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Proposal For Optimizing Energy Consumption And Evaluating The Economic Impact Through The Use Of Lighting Control Sensors In Multi-Family Housing Projects

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Abstract

This research work proposes the incorporation of a lighting control system through motion sensors in multi-family housing projects, with the main objective of contributing to energy and economic savings, with sustainable constructions and with environmental care, through reducing the carbon footprint. For this, the energy consumption in lighting of a multi-family dwelling building was analyzed with a lighting control system of manual switches and the consumption of 4 buildings with lighting control sensors. Likewise, a project with architectural characteristics similar to the selected buildings was chosen, in order to estimate the energy and economic savings that would be generated due to the incorporation of the sensors. The proposed lighting control system using sensors significantly reduced energy consumption in departments and common areas, thus obtaining a reduction in CO2 emissions. Furthermore, by means of such savings, the initial investment could be recovered in an acceptable period of time.

Keywords: economic savings, energy efficiency, lighting control sensors, multi-family housing buildings

Introduction

At a global level, buildings play a very important role in the economic sector as they consume more than a third of the electricity in the world [1]. Between 30% and 40% of world energy consumption is generated by buildings during their operational phase, which are related to the emission of one third of greenhouse gases in developed and developing countries [1, 2]. Likewise, lighting represents 19% of total energy consumption in the world and constitutes between 20% and 45% of total energy consumption in a building [2, 3]. For example, in Europe lighting in buildings is equivalent to approximately 40% of the total energy consumed, which generates around 35% of CO_2 emissions [4].

The International Energy Agency projects that by 2050 the energy demand of buildings will increase by 50%, as long as the necessary measures are not taken to optimize energy consumption. This is due to the rapid growth in the number of homes and residential areas [1]. In addition, in some Latin American countries such as Argentina, Brazil, Chile, Colombia and Mexico, per capita energy consumption in the residential sector was 3,088, 2,516, 3,972, 1,231 and 2,230 kWh / inhabitant respectively, and the price per capita consumption was 2.90, 18.50, 15.80, 14.80 and 7.50 cts. USD / kWh equivalently [5]. Likewise, in 2018 in Peru a total of 4,479,698.00 USD was billed for energy consumption, where 36.1% of the total of said billing belonged to the residential sector [6]. For this reason, the main problem that arises as a result of the aforementioned is the higher expenses equivalent to 18% in the electricity bill of the users [7].

In this context, it is very important to reduce energy consumption and the emission of CO_2 gases in buildings. Therefore, this situation could be improved by applying modern lighting control systems that generate energy savings, considering that only 1% of buildings in the residential sector use this technology [2]. According to the above, there is some research on the use of lighting control systems to generate energy efficiency in buildings. [8] proposes that the WinLigth lighting control system in buildings achieves a saving of 80.27% and 93.09% for energy consumption, compared to the lighting control scheme based on the PIR sensor and the static programming scheme. Likewise, [9] in his research he designed a lighting control system for buildings based on a network of sensors, where this system allowed an average energy saving in lighting of up to 80%. Also, [10] proposes that the implementation of LED lighting systems, combined by means of high-resolution sensor systems, allow obtaining a potential energy saving equivalent to 79% compared to typical lighting systems. On the other hand, [4] states that the use of wireless intelligent LED lighting systems such as the Zigbee communication system and, through the combination of motion sensors and light sensors, saves between 55% and 69% of the total energy consumption of the building. In other research, [12] suggests that luminaire level lighting controls (LLLC) generate an average energy savings of 43% in the building compared to manual lighting control systems. In addition, [1] states that the use of wireless sensors and actuators to detect presence and control lighting in building environments generates energy savings that are between 20% and 28% for the first two weeks of operation. Finally, [3] he states that the use of OLSPM light sensors reduces energy consumption costs and produces visual comfort for building users.

This research proposes the incorporation of a lighting control system using motion sensors in apartments and common areas in multi-family housing projects, in order to optimize energy consumption, reduce CO_2 emissions and generate economic savings in the time after the first 5 years of system operation.

