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Araştırma Makalesi / Research Article

Investigation of Building Automation Systems in Terms of Lighting Efficiency

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Abstract

Considering that energy consumption is constantly increasing along with a gradual decrease in energy resource reserves, energy is the most current and pending issue in today's world. Several academic studies have been conducted on the efficient use of energy resources. For this purpose, the idea of "smart building" has been proposed to use energy more efficiently in buildings. With building automation systems, which are indispensable elements of these smart buildings, the energy consumption of buildings can be greatly reduced. In this study, the lighting efficiency of a building automation system built at a training point in the Marmara University Mehmet Genç campus, Vocational School of Technical Sciences, was examined. The Sauter Vision Center software program was used at the observation center of the system. The results were analyzed in terms of efficiency by comparing the energy values in certain time periods obtained from the program with the energy values calculated in full use. The analysis yielded a lighting efficiency value of 54%, which was found to exceed the values reported in the literature.

Keywords: Energy Saving, Smart Building, Lighting Efficiency, Sauter Vision Center.

Bina Otomasyon Sistemlerinin Aydınlatma Verimliliği Açısından İncelenmesi

Öz

Enerji kaynak rezervlerinin giderek azalmasına ile birlikte enerji tüketiminin de sürekli arttığı düşünülürse günümüz dünyasının en güncel ve çözüm bekleyen konusu enerjidir. Enerji kaynaklarının etkin kullanılması ile ilgili çeşitli akademik çalışmalar yapılmaktadır. Bu amaçla, binalarda enerjiyi daha verimli kullanabilmek adına "akıllı bina" fikri ortaya konmuştur. Bu akıllı binaların vazgeçilmez bir unsuru olan bina otomasyon sistemleri ile binanın enerji tüketimi büyük oranda azaltılabilmektedir. Bu çalışmada Marmara Üniversitesi Mehmet Genç kampüsü Teknik Bilimler Meslek Yüksekokulunda bir eğitim noktasında yapılan bina otomasyon sisteminin aydınlatma verimliliği incelenmiştir. Sistemin gözlem merkezinde Sauter Vision Center isimli yazılım programı kullanılmıştır. Programdan alınan belirli zaman dilimlerindeki enerji değerleri ile tam kullanımda hesaplanan enerji değerleri arasındaki karşılaştırılarak sonuçlar verimlilik açısından analiz edilmiştir. Analiz sonucunda elde edilen %54 aydınlatma verimliliği değerinin literatürde verilmiş olan değerlerin üzerinde görülmüştür.

Anahtar Kelimeler: Enerji Tasarrufu, Akıllı Bina, Aydınlatma Verimliliği, Sauter Vision Center.

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1. Introduction

Buildings are responsible for almost 40% of the world's energy consumption, including 65% of electrical energy (Ozadowicz, 2017). Lighting accounts for a large part of the electrical energy consumption of non-residential and commercial buildings, especially those that are not fully equipped with LED lighting (Martirano and Senior, 2014). Therefore, one of the main strategies for this sector in recent years has been to increase energy efficiency by reducing the energy used for lighting. Various concepts, approaches, and technologies have been proposed for achieving these goals (Zhou et al. 2015). Many studies have shown that proper lighting control can significantly reduce annual energy consumption. However, this depends on many factors, such as the climatic conditions of the country and the north-south orientation of the building and its surroundings, that is, the shade of trees or reflections from neighboring buildings (Kaminska and Ożadowicz, 2018). Much attention has been paid to building construction, such as the shape of the building, the shape of the rooms, and the size of the windows and doors (Katafygiotou et al., 2014). One of the most important issues to consider when designing lighting in buildings is the efficient use of energy. In a lighting design proposal where natural lighting is maximized, providing space illumination by spending minimum energy will ensure optimum efficiency of lighting today. In addition, certain issues should be considered in terms of the energy efficiency when designing lighting. If these are taken into consideration, it will be ensured that both lighting is done in an optimum manner without harming the eyes of the person, and maximum efficiency will be obtained from energy (Fabiani et al., 2021). To date, many scientific studies have been conducted on lighting and energy efficiency. Because the issue of energy efficiency in lighting in smart buildings is a multidisciplinary issue, studies on this subject have been carried out in many fields besides electrical engineering, lighting engineering, and energy fields.

