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ADOPTING SMART BUILDING CONCEPT IN HISTORICAL BUILDING: CASE OF ABU JABER MUSEUM, JORDAN

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Abstract

Introduction: Heritage conservation attracts wide attention worldwide. Jordan has many heritage buildings that were preserved, rehabilitated, and adapted to new functions. However, these conservation efforts could not solve the energy consumption problem or maintain the economic and financial balance, thus reducing building efficiency, slowing down the conservation activity, and forcing us to consider new solutions, especially since Jordan has limited energy sources. Integrating smart technologies in historical buildings is widely effective in achieving the sustainability of their historical, symbolic architectural values. **Purpose of the study:** We aimed to explore the potential integration of smart technologies in cultural and heritage buildings. **Methods:** We suggested an alternative solution — adopting the smart building concept in the Abu Jaber Museum in Al-Salt (which recently got on the UNESCO World Heritage List since it has more than 1000 heritage buildings), using an automated lighting control system. **Approach:** We deployed the qualitative method and case study approach to investigate the potential of adopting the smart building concept in the historical building in Al-Salt, Jordan. The study sheds light on the possibilities of utilizing smart technologies in historical buildings in Al-Salt. The findings indicate that smart technologies can offer great opportunity in preserving the architectural heritage and raising the efficiency of heritage buildings. **Novelty:** The study provides a framework based mainly on automated lighting systems in historical buildings. For the first time, the focus was on historical buildings in Jordan and their performance.

Keywords

Historical buildings, lighting, smart building, conservation, Jordan.

Introduction

The world has been going through rapid transformation, especially in the past 20 years. The environment is being damaged significantly, and we are starting to run out of energy sources. Because of that, the main concern worldwide is to protect the environment and save energy as much as possible (Anson, 2014). That is why the concept of sustainability and green cities is being considered in most countries.

Jordan has many heritage buildings with values that cannot be overlooked and must be maintained and integrated with sustainable development plans. Therefore, heritage conservation is a major concern of the government in Jordan in respect to maintaining the value of historical buildings (Akram et al., 2016; Al-Adayleh, 2021). A great number of historical buildings in Jordan have been conserved and adapted to new functions to revitalize the soul of those places. However, like most countries in the world, Jordan is facing a major issue, which is the low efficiency of historical buildings caused by the lack of utilities and energy consumption problem, making it necessary to integrate traditional conservation methods with new approaches in order to solve this crucial issue (Al-Adayleh, 2021).

The study addresses the city of Al-Salt in Jordan, recently put on the UNESCO World Heritage List for its rich history. We chose the Abu Jaber Museum to explore the possibility of installing an automated lighting control system to improve the efficiency of the building. With a new automated lighting control system, we could ensure its continuous maintenance and preserve the memory of the past for the next generations. However, the building is characterized by degrading utilities.

To solve the problem, we will provide an alternative solution to enhance the quality of the Abu Jaber Museum. By applying the smart building concept to the Abu Jaber Museum, it is possible to make it more comfortable and safer for visitors. In addition, this will surely increase the number of visitors to the building. The main problem of the Abu Jaber Museum is the need for lighting (either natural or artificial) and air conditioning.

Our objective was to select a suitable lighting control system to minimize energy consumption and, as a result, enhance the accessibility of historical buildings for future generations.

Literature Review

Studies addressing the use of smart building technologies in heritage buildings, aimed to increase their efficiency and solve the energy consumption issue, are quite limited. There is still a great deal of effort to be done in this area.

Angelidou et al. (2017) investigated how to enhance the historical and cultural heritage of cities using smart city tools, solutions, and applications. They explored the incorporation of the historical and cultural heritage within three smart city strategies, and concluded that cultural heritage should be systematically exploited and formally incorporated in smart city initiatives. According to Pierucci et al. (2018), smart building-integrated adaptive technologies show benefits in terms of comfort and operational energy when compared to traditional ones.