Methodology

Sample multi-family home buildings will be determined. For this, there will be a building with a lighting control system using manual switches (Conventional Building), which has an average area per apartment of 165 m^2 and has as common areas a basement for parking, stairs and passageways. Also, four buildings with a lighting control system using motion sensors (Automated Buildings) will be analyzed. The Automated Building No. 1 has an average area per apartment of 166 m^2 and has two basements for parking, stairs and passageways. The Automated Building No. 2 has an average surface area of 95 m^2 per apartment and its common areas are made up of a basement, stairs and corridors. The Automated Building No. 3 has an average area of 95 m^2 per apartment and its common areas include the construction of a semi-basement, a basement, stairs, corridors, a roof terrace with a pool and six barbecue areas. Automated Building No. 4 has an average of 90 m^2 per apartment and its common areas are divided into a semi-basement, a basement, stairs, passageways, a roof terrace with a pool, a gym, a meeting room, a children's play area and a barbecue area. Likewise, a Multi-Family Housing Project will be selected, which will serve as the basis for making a quote for the incorporation of a lighting control system using sensors. This project has an average of 165 m^2 per apartment and has two basements for parking, stairs, passageways and a roof terrace with two swimming pools and recreation areas. In addition, the energy consumption in lighting of the buildings selected as a sample will be determined, through the application of virtual surveys to resident users.

As mentioned, the costs equivalent to the monthly energy consumption of the selected buildings will be analyzed, considering the consumption per inhabitant, by department and by surface area. Based on what has been described, a cost analysis of the initial investment will be carried out for the incorporation of a lighting control system using motion sensors in the selected project, in order to determine the recovery time of said investment. For this, the annual economic savings generated by the decrease in energy consumption and by the savings in the change of lights and maintenance service of automated buildings versus conventional buildings will be taken into account. Likewise, the reduction in CO_2 emissions resulting from the estimated energy savings will be quantified. All this information will be synthesized in comparative tables and statistical graphs that allow ordering and correctly interpreting the calculated values.

Finally, the results obtained will be analyzed using financial feasibility indicators (NPV, TIR, Payback and B / C) that allow determining the feasibility of incorporating the proposed lighting system.

Results

Quote for the incorporation of sensors

TABLE I presents the quotation proposal for the incorporation of a lighting control system using sensors for the selected Multifamily Housing Project. It shows that the total cost for the acquisition of the products is $ 5,385.25 and the cost for installation service is $ 3,951.31. Likewise, the cost for maintenance service is equivalent to $ 2,480.00, which must be performed every five years.

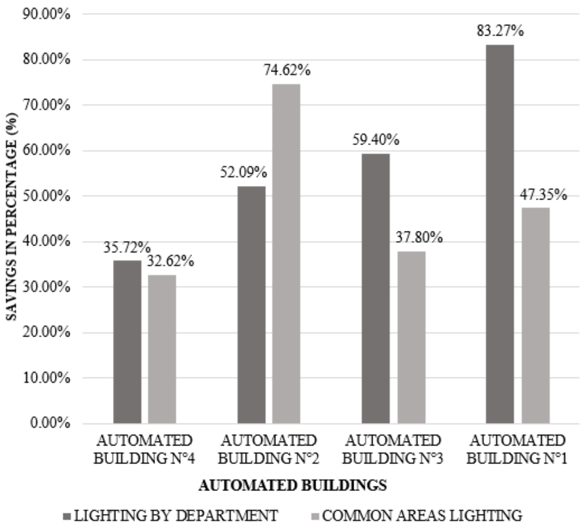
TABLE I Quote for the incorporation of a lighting control system through motion sensors for the project

Description	**Cost (USD)**
Total cost of products for the lighting control system	$5,385.25
Total cost of installation service for lighting control system	$3,951.31
Total cost of maintaining the lighting control system	$2,480.00