A review of the literature shows that remote control systems for offices and homes have been designed and implemented via telephone. The function of the remote control is to control the power supplied to a remote location via a telephone cable. The system is based on a DTMF telephone system. In the implemented system, a telephone keypad was used as an input device, where data and comments were entered (Coskun and Ardam, 1998). Smart homes and the elements of smart home research projects, smart home networks, and smart home devices were defined. In this research, we worked with MIT, Siemens, Cisco, IBM, Xerox, and Microsoft. These groups have placed laboratories in nearly 20 homes, and in these laboratories, nearly 30 devices and 3 artificial intelligence techniques over 5 networks have been used. Neural networks and fuzzy logic were not mentioned because the artificial intelligence technique is a multiagent system (Jiang et al., 2004). They realized the study and application of a smart home control system by combining it with basic knowledge. Here, information is controlled and collected using Internet input. The network inside the house is connected to radio waves via Bluetooth, and the user requests are calculated with fuzzy logic and sent to the device unit inside the house. Then, it is sent to the surrounding devices (Zhang et al., 2008). He emphasized the importance of daylighting in buildings and underlined the physical and psychological effects of natural light on people and their contribution to the performance of employees (Barrett, 2009). Considering the consumption of the electrical energy used for lighting in office buildings, he developed strategies to reduce this consumption. He also mentioned daylighting in these buildings and emphasized the necessity of using artificial lighting (Dubois and Blomsterberg, 2011). They calculated the amount of energy consumed and CO2 emissions for the lighting system of a university building for four different cases and developed recommendations for less electrical energy consumption (Stefano, 1999). He discussed the choice of lamps and the quality of illumination in artificial lighting and expressed the necessary conditions and suggestions for energy efficiency. He also emphasized the importance of lighting control systems in energy saving (Küçükdoğu, 2003). Regarding lighting simulation programs, he examined many lighting programs, including the Dialux lighting program, and applied these programs to sample buildings (Ochoa et al., 2011). In their study, they controlled a system created in a home environment using a microcontroller, and the devices connected to this system using a cell phone. Before designing the system, a circuit that decodes the key codes, that is, dual-tone multi-frequency (DTMF) tones from the person's cell phone, was designed. After decoding the DTMF tones coming to the mobile phone connected to the system, the decoded code was processed using a programmed PIC 16F84 microcontroller. This system is open for improvement. In addition, the number of controlled devices connected to the system can be increased depending on the development (Işık and Altun, 2005). In his doctoral dissertation, he studied Profibus-DP network-based building automation. In this study, a unique Profibus-DP network-based building automation design was developed and the elimination of time delays in the network using mathematical methods was emphasized. Within the scope of the project, the lighting automation was controlled within the same network. Lighting automation is performed using devices controlled by software and connected to a network. The software can control the light sources through the network. Sensors measure the light level in the environment, and light sources illuminate the environment based on this light level (Yılmaz, 2007). A 7.7% performance increase in production volume was found by improving the illuminance level (Juslen, 2007). The effect of lighting automation on energy efficiency was analyzed by Işık. In this study, 36% energy savings were achieved with lighting control using daylight and presence sensors. In the same study, it was also calculated that 42% energy savings could be achieved by placing combined sensors and controlling the illuminance level using a special algorithm (Erhan, 2018). They specifically noted that KNOX-based automation systems intended for controlling building lighting and air conditioning units are difficult to integrate and maintain in existing buildings (Butzin et al., 2014). In the study conducted in 2022, he analyzed the smart campus system utilizing ZigBee sensor network technology, developed a functional network system structure, and reported that the system yielded positive results consistent with the analysis (Gao, 2022). In this study, energy-saving calculations were conducted using actual data from the initial smart university application equipped with KNX-based automation technologies from the installation phase onwards, while assessing usage based on time.

2. Materials and Methods

2.1. System Information

A study was conducted on the lighting system data in lecture hall 4302 located on the 3rd floor of the 4th Block 3 of the 7th building of Marmara University Mehmet Genç Complex Vocational School of Technical Sciences located in the Dragos region of Kartal district of Istanbul province. Since the installation phase of the facility in Figure 1, lighting, heating, cooling, and ventilation systems have been implemented within the scope of smart building automation. The system continues to operate through generators and UPSs that provide energy in the range of 8-12 seconds in the case of power outages. In the 80-seat lecture hall 4302, 30 1-meter-long strip LED lighting fixtures were used as the lighting elements.