Studies and practices have shown that it is possible to improve efficiency and energy consumption in historical buildings by integrating the smart building concept into such buildings. Several successful attempts in implementing smart technologies in historical buildings have proven their positive impact on the historical value and uniqueness of such buildings. One of those successful examples is the Renwick Gallery of the Smithsonian American Art Museum (Washington DC, United States). It was built by the architect James Renwick Jr. in 1859 (Figure 1).

It was restored for the first time in the 1960s as an art gallery. During the 2011 Washington D.C. earthquake, the building was damaged. As a result, in 2013, it was closed for renovation and re-opened only in 2015. Figure 2 below shows the floor plans of the Renwick Gallery of the Smithsonian American Art Museum with zoning using color legends.

As shown in Figure 2, the building has three floors. Recently, smart technologies were integrated in the building to improve its efficiency. The focus was on the integration of electrical and mechanical systems, namely, the installation of LED lighting, phone, and information systems, the introduction of climate control and relevant infrastructure. As a result of smart technologies adoption, the museum got a rating of 9.74% using the smart building guide. All these measures significantly reduced the environmental footprint of the building. Besides, energy consumption decreased by ±50% although the number of visitors increased.

Another great example of smart technologies use in heritage buildings can be found in Águeda, Portugal. In 1834, this historical city built on a foundation of successive Celt, Turduli, and Greek inhabitants since 370 BC, became a municipality. The city is considered the first smart heritage city in Portugal. It was the first to adopt energy-saving, lighting, and air conditioning systems in its heritage buildings and public spaces. The municipality focused on the participation of the population, providing them with interactive mechanisms so as to create a connection to the town. According to the latest records, Águeda achieved a reduction of 20% in greenhouse gas emissions and aiming to reach 33% in 2022.

The results of various attempts show that the implementation of smart technologies in historical buildings is an efficient approach that helps enhance their historical value and reduce energy consumption

Figure 1. Renwick Gallery of the Smithsonian American Art Museum before and after rehabilitation. Source: WBDG (2017)

