INTERNATIONAL JOURNAL OF
MULTIDISCIPLINARY STUDIES IN ARCHITECTURE
AND CULTURAL HERITAGE

Print ISSN: 2735-4407 - Online ISSN: 2735-4415

VOLUME 7, ISSUE 1, 2024, 12 – 23.

Application of Building Management System for Sustainable Buildings: Museums Case Study

Doha Abd Elaziz Fahmy

Professor Assistant, Architecture Engineering, Faculty of Engineering, October 6 University
dohafahmey.eng@o6u.edu.eg

ABSTRACT

The study aims to gain a deeper understanding of the functions of the building management system and how it can contribute to sustainable museums. This research focuses on identifying user needs, determining BMS characteristics, and designing, installing, and operating the BMS based on existing literature. Factors such as the lack of understanding of the BMS and its capabilities, the absence of service and maintenance, and the performance of BMS vendors hinder the adoption of the BMS. This study aims to promote the use of building management systems by investigating their contribution to sustainability. It was concluded that the BMS enables uniform and effective control, monitoring, and handling of all equipment functions, facilitating maintenance and management operations. Building management systems are increasingly used in museums to ensure compliance with standards, protect assets against disasters, and provide appropriate environmental conditions and security. This enhances resource efficiency within museums and promotes sustainability.

Keywords: Sustainability, Energy, Museums, Environment, Building management system.

Introduction

Museums have the important task of preserving, interpreting, and promoting humanity's natural and cultural heritage. They are responsible for safeguarding and promoting this heritage, as well as managing the human, material, and financial resources dedicated to this purpose. Building management systems, commonly used in industrial settings, are becoming more popular in museums because they assist in fulfilling the essential functions outlined in the museum's mission. These systems play a crucial role in achieving energy and environmental objectives and strategies within museums. As a result, efforts have been focused on improving building efficiency and performance through targeted construction improvements.[1]. Construction services and systems, such as heating, ventilation, and air conditioning units, aim to enhance design quality, optimize operation, and reduce energy consumption and costs. Meanwhile, building management systems enable the monitoring, control, and management of various construction services, playing a vital role in achieving efficient interaction and integration of different power systems, controls, services, meters, and sensors. The functionalities of the system greatly benefit the field of control and management [3].

Print ISSN: 2735-4407 - Online ISSN: 2735-4415 | VOLUME 7, ISSUE 1, 2024, 12 – 23.

Building management systems (BMS) signify a recent breakthrough in facilities management technology. This advancement enables managers to remotely oversee a property's internal and external conditions via a computer interface, decreasing the need for human involvement in operational supervision. The BMS offers distinct advantages, including lower operational costs, reduced energy consumption, and streamlining the maintenance workforce required for building upkeep. Surprisingly, none of the surveyed commercial properties were equipped with fully integrated BMS technology. This indicates a limited familiarity with and utilization of building management concepts and methodologies, underscoring the necessity to establish implementation guidelines. Promoting the adoption of BMS necessitates strategic measures like raising public awareness about its advantages and providing tax incentives and exemptions to early adopters of this technology [4].

1. Building Management System (BMS)

A building management system (BMS) is a computer-based control system installed in buildings to regulate and monitor mechanical and electrical equipment. This includes ventilation, lighting, power, fire, and security systems. The system comprises software and hardware that run on computer workstations and communicate with devices using specific protocols. These functions vary from managing lighting and energy to providing security and safety. Technologies like data analytics, data acquisition, data storage, and data visualization are combined to offer high-quality, secure, and cost-effective services to occupants.

Protocols are the standard communication method among BMS components, facilitating data exchange regardless of manufacturing technologies or device isolation levels. Controlled devices include sensor systems, lighting, security systems, energy management, heating, ventilation, air conditioning systems, and monitoring systems. Building Energy Management aids building managers and owners in efficiently utilizing existing and expanding solar capacity. Implementing a BMS benefits non-residential and residential buildings by reducing energy consumption. Different management approaches can be employed depending on the building type to achieve energy efficiency objectives.

1.1 Building Management System Application

BMS is regarded as a fully operational control system. It comprises controllers, different communication devices, and a full set of operational software essential for achieving a fully operational control system. The control process consists of three steps: initially measuring the data, then processing the data with other information, and ultimately triggering the control action. This involves a control loop comprising three primary components: a sensor, a controller, and a controlled device (Figure 1). These three components, or functions, work together to regulate the environment [6].