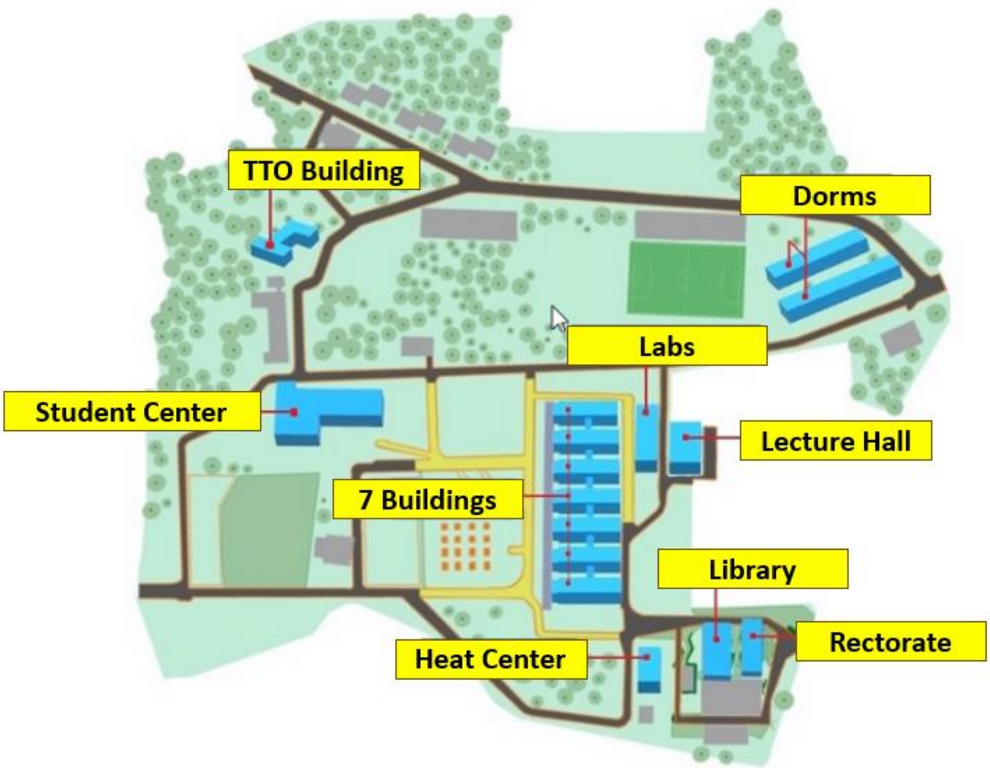

Figure 1. Campus map

Considering the weekly class hours in the fall and spring semesters, lighting times were determined and controlled, and uncontrolled energy consumption was calculated. In the lecture hall, approximately 14 hours of educational activities can be carried out between 08.30 am and 22.50 pm during the day because of the course program. The lecture hall was used for 35 class hours in the fall semester and 36 in the spring semester. Table 1 shows the usage of lecture hall 4302 throughout the year.

Table 1. Annual Usage of the lecture hall

Time	Monday	Tuesday	Wednesday	Thursday	Friday
08:30 09:20	No Course	No Course	Only Fall	Only Spring	Only Spring
09:30 10:20	No Course	No Course	Only Fall	Both Spring Both Fall	Only Spring
10:30 11:20	Both Spring Both Fall	No Course	Only Fall	Both Spring Both Fall	Only Spring
11:30 12:20	Both Spring Both Fall	No Course	Only Fall	Only Spring	No Course
13:00 13:50	Only Fall	Only Fall	Only Fall	Only Spring	No Course
14:00 14:50	Both Spring Both Fall	Only Fall	No Course	Both Spring Both Fall	No Course
15:00 15:50	Both Spring Both Fall	Only Fall	Only Spring	Both Spring Both Fall	Both Spring Both Fall
16:00 16:50	Both Spring Both Fall	Only Fall	Both Spring Both Fall	Only Fall	Both Spring Both Fall
17:00 17.50	Both Spring Both Fall	No Course	Both Spring Both Fall	Only Spring	Both Spring Both Fall
18:00 18:50	Both Spring Both Fall	Only Spring	Both Spring Both Fall	Only Spring	Both Spring Both Fall
19:00 19:50	Only Spring	Only Spring	Only Spring	Only Spring	Both Spring Both Fall
20:00 20:50	No Course	Only Spring	No Course	No Course	Both Spring Both Fall
21:00 21:50	No Course	Only Spring	No Course	No Course	Only Fall
22:00 22:50	No Course	No Course	No Course	No Course	Only Fall