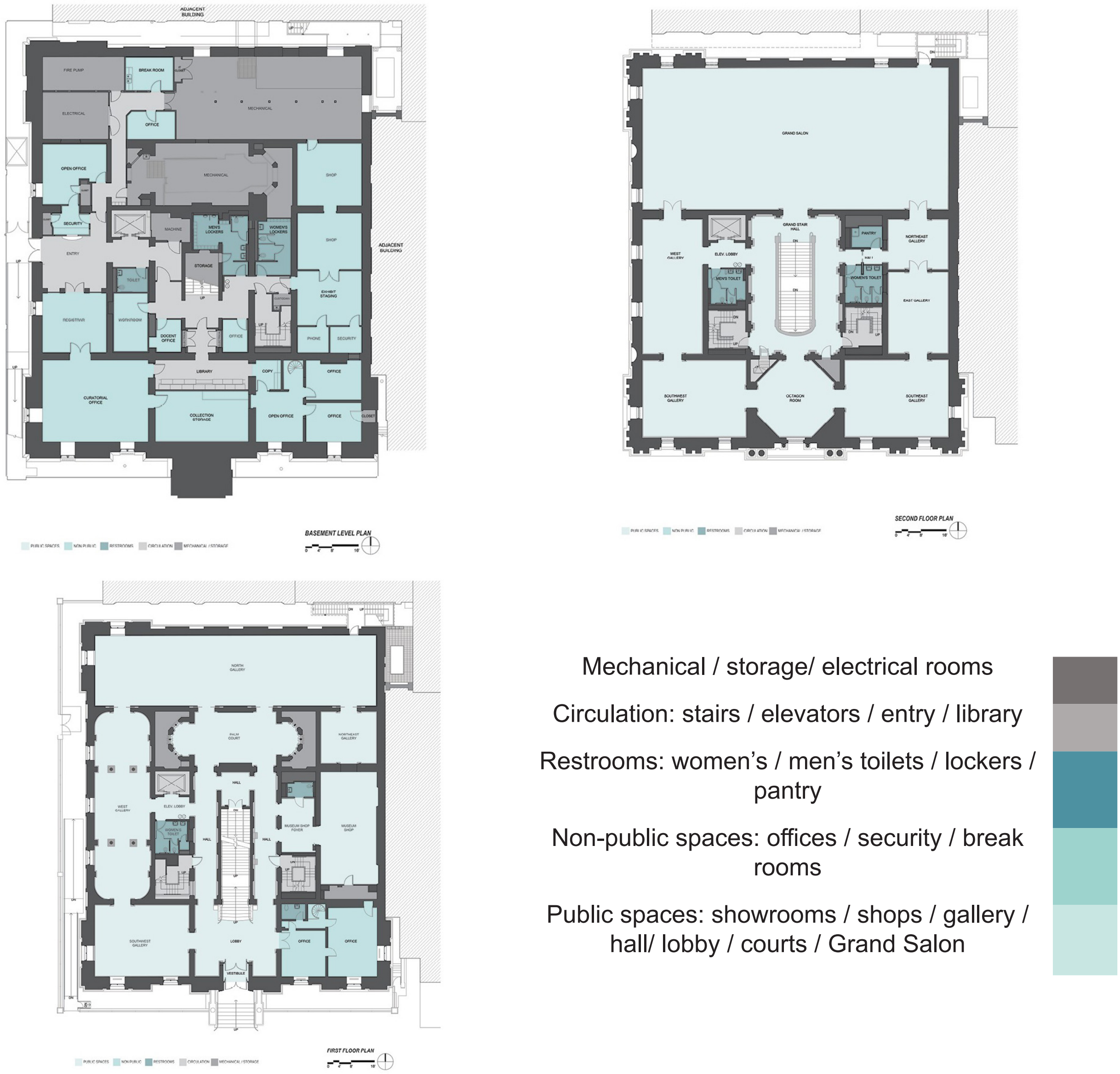


Figure 2. Floor plans of the Renwick Gallery (basement, first floor, and second floor). Source: WBDG (2017)

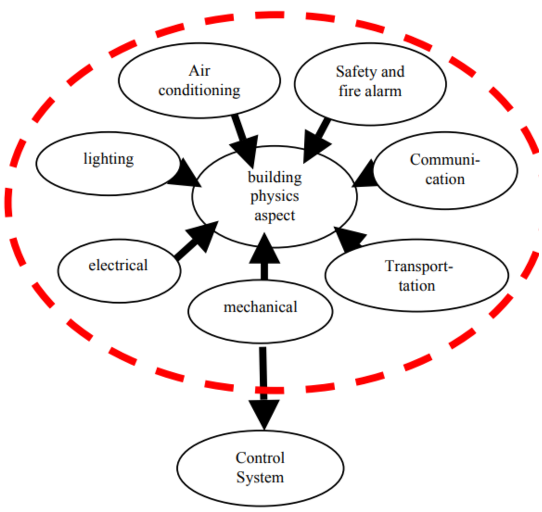


Figure 3. Smart building concept aspects. Source: Purwantiasning and Bahri (2017)

costs, while preserving the architectural heritage. As the smart heritage literature continues to grow and further applications are developed, it seems likely that it will dominate the innovative discussions of the heritage discipline and formalize alongside smart mobility and smart infrastructure.

Methodology

Our qualitative study was based on two methods: descriptive and analytical. Among other things, we also needed to gain a deep understanding of the "smart building" and its physical characteristics with a focus on the lighting system. For a qualitative analysis, we considered several previous attempts of adopting smart technologies in historical buildings. The goal was to suggest a solution or framework for integrating an automated lighting control system, using Bait Abu Jaber in Al-Salt, Jordan, as a case study. In the course of our work, we analyzed some previous studies and used the inductive approach. We performed a pilot survey to choose an appropriate building based on observations over heritage conservation projects in Al-Salt.

The criteria for choosing a building were as follows:

1. Age: 80–100 years old.
2. Landmark: not abandoned, occupied by local community, contributing to social-economic development.
3. Architecture: a distinctive architectural style.