Print ISSN: 2735-4407 - Online ISSN: 2735-4415

VOLUME 7, ISSUE 1, 2024, 12 – 23.

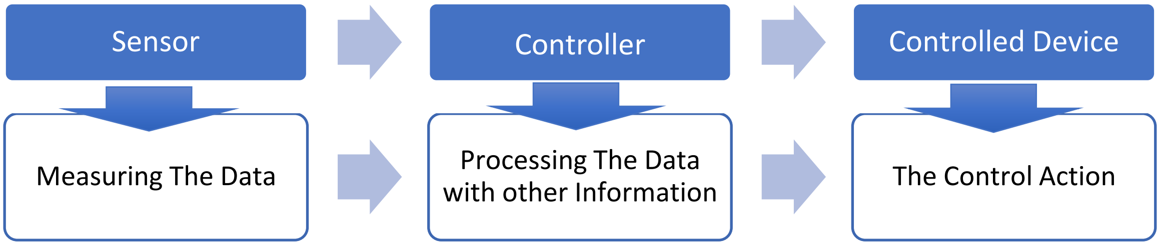

Fig (1) How the building management system works

The sensor measures the controlled medium or other control inputs in an accurate and repeatable way. For example, heating, ventilation, and air conditioning (HVAC) sensors are used to measure temperature, pressure, relative humidity, airflow status, and carbon dioxide. Additional input information (sensor data) affecting the control logic can be used, as can the status of other parameters (air flow, water flow, current) or safety (fire, smoke, high or low-temperature limits, or any number of other factors that may include physical parameters). The controller processes the sensor data, applies the control logic, and creates the output action. This signal may be sent directly to the device being controlled, or first to other logical control functions, and finally to the device being controlled. The controllers' function is to compare their input from the sensor to a set of instructions, such as setpoint, and then produce an appropriate output signal or control response (along with other logical decisions unique to the specific control application). Ultimately, the controlled device reacts to the signal from the control device, applies the control logic, and modifies the state of either the controlled medium or the final device [7]. BMS is included in the building's construction plan. In cases where the BMS should be installed in a fully equipped existing building, there are more flexible solutions connecting software and hardware. Therefore, many different protocols, standards, and programs are available on the market to cover both scenarios, such as Profibus, XML, BACnet, and KNX. The DMS selection is based on the needs and budget of the potential client or organization [8].

1.2 Building Management Operating Systems

The functional building has mechanical and electrical services and equipment that are necessary for the facility's operation and meeting the institution's mission. Systems can develop through the Internet of Things [9]. These include:

- Illumination system
- Conditioning and heating systems
- Ventilation system
- Electric power control system
- Microclimate system
- The security and observation system
- The fire alarm system
- Lifts, elevators, etc.

Print ISSN: 2735-4407 - Online ISSN: 2735-4415 | VOLUME 7, ISSUE 1, 2024, 12 – 23.

The systems require installed sensors, IoT devices, smart meters, building automation, and control systems. In recent years, significant advancements have been made in building operating systems to ensure appropriate design, establishment, and functionality, enhance building performance, optimize system operations, and meet energy and environmental objectives [10].

1.3 Improve operating efficiency

Building management systems help to improve the efficiency of operation inside the building by achieving better performance by managing the special protection and energy systems and the building's own systems, as shown in (Figure 2), through a single integrated network that coordinates and organizes all information logically through software and its capabilities based on innovative information technology [11], through the following: By accurately measuring service and energy consumption, the consumption of services typically adheres to a standard model. This enables recording actual consumption data and facilitates comparison with the standard consumption model. Modern technologies in systems help to have tremendous flexibility in the possibility of modifying programs quickly and easily according to changing requirements, and system changes can be tracked and stored in emergency situations [12]. The purpose of monitoring and setting goals is: By monitoring the alerts and the possibility of determining the alarm conditions and transmitting them to ensure a quick response and continuation of work, the monitoring and remote site connection process also helps to assess the causes of the alarm and respond to it by dealing with alerts or checking the system.