Only Fall | Only Spring | Both Spring Both Fall | No Course

2.2. System Components

2.2.1. Software

The Sauter Vision Center, a software program, provides a solution for operating and visualizing building operations. This program brings together all the data needed for the entire building and energy management, making it accessible to users anywhere and at any time. In addition, this software uses the open BACnet standard, which allows systems from all the manufacturers to be included. The OPC-UA client maintains the connection with various OPC servers, thus ensuring full connectivity with the widest range of protocols in building automation (including KNX, M-Bus, Modbus, and

DALI). SAUTER Vision Center is a web-based building-management solution for the HTML5 standard. It enables platform-independent operation on smartphones, tablets, or desktops without the need to install complex plug-ins. Thus, the staff can access individually configurable and new dashboards from anywhere and at any time as the central information interface for the installation process, energy consumption, and related alarms and key figures. Additional detailed information and reports such as alarm reports, interactive object lists, and diagrams can be accessed directly. With the interface of this program shown in Figure 2, it is possible to perform the following operations (URL-1, 2024).

- Alarm management
- Data point management
- Management of measurement data
- Collection (compression) of measurement data
- Prediction and reference module
- Comprehensive formula module
- Manual and automatic correction of measurement data
- Presentation of measured values
- Benchmarking
- Standard reporting (daily/weekly/monthly/annual energy report)
- Generation and automatic export of reports
- User management
- Data export and import

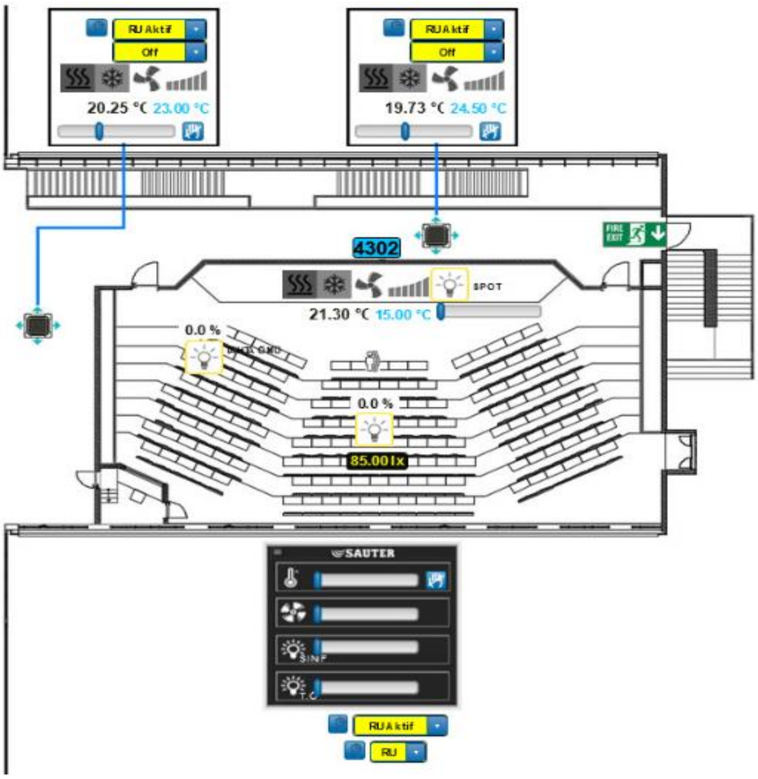

Figure 2. Program interface

Energy-efficient management of a building and its rooms relies on the optimal integration of various systems, including air conditioning, lighting, and sun protection (such as blinds and glare protection units). This integration ensures that these systems work together harmoniously to minimize energy consumption while maintaining comfort and functionality within the space. By coordinating these elements, it is possible to enhance energy efficiency, reduce operational costs, and create a more sustainable environment. Lighting control is carried out in light of the parameters in Figure 3.

