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The Application and Energy-Saving Effect Analysis of Intelligent LED Lighting Systems in Commercial Buildings

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Abstract

With the increasing global focus on energy efficiency and sustainable development, intelligent LED lighting systems, as an efficient and energy-saving lighting solution, are gradually gaining attention. This paper focuses on the application of intelligent LED lighting systems in commercial buildings in the United States, aiming to conduct an in-depth analysis of their energy-saving effects and user experience through empirical research. The study selected commercial buildings in three different regions of the United States, including office buildings, shopping centers, and hotels, as case study objects. Intelligent LED lighting systems developed by Shenzhen Romanso Electronic Co., Ltd. were deployed in these venues. These systems integrate advanced functions such as intelligent sensor networks, adaptive dimming algorithms, and remote monitoring platforms. After six months of field monitoring, detailed energy consumption data were collected, and a user satisfaction survey was conducted to compare the performance differences between intelligent LED lighting systems and traditional lighting systems. The research findings provide strong empirical support for the widespread application of intelligent LED lighting systems in commercial buildings in the United States and offer valuable references for the further optimization and promotion of intelligent lighting technologies in the future. Future research will further explore system performance optimization strategies and strive to promote intelligent LED lighting systems to more commercial building fields to achieve broader energy-saving benefits and user experience improvements.

Keywords: intelligent LED lighting, energy-saving effect, commercial buildings, user experience, energy consumption analysis, intelligent control, market potential, technology optimization, promotion strategy

1. Introduction

With the rapid development of the global economy and the acceleration of urbanization, the number and scale of commercial buildings are increasing continuously, making the energy consumption of commercial buildings an important environmental and economic issue. Against this backdrop, the rapid development of LED technology has provided new ideas and methods to address this issue. LED lighting systems, with their high efficiency, energy-saving, long life, and environmental

protection advantages, have gradually become the preferred lighting solution for commercial buildings. In particular, intelligent LED lighting systems, which integrate advanced sensor technology, intelligent control algorithms, and remote monitoring platforms, can not only significantly reduce energy consumption but also provide more flexible and personalized lighting solutions, thereby enhancing user experience and operational efficiency.

The United States, as one of the largest commercial building markets in the world, has a growing demand for intelligent LED lighting systems. According to reports from market research institutions, the U.S. commercial building lighting market is expected to maintain a double-digit growth rate in the coming years, with intelligent LED lighting systems accounting for an important share. This trend not only reflects the market's urgent need for energy saving and environmental protection but also indicates the broad application prospects of intelligent LED lighting systems in commercial buildings.

This paper aims to explore the application effects of intelligent LED lighting systems in commercial buildings in the United States through case analysis. The study selected commercial buildings in three different regions of the United States, including office buildings, shopping centers, and hotels, as case study objects. These cases cover different building types and usage scenarios, which can comprehensively reflect the performance of intelligent LED lighting systems in practical applications. By deploying intelligent LED lighting systems developed by Shenzhen Romanso Electronic Co., Ltd. in these venues and collecting and analyzing detailed energy consumption data and user feedback, the energy-saving effects and user experience of the systems were evaluated.

2. Research Background

2.1 The Development History of LED Technology

Since its inception in the 1960s, LED technology has experienced rapid development from low brightness to high brightness and from single color to full color, gradually expanding from the application of indicator lights in electronic devices to the lighting field. In the early 21st century, LED lighting technology made a breakthrough, beginning to be widely used in commercial and home lighting and gradually replacing traditional lighting technologies with its high light efficiency, long life, low energy consumption, and environmental protection advantages. In recent years, with the rise of the Internet of Things, big data, and artificial intelligence, intelligent lighting technology has emerged. By integrating sensors, controllers, and communication modules, intelligent lighting systems can achieve automatic dimming, scene switching, and remote monitoring functions, not only improving the flexibility and comfort of lighting systems but also significantly reducing energy consumption.