Energy savings

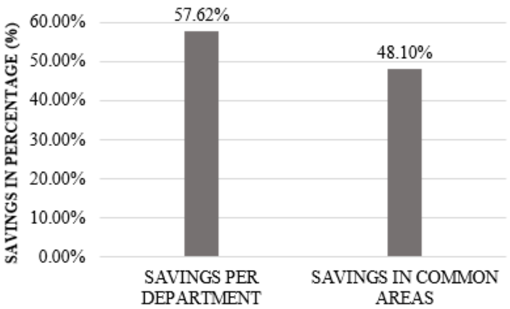
Fig. 1 shows the percentage savings obtained monthly in homes that have a lighting control system using motion sensors. On the one hand, the building that has the highest energy savings by department is the Automated Building No. 1 with a percentage of 83.27% and the one with the lowest savings is the Automated Building No. 4 with a value of 35.72%. The difference between the percentages of energy savings between each of the buildings is due to the number of environments that exist per department (larger or smaller surface area) and also to the number and time of use of the luminaires during the day. On the other hand, the multifamily building that has the greatest energy savings for lighting in common areas by department is the Automated Building No. 2 with a percentage of 74.62% and the one with the lowest savings is the Automated Building No. 4 with a value of 32.62%. The difference in percentages of energy savings between each of the houses is due to the density of passageways, the number of basements, the number of apartments, the number of users and the existence of other spaces in common areas (gym, area grills, among others).

Figure 1. Energy savings in lighting for automated buildings



Likewise, Fig. 2 shows the average percentage energy savings of the automated homes analyzed. For the apartments an average energy saving equivalent to 57.62% in total can be obtained and for the common areas the average energy saving is equivalent to 48.10% in total.

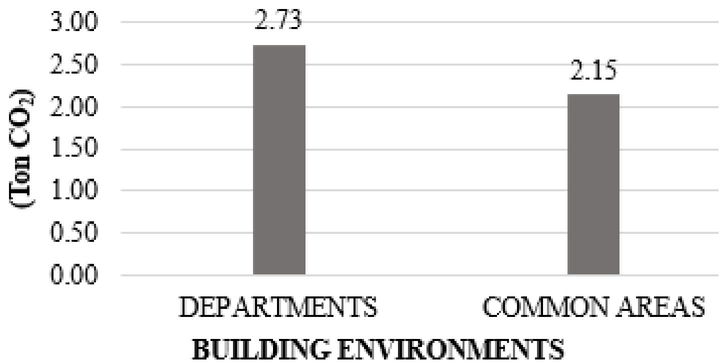
Figure 2. Average energy savings in lighting for automated buildings



CO_2 reduction

Fig. 3 presents the amount of greenhouse gases (CO_2) that could be reduced as a result of energy savings in the chosen Multifamily Housing Project. In this sense, in the departments a reduction of 2.73 Ton of CO_2 can be achieved and in the common areas of 2.15 Ton of CO_2, finally obtaining a total reduction of 4.88 Ton of CO_2 per year for the project.

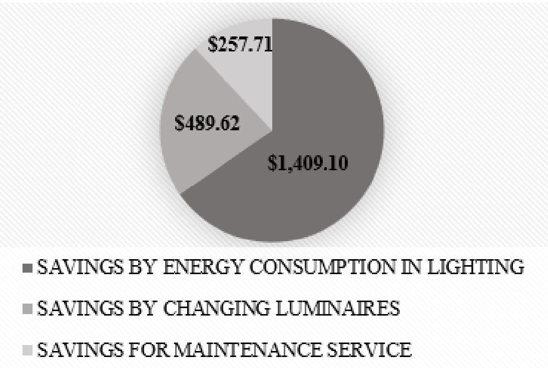
Figure 3 Reduction of CO_2 emissions for the Multi-Family Housing Project



Financial Savings

Fig. 4 shows the main annual economic savings that can be obtained by incorporating the proposed system in the selected Multifamily Housing Project. The saving for lighting energy consumption is equivalent to $ 1,409.10, the saving for changing the lights has a value of $ 489.62 and the saving for the maintenance service for changing the lights has a cost of $ 257.71, obtaining a total saving of $ 2,156.44. It is important to point out that the savings for changing the luminaires and maintenance service are generated because these values will no longer be considered as economic expenses during the useful life of the proposed system.

Figure 4 Annual economic savings for the project



Investment payback time

TABLE II shows the financial feasibility indicators obtained by proposing the incorporation of a lighting control system using motion sensors for the Multifamily Housing Project under study. For this, considering a period of 20 years (useful life of the sensors), a Net Present Value (NPV) equivalent to $ 12,881.69 was obtained, which represents profitability in the project. Likewise, the recovery time of the initial investment (Payback) was approximately 5 years and 6 months.