Materials and Methods

1. Smart Building Concept

The "smart building" term has several definitions proposed. According to one of the definitions (Al-Omari, 2007; Brusaporci and Maiezza, 2021), a smart building is any structure that uses automated processes to automatically control the building's operations, including heating, ventilation, air conditioning, lighting, security, and other systems. This definition is close to another one (Gunatilaka et al., 2021; Khoshelham, 2018): a smart building is a building, which is equipped with fully automated building service control systems. According to Omar (2018), a smart building is a building that has the ability to learn and take into account its users' interactions with the space.

In conclusion, we can say that a smart building is a building that uses technology to enable efficient and economical use of resources, while creating a safe and comfortable environment for its occupants. Smart buildings utilize a wide range of existing technologies and are designed or retrofitted in a way that allows for the integration of future technological developments. Internet of Things (IoT) sensors, building management systems, artificial intelligence (AI), and augmented reality are a few of the mechanisms and robotics that may be used in a smart building to control and optimize its performance.

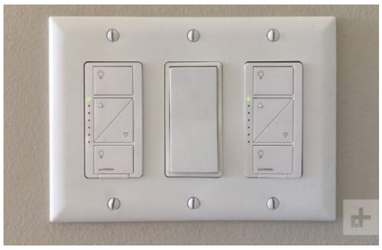
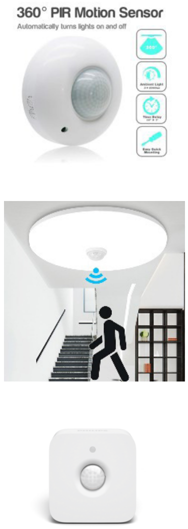
2. Smart Heritage Building Concept

Over the past 15 years, a great number of academic literature records highlighted smart heritage. As we can see, researchers (Batchelor et al., 2021; Purwantiasning and Bahri, 2017) referred to smart heritage as "the use of technology to optimize decision making on the use and management of heritage buildings". Researchers also mentioned that "smart heritage focuses on adopting more participatory and collaborative approaches, making cultural data freely available (open), and consequently increasing the opportunities for interpretation, digital curation, and innovation" (Batchelor et al., 2021; Purwantiasning and Bahri, 2017). The majority of literature sources identify smart heritage as "offering an innovative new frontier in the convergence of smart technology and heritage disciplines". When it comes to applying the smart building concept, several aspects should be taken into consideration (Khoshelham, 2018; Purwantiasning and Bahri, 2017). Those aspects are lighting, air conditioning, safety and fire alarm systems, communication, transportation, mechanical (plumbing, etc.), and electrical.

By lighting we mean an automated lighting system to reduce energy costs and improve sustainability. Any lighting system should include several main components: a switch, a dimmer, sensors, and programmers (Latifah, 2015). Each of them are described in detail in the table below.

Table 1. Components of a lighting system (compiled by the authors, 2022)

Name	Description	Image
Switch	A Wi-Fi enabled device that allows you to control the light.	 Figure 4. Wi-Fi switch. Source: LoraTap (2022)

Dimmer	A device used to adjust the brightness of the light.	 Figure 5. Light control dimmer. Source: Digital Trends (2022)
Sensor	A device used to detect and convert light energy into electronic signal depending on a user's motion. Provides self-identification, smart calibration.	 (a) (b) (c) Figure 6. Light sensors: (a) a PIR sensor, (b) a motion sensor, (c) a lux sensor. Source: Walnut Innovations (2022)
Programmer	A device used to control lights in particular conditions.	

3. Sensor Types

1. PIR: (passive infrared sensor) an electronic sensor that measures infrared (IR) light radiating from objects. It can detect movements of objects and radiant heat emitted from them. The sensor ensures auto-switching of lights or other fixtures based on human occupancy in residential and commercial buildings.

2. Lux sensor: concerned with the amount of light falling on a surface (light intensity).

3. Motion sensor: detects movement in and around your home and triggers an action in response. Motion sensors are recommended to be placed at least 6–8 feet off the ground.