2.2 The Advantages of Intelligent Lighting Systems

Intelligent lighting systems have demonstrated significant energy-saving and environmental protection benefits in commercial buildings. For example, in office buildings, the system reduces energy consumption by 32%, in shopping centers by 38%, and in hotels by 36%. At the same time, user satisfaction has also been significantly improved, with overall satisfaction rising from 70% with traditional lighting systems to 84%, an increase of 14 percentage points. LED lighting itself has the advantages of high light efficiency and low energy consumption, with an average service life of up to 50,000 hours (Borile S, Pandharipande A, Caicedo D, et al., 2017). This long-life characteristic, combined with the automatic dimming and intelligent control functions of the intelligent system, further optimizes energy use and reduces waste, reducing maintenance costs by 30% to 35%. In addition, intelligent lighting systems also contribute to reducing energy consumption and using environmentally friendly materials, reducing environmental impact by 20% to 25%. It also supports flexible control and intelligent management, providing a variety of control methods to meet different user needs, thereby enhancing the user experience. These advantages make intelligent lighting systems have broad application prospects in commercial buildings.

Table 1.

Building Type	LED Lifespan (hours)	Maintenance Cost Reduction (%)	Environmental Impact Reduction (%)

Office Building	50000	30%	20%
Shopping Center	50000	35%	25%
Hotel	50000	32%	22%

2.3 Research Significance and Purpose

Given the potential of intelligent lighting systems in energy saving and enhancing user experience, this study aims to explore their application effects in commercial buildings in the United States. Through case analysis, the energy-saving effects and user experience of intelligent lighting systems are evaluated to provide data support and practical guidance for the promotion of intelligent lighting systems in the future.

3. Research Methods

3.1 Case Selection

To comprehensively evaluate the application effects of intelligent LED lighting systems in different commercial buildings, this study carefully selected three commercial buildings in different regions of the United States as research objects. These cases include a modern office building located in the eastern United States, with a construction area of about 50,000 square meters, covering main usage scenarios such as offices, meeting rooms, and public areas; a large shopping center located in the central United States, with a construction area of about 100,000 square meters, covering main usage scenarios such as shops, corridors, and parking lots; and a high-end hotel located in the western United States, with a construction area of about 30,000 square meters, covering main usage scenarios such as guest rooms, restaurants, and meeting rooms. The selection of these cases fully considers the diversity of geographical location, building type, and usage scenario, ensuring that the research results have broad representativeness.

Table 2.

Building Type	Floor Area (square meters)
Office Building	50,000
Shopping Center	100,000
Hotel	30,000

3.2 System Deployment

In the selected commercial buildings, intelligent LED lighting systems developed by Shenzhen Romanso Electronic Co., Ltd. were deployed. These systems integrate advanced functions such as intelligent sensor networks, adaptive dimming algorithms, and remote monitoring platforms. The intelligent sensor network, through ambient light sensors, passive infrared sensors, and temperature sensors, monitors environmental changes in real time to provide precise data support for the system. The adaptive dimming algorithm automatically adjusts light brightness and color temperature based on sensor data to ensure optimal lighting effects under different environmental conditions. The remote monitoring platform allows users to monitor and control the lighting system anytime and anywhere through mobile applications or web interfaces, achieving flexible lighting management. This integrated intelligent LED lighting system not only improves lighting efficiency but also significantly enhances user experience.

3.3 Data Collection

To accurately assess the performance of intelligent LED lighting systems, this study collected energy consumption data and user feedback over six months. Energy consumption data were recorded in real time by smart meters installed in each commercial building, covering energy consumption under different time periods and usage scenarios. User feedback was collected through questionnaires and on-site interviews, focusing on users' evaluations of the comfort, convenience, and overall satisfaction of intelligent LED lighting systems. In addition, to more comprehensively assess the energy-saving effects of the systems, the collected energy consumption data were compared with traditional lighting systems. Through this comparison, the energy-saving advantages of intelligent LED lighting systems can be more intuitively demonstrated.

3.4 Effect Evaluation

Based on data collection, this study comprehensively evaluated the application effects of intelligent LED lighting systems through energy consumption analysis and user satisfaction surveys. The evaluation method not

only provided quantitative energy-saving data but also reflected the actual application effects of the systems from the user's perspective, providing strong support for the further optimization and promotion of intelligent LED lighting systems.

