Salud, Ciencia y Tecnología - Serie de Conferencias. 2024; 3:1012
doi: 10.56294/sctconf20241012

Categoría: Education, Teaching, Learning and Assessment

ORIGINAL

Toward a smart street lighting in Morocco: Case study of Ifrane city

Hacia un alumbrado público inteligente en Marruecos: Estudio de caso de la ciudad de Ifrane

Asbai Mustapha[1] ✉, Ghilane Hind[1], Alaoui Lalla Latifa[1]

[1] University Mohammed V, Rabat, Morocco.

Cite as: Mustapha A, Hind G, Lalla Latifa A. Toward a smart street lighting in Morocco: Case study of Ifrane city. Salud, Ciencia y Tecnología - Serie de Conferencias. 2024; 3:1012. https://doi.org/10.56294/sctconf20241012

Submitted: 17-02-2024 **Revised:** 01-05-2024 **Accepted:** 09-07-2024 **Published:** 10-07-2024

Editor: Dr. William Castillo-González

ABSTRACT

Smart street lighting system is one of the technologies that support green environmental related works. Thanks to the technology advancement, this branch of street lighting can benefit from the implementation of new solutions that will help organizations around the word to better manage the electricity consumption and develop a strong smart city. Indeed, smart street lighting are a component of the smart city system. By using smart lighting, cities can improve safety, reduce costs, and increase energy efficiency. This work seeks to evaluate, through a qualitative study, the implementation of smart street lighting solution in certain areas of the kingdom to identify the result generated after integrating new street lighting energy management system to reduce energy consumption. To answer this objective, we conduct a qualitative study developed through the case study method, and we focus on the case of Ifrane city. The data was collected according to a documentary study. The main results claim that smart lighting makes it possible to reduce up to 42 % of costs, and a better result can be achieved with better management practices.

Keywords: Smart Street Lighting; Smart Cities; Remote Management System.

RESUMEN

El sistema de iluminación inteligente de calles es una de las tecnologías que apoyan trabajos relacionados con el medio ambiente verde. Gracias al avance tecnológico, esta rama del alumbrado público puede beneficiarse de la implementación de nuevas soluciones que ayudarán a las organizaciones de todo el mundo a gestionar mejor el consumo de electricidad y desarrollar una sólida ciudad inteligente. De hecho, el alumbrado público inteligente es un componente del sistema de ciudad inteligente. Mediante el uso de iluminación inteligente, las ciudades pueden mejorar la seguridad, reducir costos y aumentar la eficiencia energética. Este trabajo busca evaluar, a través de un estudio cualitativo, la implementación de una solución de alumbrado público inteligente en ciertas áreas del reino para identificar los resultados generados después de integrar un nuevo sistema de gestión energética de iluminación pública para reducir el consumo de energía. Para responder a este objetivo, llevamos a cabo un estudio cualitativo desarrollado mediante el método de estudio de caso, centrándonos en el caso de la ciudad de Ifrane. Los datos se recopilaron mediante un estudio documental. Los principales resultados indican que la iluminación inteligente permite reducir hasta un 42 % de los costos, y mejores prácticas de gestión pueden conducir a resultados aún mejores.

Palabras clave: Iluminación Inteligente de Calles; Ciudades Inteligentes; Sistema de Gestión Remota.

INTRODUCTION

After the first international recommendations for the lighting of roads,[1] the electricity consumption and environmental issues have become more and more important. From the potential to contribute to light pollution and the negative environmental effects of power use, the amount of electricity used for urban lighting frequently accounts for a significant portion of municipal budgets Leccese et al.[2], Kostic et al.[3], Radulovic et al.[4], Mockey Coureaux et al.[5]

S. K. Cho et.al. made a survey and described that in average 30 % of a city's electricity is consumed by lighting the streets. This is why it's important to consider this problem and face the environmental issues of power use and light pollution.

To develop the lighting system of the cities according to the environmental constraints, new technologies and management practices has made it possible through an adaptive lighting solution to improve the quality of life of users in the cities. The concept discussed is "energy on demand" meaning that energy is provided only when it's needed. This solution need a combination between managerial and technical practices. Among the new technologies, we will focus on IOT. According to the literature, IoT is a combination of Operational Technology (OT) and Information Technology (IT) which allows unstructured machine-generated data to be analyzed for insights that will drive improvements.[6]

IOT technology is used in different sectors, and mainly in the lighting sector. The principle allows to better manage the street light. The Internet of Things, or IoT, allows to monitor and control the state of street lights in real time from any location.(7) In this article, we will try to evaluate how the technology and management practices can help organizations to better manage the cities by using efficiently their resources.

