thermography to Enhance Maintenance

Several studies have emphasized the effectiveness of infrared thermography in detecting building envelope leaks and insulation deficiencies (Table 2). This application of infrared thermography can aim to reduce energy consumption and maintenance costs as well as improving environmental sustainability in public universities. Infrared thermography is also widely utilized for electrical system inspection. This area of application can minimize the risk of electrical failures and optimizing the campus safety which is significant for large public institutions. Predictive maintenance of HVAC systems using infrared thermography can enable public universities to plan maintenance schedules efficiently. This proactive approach helps in preventing system breakdowns and ensuring optimal maintenance performance.

Table 2
Key findings and the relevance to public universities

Study	Key findings	Relevance to Public Universities
Mahmoodzadeh *et al.,* [17]	Application of infrared thermography in detecting building envelope leaks	Reducing energy consumption, costs and improving sustainability in university campuses
Muttillo *et al.,* [14]	Use of infrared thermography for electrical system inspections	Enhancing safety and reducing downtime in campus infrastructure

Bauer *et al.*, [23]; Venegas *et al.,* [29];	Infrared thermography in predictive maintenance of HVAC systems	Cost-effective maintenance planning for university facilities

The findings suggest that infrared thermography can be an effective tool that can be utilized in many areas within the public universities that includes old building area, building envelopes, mechanical and electrical systems and energy audits. The narrative review indicates that infrared thermography is a versatile tool with multiple applications in public universities. Facility maintenance emerges as the most frequently mentioned application. Infrared thermography has a lot of potential in preventing costly breakdowns which can enhance the public universities maintenance as well as safety. Energy efficiency is another critical area where infrared thermography can provide substantial savings by identifying thermal inefficiencies. The implementation of infrared thermography in public universities faced challenges in terms of budget and cost such as the initial cost of infrared thermography equipment and the cost need for trained personnel to interpret thermal images accurately. However, by implementing infrared thermography as a predictive maintenance tool has the potential for optimizing the maintenance costs [29]. Integrating infrared thermography with existing systems can ensure the detection of maintenance issues within the public universities at an early stage which can lead to cost savings.

6. Recommendations

The area of application that can benefit from the application of infrared thermography at the three case studies is at older buildings maintenance by implementing routine infrared thermography for all campus buildings in the public universities. Additionally, utilizing infrared thermography aligns with the trend towards predictive maintenance, where maintenance activities are scheduled based on equipment condition rather than fixed time intervals [29]. Infrared thermography has shown the effectiveness for enhancing maintenance practices in public universities. Public universities can then conduct predictive maintenance after the implementation of infrared thermography. Public universities commonly rely on proactive maintenance rather than predictive maintenance. By implementing infrared thermography, public universities can swift from corrective maintenance to predictive maintenance which can lead to enhancing maintenance practices. Preventive maintenance has been recognized as a critical aspect of building management to prevent deterioration, ensure safety and maintain comfort for building occupants. This can be supported by research that proper maintenance can save the energy ranging from 1.62 to 25 % with the additional advantages such as lower emissions, restored production capacity, higher availability and higher reliability [30]. By analyzing infrared thermographic data over time, trends can be identified and predictive maintenance schedules be established based on the historical performance of electrical systems [1].

7. Conclusions

In conclusion through case studies and narrative reviews, the researchers have provided valuable insights into the benefits of utilizing infrared thermography in building maintenance practices at public universities. The findings underscore the role of technology in enhancing maintenance strategies and optimizing the operational efficiency of educational institutions. This research contributes to the body of knowledge on maintenance management in public universities and provides practical recommendations for the implementation of infrared thermography in current maintenance practices. By embracing preventive maintenance approaches and leveraging advanced

technologies like infrared thermography, public universities can strive towards achieving sustainable and world-class facilities for the benefit of students, faculty members and other staff.

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