1) **Energy Consumption Analysis**

Energy consumption analysis is a key link in evaluating the energy-saving effects of intelligent LED lighting systems. This study collected energy consumption data over six months in different types of commercial buildings and compared them with traditional lighting systems. The specific data are as follows:

- Office Building: In the modern office building located in the eastern United States, the intelligent LED lighting system reduced energy consumption by 32%. Through ambient light sensors and passive infrared sensors, the system can automatically adjust light brightness according to natural light intensity and human activity, ensuring optimal lighting effects at different times. This energy-saving effect not only significantly reduces operating costs but also reduces carbon emissions, in line with the requirements of sustainable development.
- Shopping Center: In the large shopping center located in the central United States, the intelligent LED lighting system reduced energy consumption by 38%. By installing intelligent sensors in corridors, shops, and parking lots, the system can automatically adjust light brightness according to pedestrian density, ensuring energy savings in areas with fewer people while providing sufficient lighting in densely populated areas. This energy-saving effect not only significantly reduces operating costs but also enhances the shopping experience for customers.
- Hotel: In the high-end hotel located in the western United States, the intelligent LED lighting system reduced energy consumption by 36%. Through the remote monitoring platform, hotel managers can flexibly adjust lighting settings according to different usage scenarios (such as guest rooms, restaurants, and meeting rooms) to ensure optimal lighting effects at different times and in different usage scenarios. This energy-saving effect not only significantly reduces operating costs but also improves the customer's accommodation experience.
- These data show that intelligent LED lighting systems can significantly reduce energy consumption in different types of commercial buildings and have broad energy-saving potential.

2) **User Satisfaction Survey**

User satisfaction surveys are an important part of evaluating the application effects of intelligent LED lighting systems. This study collected user evaluations of intelligent LED lighting systems through questionnaires and interviews, focusing on the comfort, convenience, and overall satisfaction of the systems. The survey results are as follows:

- Overall Satisfaction: Users' overall satisfaction with intelligent LED lighting systems increased from 70% with traditional lighting systems to 84%, a rise of 14 percentage points. This significant increase indicates that intelligent LED lighting systems have significant advantages in user experience.
- Comfort: Users' evaluations of the comfort of intelligent LED lighting systems were generally higher than those of traditional lighting systems, especially in reducing eye fatigue and improving visual comfort. Through intelligent dimming functions, the system can automatically adjust light brightness and color temperature according to ambient light and user needs, ensuring optimal visual effects in different usage scenarios.
- Convenience: Users highly praised the remote control and automatic dimming functions of intelligent LED lighting systems, believing that these functions greatly enhanced the convenience and flexibility of use. Through mobile applications or web interfaces, users can monitor and adjust lighting settings anytime and anywhere to meet different needs and improve the user experience.

These evaluation results not only provide quantitative energy-saving data but also reflect the actual application effects of intelligent LED lighting systems from the user's perspective, providing strong support for the further optimization and promotion of the systems.

Through these data and user feedback, the design and functions of intelligent LED lighting systems can be further optimized to improve their market competitiveness and application scope.

Table 3.

Evaluation Indicator/Building Type	Office Building	Shopping Center	Hotel
User Satisfaction Improvement (percentage points)	14	14	14
Comfort Evaluation Improvement (percentage points)	18	20	19
Convenience Evaluation Improvement (percentage points)	16	17	16

4. Research Results

4.1 Significant Energy-Saving Effects

The research results show that intelligent LED lighting systems performed outstandingly in energy saving. Through six months of energy consumption data monitoring, intelligent LED lighting systems achieved an average energy consumption reduction of 35% in three different types of commercial buildings. Specifically, energy consumption in office buildings decreased by 32%, in shopping centers by 38%, and in hotels by 36%. These data indicate that intelligent LED lighting systems can significantly reduce energy consumption in different types of commercial buildings, with the most significant energy-saving effect in shopping centers.

4.2 Enhanced User Experience

User satisfaction surveys reveal that intelligent LED lighting systems have also significantly improved user experience. Overall satisfaction increased from 70% with traditional lighting systems to 84%, a rise of 14 percentage points. In terms of comfort, users' evaluations of intelligent LED lighting systems were generally higher than those of traditional lighting systems, especially in reducing eye fatigue and enhancing visual comfort. Regarding convenience, users highly praised the remote control and automatic dimming functions of intelligent LED lighting systems, believing that these functions greatly enhanced the convenience and flexibility of use. (Chen Z, Jiang C & Xie L., 2018)

Table 4.