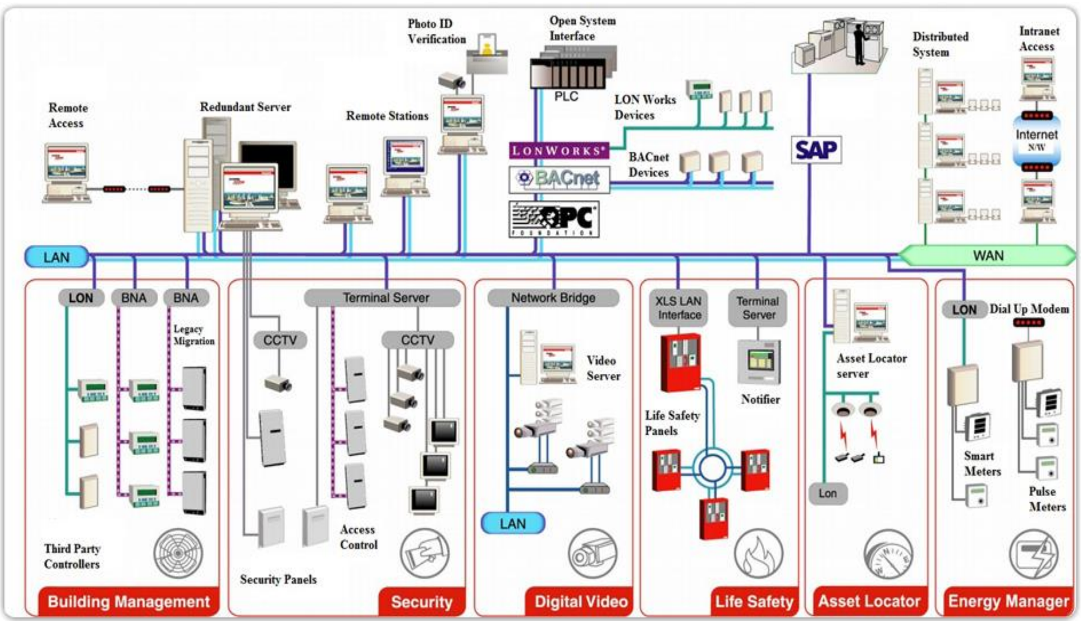

Fig (2) operating systems of buildings

Print ISSN: 2735-4407 - Online ISSN: 2735-4415

VOLUME 7, ISSUE 1, 2024, 12 – 23.

2. Sustainability in Management Systems

The Sustainability Improvement Management System aims to enhance building sustainability by integrating quality, environmental, social responsibility, and occupational health and safety management systems with lean manufacturing. Enhance building sustainability performance by creating synergies and reducing waste, duplication, and bureaucratic processes [13].

2.1 Energy management system

Energy management systems help to operate the building's energy consumption components more efficiently, reducing operational costs and increasing productivity. The building management system [14] monitors and controls the building's air conditioning and lighting devices, which are among the most important elements.

- The task involves providing the building's air conditioning system with multiple sensors and controllers for temperature and pressure and then connecting them to control programs.
- Implement lighting systems with sensors that measure lighting intensity, control lighting as needed in spaces, and integrate natural and artificial lighting.

2.2 Management of cooling and heating systems

The cooling and heating systems regulate the airflow throughout the building. They adjust the combination of heating and cooling to maintain the desired room temperature using temperature controls and operating timings. Using systems like the Excise Movement and Control System (EMCS) allows energy dissipation and consumption to be avoided, resulting in savings in the usage of cooling and heating systems [15]. Implementing intelligent monitoring technology, either locally or centrally, helps to efficiently monitor energy consumption and control devices automatically through local devices or a centralized control room[16].

2.3 Lighting Equipment Management

There are various ways to manage and control lighting, including behavioral patterns such as turning off lamps in unused areas, design methods such as utilizing natural lighting, and modern technologies. Technical methods are employed to regulate the lighting distribution and provide multiple illumination levels in a confined space. Automated control of lighting equipment by installing timers and using occupancy sensors and photocells is considered more efficient [17].

Print ISSN: 2735-4407 - Online ISSN: 2735-4415

VOLUME 7, ISSUE 1, 2024, 12 – 23.

3. Building Management Systems in Museums

Building Management Systems (BMS) are increasingly popular in museums today. They are used to fulfill the basic functions specified in the museum's mission, which include compliance with international institutional standards of health, safety, and accessibility for employees and visitors. Additionally, BMS protects the public, employees, collections, and other resources against natural and man-made disasters. The systems also provide appropriate environmental conditions and security to protect collections from theft or damage in exhibits, exhibitions, work areas, storage, and during transportation [18].