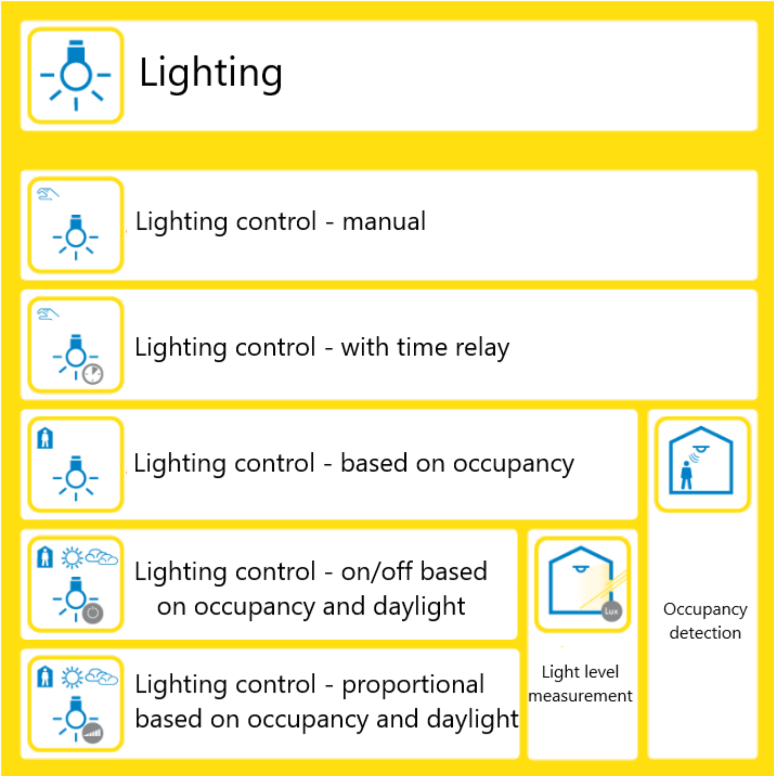

Figure 3. Lighting Control Parameters

2.2.2. Lighting Armature

The OSRAM brand linear-type luminaire in Figure 4, which is 1 m long, rod-shaped with three strip LEDs, and operates at 24 V, was used as the lighting fixture. Thirty luminaires were used in the lecture hall 4302. Several luminaires are connected to a single fuse. In the selected lecture hall, four fuses were used to protect the luminaires. 1 meter LED luminaire draws an average power between 45-54 W.

Figure 4. Lighting Armature

2.2.3. Drivers

The OSRAM brand driver was selected for compatibility with the luminaire. This driver has many features, such as being programmable, flexible current adjustment, low power consumption in standby mode, and easy control with sensors. Figure 5 shows a photograph of the LED driver used.

Figure 5. LED Driver

2.2.4. Control Components

The control element is realized through the control panel in Figure 6, both manually with switches inside the amplifier and remotely with technical personnel through the software interface. Here, the settings of the light amount of the luminaires and the on and off operations were also performed. In addition, the temperature and fan settings can be manually set from the control panel.

Figure 6. Program Control Panel

2.2.5. Sensors

For continuous control of the light intensity in the environment, there is a 1 lux sensor with high sensitivity on the ceiling 50 cm away from the presence sensor in Figure 7 and 1 presence sensor in Figure 8 in the center of the lecture hall ceiling for automatic switching on and off of the lighting system. The lux sensor setting was set to 100 lx. The set setting can be changed according to the season with the software interface from the control panel or control room.

Figure 7. The Lux Sensor

Figure 8. Presence Sensor

2.3. System Operation

The value of the luminous flux in the environment changes according to whether the instructor uses a projector during the lecture, the amount of daylight coming from the windows, and the demands of students. At this point, the luminaires flash automatically to provide the luminous flux set by the automation. The lighting automation of the lecture hall is activated by the presence sensor; however, it can also be operated manually. In addition, remote control was provided by technical personnel using the program interface. In this study, the ambient light intensity set in the software was 100 lx to operate the system with energy savings. Figures 9 and 10 show the dark and light conditions of amplifier 4302. The energy monitoring module integrates energy meters and other data from buildings to create a comprehensive energy consumption display. Daily, weekly, monthly and annual consumption can then be automatically calculated and displayed in diagrams.

Figure 9. Dark state of lecture hall 4302

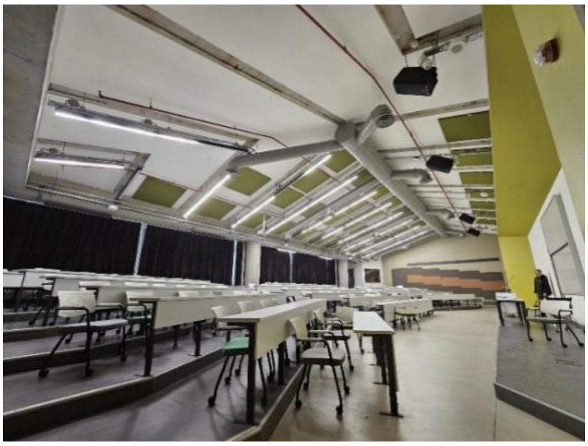

Figure 10. Lighting state of lecture hall 4302

3. Findings and Discussion

The amount of energy consumed in the lecture hall 4302 in the fall and spring semesters was calculated by considering the hours of use in the lecture hall 4302 and the amount of energy consumed in uncontrolled continuous use and controlled use where the automation system is active. The data obtained for both cases were compared, and the energy-saving rate due to the use of the automation system was calculated.