Case study of the Abu Jaber Museum (Bait Abu Jaber), Al-Salt

Since the study addressed historical buildings in Jordan, we decided to shed new light on Al-Salt, which was recently (in 2021) inscribed on the World Heritage List by UNESCO. The city has a high potential value, which is due to dense heritage buildings (the number of which exceeds 1000): churches, mosques, and residential buildings aged more than 100 years (Khirfan, 2013). They all were built from yellow stone, and that distinguishes the city from the others. We chose the Al-Salt historical museum (Bait Abu Jaber) as a case study to apply the smart building concept to. According to Khirfan (2013), this historical museum was initially supposed to highlight "the Golden Age of Salt".

Bait Abu Jaber was built in the late 1800s as a residential house for the Abu Jaber family. It is one of the oldest buildings in Al-Salt, which was constructed in two phases: the first phase was completed in 1896, and the second phase was completed in 1902 with a new floor added. The building has a thick wall of 60–100 cm and a cross vault roof (Figures 7–8).

In 2010, the building was rehabilitated and transformed into a museum (Figures 9–10). Its location in the center of Al-Salt has a vital and strategic role since the museum is expected to attract visitors, while preserving the historical value of the building.

Results and Discussion

The Abu-Jaber residence is a significant residential compound in the city of Salt, the former capital of Jordan. It is where Prince Abdullah resided upon the founding of Jordan as a state in 1923. Besides, it is one of the finest examples of a merchant house of the 19th century, incorporating architectural detailing from the greater Syria region in addition to Europe. Its architecture represents the golden age of Salt, when the city was the hub of commercial, political, social, and artistic activity. It was built in stages incorporating the courtyard house and the three-bay houses on its floors (Malhis and Al-Nammari, 2015).

When analyzing the building, we found out that despite great conservation efforts applied to the building, its efficiency is low, and the museum lacks utility services since the maintenance is too expensive. Besides, more than 38% of its income are spent on energy, which is quite high percentage. Therefore, we intended to provide an alternative solution to this issue, which would help increase the efficiency of historical buildings. The approach we used can be seen as a two-stage process: documenting and assessing the current state of the building in terms of lighting; preparing a plan for the installation of an automated control system in the building. Figure 11 shows that the south elevation of the museum has small, narrow openings. Figure 12 shows that the east and west sides of the museum are not that wide to let inside some significant amount of natural light. In other words, the light intensity in the building is low.

Information on light intensity standards for various spaces can be found in the IES Lighting Handbook (KUPDF.NET, 2018). The recommended level of light intensity for museums is 300–500 lux. However, the level of light intensity in Bait Abu Jaber corresponds to that suitable for residential buildings. In other words, it does not meet the requirements of the standards and is not enough for a museum. Figure 13 shows that the level of light intensity in the museum rooms is low.

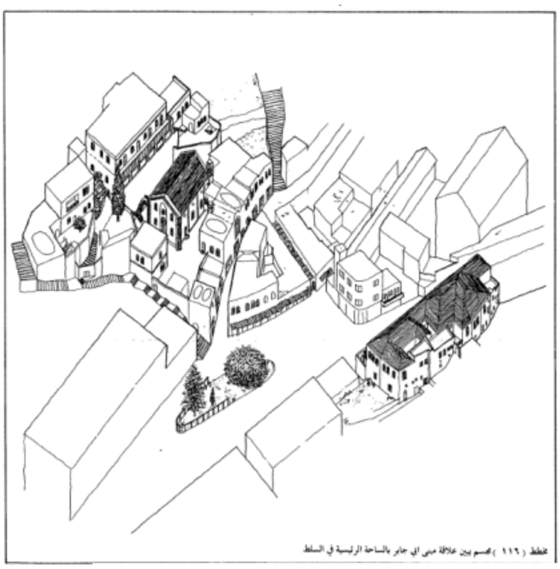
With that in view, to meet the requirements of the standards for lighting in a museum, we suggest using a smart lighting system that includes the following three components:

People's movement through the museum shows that some rooms/spaces require a different level of lighting because of their nature. Thus, it is required to enhance lighting in the museum to make the area more comfortable for visitors. That is why we decided to suggest installing a motion sensor to ease the detection of visitors' movement.