TABLE 2. Financial Feasibility Indicators for The Project

Indicators	Value
NPV	$12,881.69
PAYBACK	5.48 years

Validation

Quote for the incorporation of sensors

[13] carried out a study on the implementation of a basic lighting control system using the KNX system. This study was carried out in a house in Spain in order to achieve energy efficiency to reduce operating costs in lighting. The total cost to implement the aforementioned system was 9,613.86 euros ($ 10,924.84). In addition, considering that the price for this research has a value of $ 9,336.57, the result obtained in this academic article can be validated, since the values are in the same range.

Energy savings

[11] conducted a study on the implementation of an intelligent lighting system based on LED technology to achieve energy efficiency in residential buildings. This system used ZigBee and Wi-Fi communication protocols to control the lighting of the buildings, taking into account natural light, the presence of people

and the requirements of users. This system achieved a reduction in energy consumption between 60% and 70% compared to the conventional lighting system, without neglecting the visual comfort of the users.

Likewise, [4] he proposed a new system that allows controlling LED lighting through a network of low-power, low-cost wireless sensors. To do this, they implemented light and motion sensors, coupled through the Zigbee system, in order to reduce energy consumption and generate comfort for the users of the buildings. The result obtained in this research affirms that a reduction between 55% and 69% of the total energy consumption of the building was achieved.

Another important investigation was carried out by [12], in which built-in lighting controls were used in buildings, in order to reduce their energy consumption. These controls were integrated by sensors that were in charge of detecting the presence and movement of users within the building. In this way, the lighting could be activated or deactivated only when the user required it. The result of the present study showed that up to 43% energy savings can be achieved in relation to traditional lighting control systems.

CO_2 reduction

[13] proposed the implementation of a KNX system for lighting control in a home located in the city of Galapar, Madrid, Spain. This study concluded that up to 1.51 Ton of CO_2 can be reduced annually in the selected home.

In the study carried out by [14] the application of lighting controls in interior environments of a building that are free of glare was proposed. These controls can be applied in new buildings and also in existing ones. The result obtained in the research was a reduction of 27.9 kg of CO_2 / m^2 annually as a result of the energy efficiency that was generated in the studied building.

Financial savings

In an investigation carried out by [1], the implementation of a lighting control system using motion sensors was proposed, which was called WSAN. This system was implemented in a building in which the demand for electricity for weekly lighting was practically constant throughout the year. The result obtained in this research was a reduction in the energy consumption of the building, which led to an economic saving equivalent to 47 euros per month and a total of 564 euros per year ($ 640.91). For this reason, the economic savings presented in this academic article are validated, since a greater value was obtained than the savings presented.

Investment payback time

According to [15], when implementing lighting control systems using sensors, the terms for the recovery of said investment fluctuate between 6 months and 5 years. Furthermore, in a study carried out in Chile by [16] for the automation of the lighting of a multifamily building, the recovery time of the initial investment was 2 years and one month. In this sense, the proposed recovery time is close to the range of time suggested in the research presented.

Conclusions

It is feasible to incorporate a lighting control system using motion sensors in the selected project, since a NPV of $ 12,881.69 was obtained and a recovery time of the initial investment of 5 years and 6 months.

The average energy savings of buildings with lighting automation is 57.62% for apartments and 48.10% for common areas, where these savings can generate a reduction in CO_2 emissions equivalent to 4.88 Ton / year in the selected project.

The economic savings through the use of motion sensors in the departments of the mapped buildings fluctuate between 1.56 and 5.57 times, and the savings in the common areas fluctuate between 1.48 and 3.94 times, approximately.

Recommendations

Acquire the products taking into account the economy of scale, so that the initial investment is distributed among all the users of the building and the cost is more accessible.

Use the BIM methodology to simulate the energy consumption of the building in the project design and thus guarantee energy efficiency in the operational phase of the building.

For future research, it is recommended that lighting control sensors consider light intensity regulation, with the aim of obtaining greater energy savings in the building.

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