3.1 Case study: Archaeological Museum of Thessaloniki

The Archaeological Museum of Thessaloniki is a state museum under the Ministry of Culture (Figure 3), which became an independent entity in 2001. It has been recognized as a listed monument of modern heritage, representing architectural modernism in Greece. The museum's collections consist of artifacts and assemblages from excavations carried out by the Greek Antiquities Service in Macedonia since 1912. Additionally, the museum displays items from private collections donated to the museum over time [19].

Fig (3) Archaeological Museum of Thessaloniki

Print ISSN: 2735-4407 - Online ISSN: 2735-4415 | VOLUME 7, ISSUE 1, 2024, 12 – 23.

3.1.1 Building Management System

The museum building management relies on three different systems. The Tracer Summit® building automation system uses the BACnet protocol to control, monitor, and optimize electrical power, lighting, heating, ventilation, air conditioning, water supply, and other automation systems like elevators. Energy management is also used to monitor peak demand, detect currents and leaks, measure power consumption, manage electricity distribution, and record data (Figure 4). For lighting control, the system provides constant and timed lighting, automatic lighting, switching and dimming, and creating light scenes. It also controls curtains and shutters, tracking sunlight, and protecting from wind and rain. Lastly, the HVAC system manages room/area temperature and humidity control, centralized and automatic control, timed operating modes, and safety programs [18].

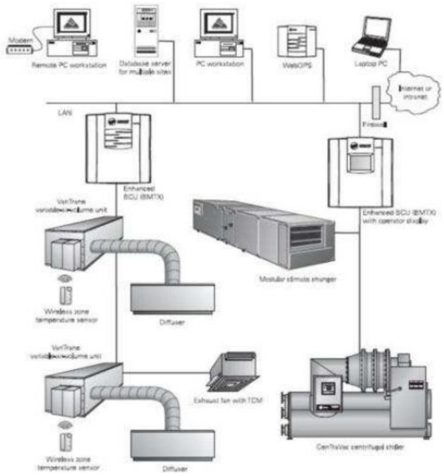

Fig (4) A typical example of Tracer Summit® architecture.

3.1.2 Energy Management System Control

The system uses the BACnet protocol to control, monitor, and optimize electric power, illumination, HVAC, water supply, and other automation systems, such as lifts and elevators. For energy management, it is used to monitor peak demand, detect current leaks, meter consumed energy, perform load shedding (rationing of available electricity), and log the collected data. It is integrated with the Building Management System (BMS) to control lighting efficiently. Automated lighting activation occurs upon detecting human presence, ensuring energy conservation. Time profiles are programmed to align with working hours, switching off lights in offices and conservation studios while activating security lights.

3.1.3 Operation Management

Building Management Systems (BMS) lead to lower operating costs and significant energy savings by optimizing resource usage and proper maintenance. critical environments are closely monitored, and utility costs are managed effectively. Maintenance information is readily accessible, allowing for scheduled equipment maintenance and minimizing staff downtime. Building Management Systems (BMS) save time, increase flexibility, and enable rapid alarm indication and fault diagnosis. By connecting all communication devices, they reduce design and installation time. BMS integrates products of different manufacturers and communication media into one installation and a centrally managed platform. It also facilitates accurate reporting for process validation through secure and paperless record-keeping.

Print ISSN: 2735-4407 - Online ISSN: 2735-4415

VOLUME 7, ISSUE 1, 2024, 12 – 23.

3.2 Case study: Melbourne Museum

The Melbourne Museum is an Australian museum located in Carlton Gardens (Figure 5). It features a contemporary gallery that houses natural and cultural history artifacts. In 2016, the museum invested significantly in a new building management system (BMS) to meet the evolving demands of managing a complex public asset, particularly one that contains sensitive and significant cultural artifacts.

Fig (5) Melbourne Museum

3.2.1 Building Management System

The museum employed CIM for BMS commissioning validation using fault detection and diagnosis (FDD) and data analytics. It was on track to reduce its annual energy bill by $203,000 – a 20% reduction in electricity and 28% in gas. Additionally, the museum achieved a $35,000 saving from resetting its demand threshold. All of this was achieved for a 4.5-month investment payback, a payback that comes three to four times faster than many other industry practices.

- energy optimization, specifically in gas and electricity usage.
- maintenance-related FDD.
- maintaining optimum moisture content.

3.1.2 Energy Management System Control

Temperature and humidity are closely connected, making it essential to control both. CIM has created a user-friendly dashboard to display easily understandable summaries of humidity KPIs for each zone and to point out areas needing immediate attention and action. The Melbourne Museum achieved $163,890 in energy savings, including a 26% reduction in electrical energy usage and a 15% decrease in gas consumption compared to the standard model. This led to a five-month investment payback and an 11.9% demand reduction, resulting in $24,090 in annual savings [20].