Building Type	Consumption Reduction	Satisfaction Increase
Office Building	32%	14%
Shopping Center	38%	14%
Hotel	36%	14%

4.3 Practical Application Cases

In this study, the application effects of intelligent LED lighting systems in different types of commercial buildings are further demonstrated through specific cases, including office buildings, shopping centers, and hotels. These cases not only verify the energy-saving effects of intelligent LED lighting systems but also showcase their significant advantages in enhancing user experience.

- **Office Building:** In a modern office building located in the eastern United States, the intelligent LED lighting system achieved a 32% reduction in average energy consumption through its automatic dimming function, which adjusts indoor lighting according to changes in natural light. The system, equipped with ambient light sensors and passive infrared sensors, monitors natural light intensity and human activity in real time, automatically adjusts light brightness to ensure optimal lighting effects for employees at different times. User satisfaction surveys show that employees highly praised the comfort and convenience of the intelligent LED lighting system, with satisfaction increasing from 70% to 84%. This automatic dimming function not only reduces eye fatigue but also improves work efficiency, providing a more comfortable working environment for employees.
- **Shopping Center:** In a large shopping center located in the central United States, the intelligent LED lighting system achieved a 38% reduction in average

energy consumption by automatically adjusting light brightness in areas with high pedestrian density through its sensor network. The system, installed in corridors, shops, and parking lots, adjusts light brightness according to pedestrian density, ensuring energy savings in areas with fewer people while providing sufficient lighting in densely populated areas. User satisfaction surveys show that customers highly praised the comfort and convenience of the intelligent LED lighting system, with satisfaction increasing from 68% to 82%. This intelligent dimming function not only enhances the shopping experience for customers but also significantly reduces operating costs, bringing significant economic benefits to the shopping center.

- **Hotel:** In a high-end hotel located in the western United States, the intelligent LED lighting system achieved a 36% reduction in average energy consumption by allowing hotel managers to flexibly adjust lighting settings according to different usage scenarios (such as guest rooms, restaurants, and meeting rooms) through its remote monitoring platform. The system enables real-time monitoring and adjustment of lighting settings in various areas to ensure optimal lighting effects at different times and in different usage scenarios. User satisfaction surveys show that customers highly praised the comfort and convenience of the intelligent LED lighting system, with satisfaction increasing from 72% to 86%. This flexible lighting management not only enhances the accommodation experience for customers but also improves the hotel's operational efficiency, bringing significant economic benefits to the hotel.

Through these practical application cases, the application effects of intelligent LED lighting systems in different commercial buildings are fully verified. They not only perform outstandingly in energy saving but also show great potential in enhancing user experience. These cases provide strong empirical support for the further promotion of intelligent LED lighting systems.

5. Discussion

5.1 Market Potential of Intelligent LED Lighting Systems

Intelligent LED lighting systems have broad application prospects in commercial buildings in the United States. With the increasing global emphasis on energy conservation and emission reduction, as well as the continuous progress of LED technology, intelligent LED lighting systems have become the preferred lighting solution for commercial buildings due to their high energy efficiency, flexible control, and enhanced user experience. According to market research institutions' forecasts, the U.S. commercial building lighting market will maintain a double-digit growth rate in the coming years, with intelligent LED lighting systems accounting for an important share. In particular, in commercial buildings such as office buildings, shopping centers, and hotels, intelligent LED lighting systems can not only significantly reduce energy consumption but also enhance operational efficiency and user satisfaction through intelligent control, offering great market potential.

5.2 Directions for Technological Optimization

Despite the significant energy-saving effects and enhanced user experience achieved by intelligent LED lighting systems, there is still room for further optimization. Future research and technological development can focus on improving system performance, enhancing system stability, and integrating more functions. By further optimizing the intelligent sensor network to improve sensor accuracy and response speed, more precise ambient light monitoring and human detection can be realized. Meanwhile, improving the adaptive dimming algorithm to make it smarter in adjusting light brightness and color temperature according to ambient light and user needs can further reduce energy consumption. In addition, enhancing the reliability and stability of the system to reduce lighting interruptions caused by network failures or hardware issues is crucial. Through redundant design and fault warning mechanisms, the system's stability and reliability during long-term operation can be ensured. Integrating the Internet of Things, big data, and artificial intelligence technologies to develop more intelligent functions, such as energy management, fault diagnosis, and predictive maintenance, will further elevate the system's intelligence level.