To ensure maximum performance, such sensors should be placed in the following locations:

Figure 7. Exterior of the Abu Jaber Museum. Source: Turath office. Documents on the Abu Jaber Museum. 2021

Figure 8. Exterior of the Abu Jaber Museum. Source: Turath office. Documents on the Abu Jaber Museum. 2021



Figures 9–10. Location of the Abu Jaber Museum in Al-Salt. Source: Turath office. Documents on the Abu Jaber Museum. 2021

Figure 11. South elevation of the Abu Jaber Museum with small, narrow openings. Source: Malhis and Al-Nammari (2015)

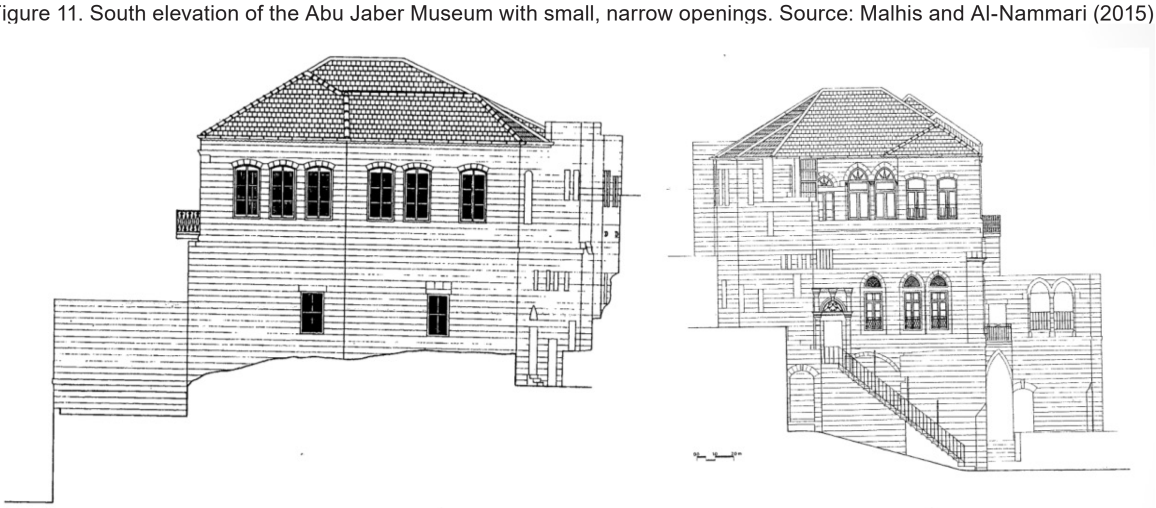


Figure 12. East and west elevations of the Abu Jaber Museum. Source: Malhis and Al-Nammari (2015)