3.1. Uncontrolled Usage

In the case where the lighting automation system does not work, that is, in the absence of sensors and remote control, if it is assumed that all luminaires are manually turned on at 08.30 in the morning and turned off at 22.30 in the evening in lecture hall 4302, there is a continuous use of 14 hours. When each of the 30 linear-type luminaires draws 45 W of power, their energy consumption is calculated, as shown in Table 2.

Table 2. Energy Consumption in Uncontrolled Usage

Time Periods	Energy Consumptions (kWh)
Hourly	30x45x1=1350Wh=1.35 kWh
Daily	1.35x14= 18.9 kWh
Weekly	18.9x5= 94.5 kWh
Monthly	94.5x4= 381.6 kWh
Periodic	381.6x4= 1526.4 kWh
Annual	1526.4x2= 3052.8 kWh

3.2. Controlled Usage

When entering lecture hall 4302, the presence sensor activates the lighting automation system, and the brightness intensity is controlled by the lux sensor. During the fall and spring semesters, usage follows weekly class hours, resulting in an average of 6.5 hours of daily use when considering the weekly course schedules. The energy consumption of the 30 linear type luminaries, each drawing 45 W power, is calculated in Table 3.

Table 3. Energy Consumption in Controlled Usage

Time Periods	Energy Consumptions (kWh)
Hourly	30x45x1=1350Wh=1.35 kWh
Daily	1.35x6,5= 8.775 kWh
Weekly	8.775x5= 43.875 kWh
Monthly	43.875x4= 175.5 kWh
Periodic	175.5x4= 702 kWh
Annual	702x2= 1404 kWh

3.3. Energy Savings Calculations

In controlled settings, lighting is not used continuously, whereas in uncontrolled settings, lighting is manually operated from early morning until late at night. When comparing the values shown in Figure 11, the savings achieved from the installed automation system are calculated as follows.

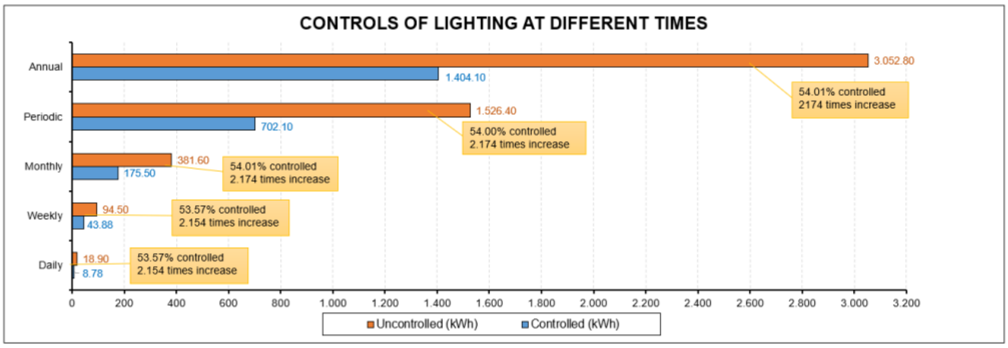

Figure 11. Controls of lighting at different times

Annual energy saving rate (ESR),

$$\% \, ESR = \frac{Uncontrolled\ ES - Controlled\ ES}{Uncontrolled\ ES} x100 \tag{1}$$

$$\% \, ESR = \frac{3052.8 - 1404}{3052.8} = \frac{1648.8}{3052.8} = \%54$$

4. Conclusions and Recommendations

In this research, the energy saving achieved through the lighting automation application at Marmara University Mehmet Genc campus, School of Technical Sciences, lecture hall 4302, was calculated to be 54%. The implementation of this application in a single classroom and its extension to the entire university highlighted the significance of the established automation system in terms of both size and cost of energy savings. The Energy Efficiency Strategy Document targets a minimum 20% reduction in energy consumption by 2024 to mitigate energy losses. Furthermore, the fact that our achieved savings rate exceeds the success benchmarks of 20% to 40% found in the literature is significant for the system's efficiency. Surpassing this target with our achieved energy saving percentage is crucial for the university's and the national economy's well-being. Consequently, it is foreseeable that all public institutions and organizations in our country will adopt automation systems in the future.

Authors' Contributions

All authors contributed equally to the study.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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