Print ISSN: 2735-4407 - Online ISSN: 2735-4415

VOLUME 7, ISSUE 1, 2024, 12 – 23.

3.3 Case study: Museum Hermitage Amsterdam

The Hermitage Museum is located in Amsterdam (Figure 6), the Netherlands. The museum is housed in a late 17th-century building that has been changed frequently for centuries. It was substantially renovated in 1970 when it was transformed into a nursing home. The most recent renovation dates from 2007–2009, when the building was transformed into a state-of-the-art museum. The historical building envelope was conserved and insulated from the inside; floor heating was applied in the nonexhibition areas, such as the restaurant and foyer.

Fig (6) Museum Hermitage Amsterdam

3.3.1 Building upgrading systems

The exterior facade has been restored to maintain the historical appearance, while the rest of the building has been reconstructed to suit the museum's needs better. The building envelope has been improved to a high insulation level: the external walls have been insulated from the inside (total thermal resistance 3.7 m2K/W), the glazing has been upgraded to double glazing with reflective coatings (U-value 1.8W/m2K), and significant effort has been put into making the building envelope airtight (infiltration rate < 0.1 h−1) [21].

The layout of the building is shown in Fig. 1a. It has a symmetrical floorplan, with two nearly identical exhibition wings recognizable by the glass roof on the left and right sides in Fig. 1a. The central part at the top of Fig. 1a houses the main entrance, a restaurant, an auditorium, and restrooms.

3.1.2 Energy Management System Control

To create a stable environment with no seasonal variations, the museum maintains an indoor climate of 21°C and 50% relative humidity, with minimal fluctuations permitted.The Hermitage Amsterdam has observed significant energy savings due to relaxing indoor climate conditions for temperature and relative humidity (RH). The museum's well-insulated structure has resulted in substantial energy savings. Additionally, museums with modern building envelopes can achieve the highest energy savings by adjusting indoor climate specifications. Further research is needed to study the effects of Class A with seasonal adjustments, but this was beyond the study's scope due to associated degradation risks. Due to control system

Print ISSN: 2735-4407 - Online ISSN: 2735-4415

VOLUME 7, ISSUE 1, 2024, 12 – 23.

limitations, comfort requirements determined temperature setpoints 24 hours a day. Intensive monitoring and control of fluctuations induced by the transition from closing to opening hours are essential [22].

Conclusion and Discussion

Museums depend on Building Management Systems (BMS) to enhance building efficiency. BMS allows for monitoring and controlling services such as heating, ventilation, and air conditioning. These systems utilize computer-based control systems to regulate and monitor mechanical and electrical equipment. They are instrumental in reducing energy consumption and costs, as well as enhancing overall design quality. The building management system enables uniform control, monitoring, and effective equipment management, facilitating maintenance and improving resource use efficiency.

BMS incorporates data analytics, acquisition, storage, and visualization to provide high-quality, secure, and cost-effective services to occupants. It also uses specific protocols for communication among components, allowing data exchange across different technologies. Building Energy Management helps building managers efficiently utilize solar capacity.

Energy management systems help buildings operate more efficiently by controlling air conditioning, lighting, heating, and ventilation. They help reduce operational costs and monitor energy consumption, leading to significant savings by:

- Use building management systems to control power, lighting, HVAC, and energy consumption, which leads to cost savings and efficient resource management.
- Building management system leading to a reduction in electricity and gas usage through improved commissioning validation and data analytics.
- achieved significant energy savings by adjusting indoor climate conditions.
- The well-insulated structure has led to substantial energy conservation.

BMS are considered fully operational control systems, with the control process consisting of measuring data, processing it, and triggering control actions. Building Management Operating Systems cover essential building operations, including insulation, conditioning, heating, ventilation, power control, security, fire alarms, and elevators. These systems utilize sensors, IoT devices, smart meters, and building automation to improve efficiency and sustainability.

Print ISSN: 2735-4407 - Online ISSN: 2735-4415

VOLUME 7, ISSUE 1, 2024, 12 – 23.

References:

[1] Dascalaki, E. G., Argiropoulou, P., Balaras, C. A., Droutsa, K. G., & Kontoyiannidis, S. (2021). Analysis of the embodied energy of construction materials in the life cycle assessment of Hellenic residential buildings. Energy and Buildings, 232, 110651.