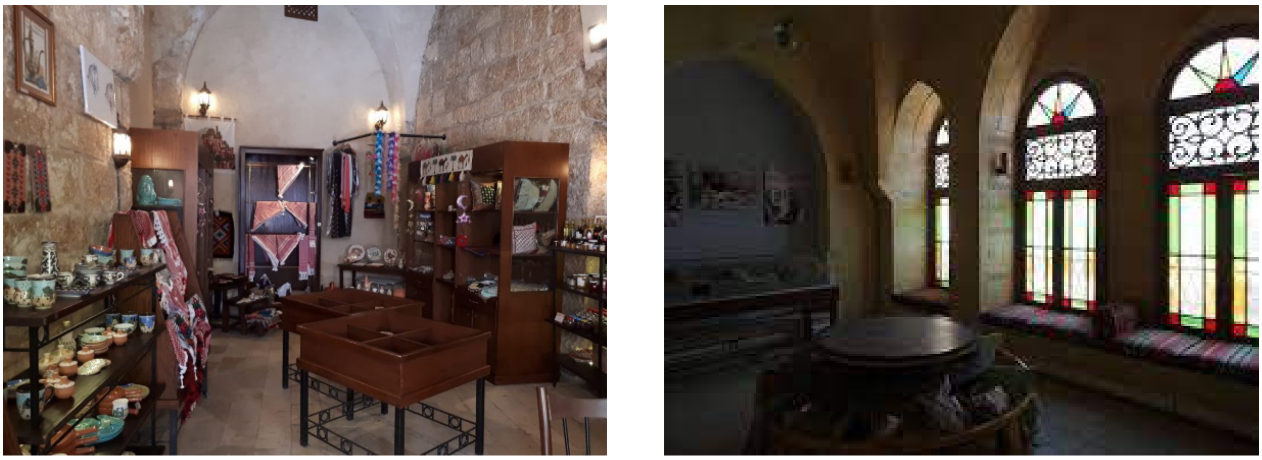


Figure 13. Photos of the Bait Abu Jaber interior, showing the actual state of affairs in terms of light intensity. Source: Turath office. Documents on the Abu Jaber Museum. 2021

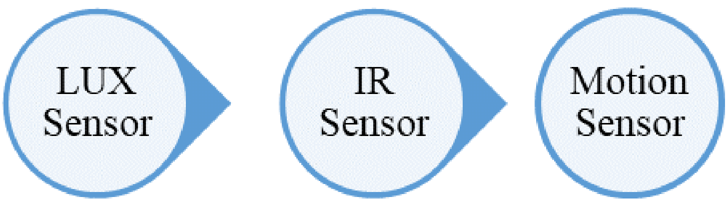


Figure 14. Smart lighting system suggested by the authors (2021)

Corners: these locations ensure the widest possible view of the space below (provided that they are directed at the doorway).

Front and back doors: placing motion sensors above doorways keeps them out of sight and makes it nearly impossible for intruders to enter without setting off the alarm.

High-traffic areas: equipping stairways, main hallways and other high-traffic areas with motion sensors ensures that intruders trigger the alarm regardless of where they're trying to go.

Near valuables: putting a motion detector near or behind valuable items will make it so that the alarm is sounded if an intruder attempts to move or steal them.

Besides, light intensity sensors and controls should be installed near the wall openings. Figure 15 shows the floor plans of the Abu Jaber Museum and the level of light intensity in the museum rooms, using color codes.