5.3 Promotion Strategy Suggestions

To promote intelligent LED lighting systems to more commercial buildings, a multi-faceted approach is necessary. First, strengthening market education and publicity to raise commercial building owners' and managers' awareness of the advantages of intelligent LED lighting systems is essential. By holding seminars, publishing case studies, and providing data support on energy-saving effects, they can better understand the long-term economic and environmental benefits of intelligent LED lighting systems. Second, establishing partnerships with building designers, lighting consultants, and construction teams to incorporate intelligent LED lighting systems into architectural design and renovation projects is vital. Additionally, offering flexible financing options and after-sales services to reduce commercial building owners' initial investment risks and increase their acceptance of intelligent LED lighting systems is crucial. Through these strategies, the widespread application of intelligent LED lighting systems in commercial buildings in the United States can be accelerated, promoting the sustainable development of the industry. These strategies not only enhance users' awareness and acceptance of intelligent LED lighting systems but also ensure their successful implementation and long-term operation through practical application cases and technical support.

6. Conclusion

This study has thoroughly analyzed the performance of intelligent LED lighting systems in energy saving and user experience by deploying them in different types of commercial buildings in the United States. The results show that intelligent LED lighting systems have not only significantly reduced energy consumption but also greatly enhanced user satisfaction, demonstrating their enormous application potential and advantages in the field of commercial building lighting.

6.1 Research Summary

In terms of energy-saving effects, intelligent LED lighting systems, equipped with integrated intelligent sensor networks, adaptive dimming algorithms, and remote monitoring platforms, have achieved an average energy consumption reduction of 35%. This energy-saving effect has been verified in different types of commercial buildings, with the most significant energy-saving effect in shopping centers, reaching 38%. This indicates that intelligent LED lighting systems can flexibly adjust lighting strategies according to different building usage scenarios and needs, thereby realizing efficient energy management.

In terms of user experience, user satisfaction surveys show that intelligent LED lighting systems have received high praise from users in terms of comfort and convenience. Overall satisfaction increased from 70% with traditional lighting systems to 84%, a rise of 14 percentage points. Users particularly appreciated the automatic dimming function and remote control capabilities of the systems, which not only enhanced lighting comfort but also greatly increased the convenience of use. (Cheng Z, Zhao Q, Wang F, et al., 2016)

6.2 Future Work Outlook

Despite the significant achievements of intelligent LED lighting systems, there is still room for further optimization. Future research and technological development can focus on further improving system performance, enhancing system stability, and integrating more functions. By optimizing the intelligent sensor network to improve sensor accuracy and response speed, more precise ambient light monitoring and human detection can be realized. Meanwhile, improving the adaptive dimming algorithm to make it smarter in adjusting light brightness and color temperature according to ambient light and user needs can further reduce energy consumption. In addition, enhancing the reliability and stability of the system to reduce lighting interruptions caused by network failures or hardware issues is crucial. Through redundant design and fault warning mechanisms, the system's stability and reliability during long-term operation can be ensured. Integrating the Internet of Things, big data, and artificial intelligence technologies to develop more intelligent functions, such as energy management, fault diagnosis, and predictive maintenance, will further elevate the system's intelligence level.

To promote intelligent LED lighting systems to more commercial buildings, a multi-faceted approach is necessary. First, strengthening market education and publicity to raise commercial building owners' and managers' awareness of the advantages of intelligent LED lighting systems is essential. By holding seminars, publishing case studies, and

providing data support on energy-saving effects, they can better understand the long-term economic and environmental benefits of intelligent LED lighting systems. Second, establishing partnerships with building designers, lighting consultants, and construction teams to incorporate intelligent LED lighting systems into architectural design and renovation projects is vital. Additionally, offering flexible financing options and after-sales services to reduce commercial building owners' initial investment risks and increase their acceptance of intelligent LED lighting systems is crucial.

In summary, the advantages of intelligent LED lighting systems in energy saving and user experience make them the preferred lighting solution for commercial buildings. Future research and technological development will further optimize system performance and enhance market promotion strategies to promote the widespread application of intelligent LED lighting systems in more commercial buildings, contributing to sustainable development.

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