[2] Mirnaghi, M. S., & Haghighat, F. (2020). Fault detection and diagnosis of large-scale HVAC systems in buildings using data-driven methods: A comprehensive review. Energy and Buildings, 229, 110492.

[3] O'Grady, T., Chong, H. Y., & Morrison, G. M. (2021). A systematic review and meta-analysis of building automation systems. Building and Environment, 195, 107770.

[4] Ogolla, W., & Kieti, R. (2022). Application of building management system (BMS) in commercial property management in Kenya. In Understanding African Real Estate Markets (pp. 188-200). Routledge.

[5] Luzi, M., Vaccarini, M., & Lemma, M. (2019). A tuning methodology of Model Predictive Control design for energy efficient building thermal control. Journal of Building Engineering, 21, 28-36.

[6] Mariano-Hernández, D., Hernández-Callejo, L., Zorita-Lamadrid, A., Duque-Pérez, O., & García, F. S. (2021). A review of strategies for building energy management system: Model predictive control, demand side management, optimization, and fault detect & diagnosis. Journal of Building Engineering, 33, 101692.

[7] O'Dwyer, E., Pan, I., Charlesworth, R., Butler, S., & Shah, N. (2020). Integration of an energy management tool and digital twin for coordination and control of multi-vector smart energy systems. Sustainable Cities and Society, 62, 102412.

[8] BACnet Committee – Website of the BACnet Committee (ASHRAE SSPC 135) , accessed April 2024.

[9] Hahm, O., Baccelli, E., Petersen, H., & Tsiftes, N. (2015). Operating systems for low-end devices in the internet of things: a survey. IEEE Internet of Things Journal, 3(5), 720-734.

[10] Lucchi, E. (2020). Environmental risk management for museums in historic buildings through an innovative approach: a case study of the Pinacoteca di Brera in Milan (Italy). Sustainability, 12(12), 5155.

[11] City of Melbourne, Building Management Systems (BMS), https://www.melbourne.vic.gov.au/SiteCollectionDocuments/bms-the-basics-explained.pdf, accessed June 2024.

[12] Oti, A. H., Kurul, E., Cheung, F., & Tah, J. H. M. (2016). A framework for the utilization of Building Management System data in building information models for building design and operation. Automation in Construction, 72, 195-210.

[13] Souza, J. P. E., & Alves, J. M. (2018). Lean-integrated management system: A model for sustainability improvement. Journal of cleaner production, 172, 2667-2682.

Print ISSN: 2735-4407 - Online ISSN: 2735-4415

VOLUME 7, ISSUE 1, 2024, 12 – 23.

[14] Seferlis, P., Varbanov, P. S., Papadopoulos, A. I., Chin, H. H., & Klemeš, J. J. (2021). Sustainable design, integration, and operation for energy high-performance process systems. Energy, 224, 120158.

[15] Arteconi, A., Mugnini, A., & Polonara, F. (2019). Energy flexible buildings: A methodology for rating the flexibility performance of buildings with electric heating and cooling systems. Applied Energy, 251, 113387.

[16] Ghilardi, L. M. P., Castelli, A. F., Moretti, L., Morini, M., & Martelli, E. (2021). Co-optimization of multi-energy system operation, district heating/cooling network and thermal comfort management for buildings. Applied Energy, 302, 117480.

[17] Zou, S. J., Shen, Y., Xie, F. M., Chen, J. D., Li, Y. Q., & Tang, J. X. (2020). Recent advances in organic light-emitting diodes: toward smart lighting and displays. Materials Chemistry Frontiers, 4(3), 788-820.

[18] Karolidis, D. (2009, January). A report on Building Management Systems in museums, with a reference to the Archaeological Museum of Thessaloniki. In BMS Group meeting, Amsterdam.

[19] http://odysseus.culture.gr/h/1/eh151.jsp?obj_id=3332, accessed June 2024.

[20] CIM, website https://www.cim.io/case-studies/case-study-melbourne-museum, accessed June 2024.

[21] M.P.E. Maas, Optimizing Cimate Control Systems for Museums, University of Technology Eindhoven, 2012.

[22] Kramer, R. P., Schellen, H. L., & Van Schijndel, A. W. M. (2016). Impact of ASHRAE's museum climate classes on energy consumption and indoor climate fluctuations: Full-scale measurements in museum Hermitage Amsterdam. Energy and Buildings, 130, 286-294.