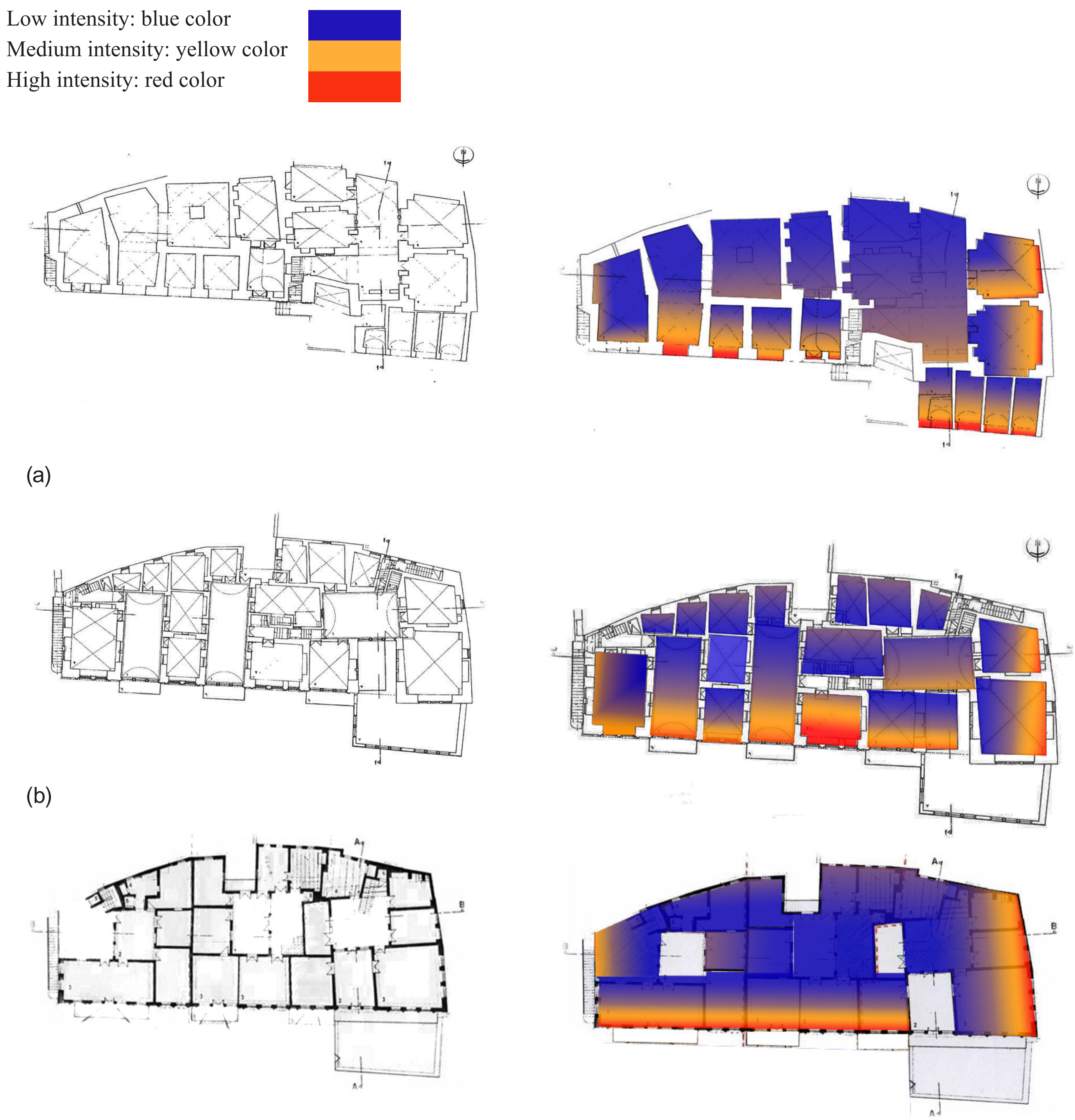


Figure 15. On the left: floor plans of the Abu Jaber Museum (basement, first floor, and second floor). Source: Turath office. Documents on the Abu Jaber Museum. 2021.
On the right: lighting evaluation for the Abu Jaber Museum, which shows light intensity in the museum (drawing by the authors, 2022)

Conclusion

The conservation of historical buildings in Al Salt, Jordan, is the main concern of the local government since the city recently got on the UNESCO World Heritage List. Adopting new solutions in historical buildings to ensure their maintenance and save energy is becoming essential. Therefore, we aimed to introduce the smart building concept into a historical building (Abu Jaber Museum) in Al-Salt, Jordan. For that purpose, we suggested introducing one of the smart building technologies (automated lighting system) in the museum to improve its efficiency and maintain the economic and financial balance.

The results showed that the level of light intensity in the museum does not meet the level recommended in the applicable standards, which has an adverse effect on building efficiency. With that in mind, we suggested a smart lighting system and its simulation model. The simulation results showed that energy consumption might be reduced by 40–43%, potentially lowering maintenance costs for the Abu Jaber Museum in particular and historical buildings in general.

In conclusion, we can say that historical buildings are environmentally friendly. Therefore, smart technologies can offer buildings a great possibility to become smart buildings while keeping their historical value.

This study lays the groundwork for future research on adopting the smart building concept in historical buildings in Jordan. The findings of the study have several important implications for future practices regarding heritage buildings. The study also presented a new approach that can be of interest to users, architects, interior designers, local authorities, and other stakeholders in gaining a better understanding and ensuring heritage building rehabilitation and development.

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