Streetlight and new technologies

These days, there is a lot of global worry about energy consumption.[29] Therefore, it is everyone's duty to figure out how to use modern technologies to save energy efficiently.

Smart street lighting for cities

The growing number of people residing in cities increases the needs of citizens and places stakeholders in front of a number of difficulties. The huge amount of energy required and its associated cost represent one of the most significant difficulties to be addressed. The world's energy consumption is increasing at the fastest rate ever due to population increase and economic expansion, and there is still a major shortage of energy supplies.[8]

Stakeholders are searching for innovative yet feasible techniques to reduce the amount of energy that cities use by using an intelligent on/off mechanism, targeted progressive dimming, and an organized approach to power consumption, energy expenses can be rapidly lowered to 35 %. The total cost of consumption can be lowered by up to 42 % by using proper maintenance.[9]

Streetlights may be remotely controlled and monitored from a central management system thanks to a number of ingenious energy management technologies. Streetlights can now be remotely programmed to dim or turn off when energy conservation is required thanks to commercial and research solutions. Along with many other things, they provide maintenance and repair orders, energy consumption information, warnings for unusual bulb operating or outages, and much more.[10] Technologies used to develop smart street lighting solution IOT is considered an essential solution for data absorption but also its analysis. Any device or object having sensors that can share information over a network (the Internet) without the need for human involvement is considered to be part of the Internet of Things (IoT).[11,12,13]. The Internet of Things (IoT) is utilized in many different applications, such as industrial management, smart homes, sensors in the chemical industry, healthcare, military applications, and surveillance systems that investigate anomalies in security.[1,14,15]

We are particularly interested in the use of IoT for smart lighting. The IoT solution helps to better manage the street light. The Internet of Things, or IoT, allows us to monitor and control the state of street lights in real time from any location.[16]

IoT is a physical object that is connected to the internet and is equipped with sensors, software, and electronics to gather and share data from its surroundings.[17,18,19] The use of new technologies for the light sources (such as LED technology)[20,21] and the creation of various remote-control systems based on intelligent light posts that communicate data to a central control system to streamline maintenance and management tasks.[22,23]

The goal is to increase lighting efficiency in streetlights by a factor of five by substituting light-emitting diode (LED) technologies, which have a lower power consumption, with high-pressure sodium (HPS) bulbs.[24]

Managemnt system of smart street lighting

Energy savings, lower maintenance costs, burn hour optimization, high uptime, immediate fault location, load balancing, load shedding, and a user-friendly interface that makes it simple for users to locate the

https://doi.org/10.56294/sctconf20241012

information they need are just a few of the benefits of smart lighting. Other benefits include a visual graphical environment for tracking failures, monitoring system health, and gathering, organizing, and storing data. An alert is delivered right away to the web platform if a defect is found. If required, the alert can be sent by SMS or email to the appropriate parties. Lastly, automatic statistics production for historical data analysis is made possible by smart lighting.[25]

We cite as an example of smart lighting advantages, the city of Barcelona has implemented a smart lighting system that can adjust the brightness of lights based on traffic, weather, and special events.

The city of Los Angeles replaced its 215,000 street lights with smart LED lights, which can be controlled remotely and save 63 % on energy costs.

The city of Rotterdam in the Netherlands has some of its fleets equipped with smart motion sensors that automatically turn lights on when a pedestrian or cyclist approaches and turn them off when they move away.

New technologies are expensive, local governments are constrained, and politics is geared toward short election cycles, making it difficult to establish a highly operational and financially efficient centralized technology deployment model that is reused in areas on a global or national scale.

The streetlights must adapt their behavior to the surrounding environment for them to operate autonomously. As a result, they must be able to detect some pertinent aspects of the surroundings, like ambient lighting, the presence of cars or people, or their behavior (i.e., system diagnosis). Thus, sensors of some kind must be installed in streetlights. Furthermore, streetlights must be able to respond based on information gathered from their surroundings. In this instance, action translates into the ability to regulate lighting intensity and operate at a lower level when not required.[26,27]

METHOD

As part of this study, we focus on the case study method(27) presents the case study method as an empirical investigation that seeks to study a phenomenon in its context. Stake states that the case study method is one of the most widely used methods for conducting qualitative studies. Indeed, several authors testify to its relevance.(27) We remind that our objective is to evaluate, through a qualitative study, the ROI of the implementation of intelligent public lighting in certain areas of the kingdom to identify the advantages and challenges encountered. Return on investment (ROI) is the financial gain from investing funds in creating, modifying, or overseeing a system or product. According to Chang et al.(28), return on investment (ROI) is a popular economic metric used to assess an investment's effectiveness or compare the effectiveness of several distinct investments.

Morocco is betting on the transformation of six cities into smart cities by 2026. The project targets Casablanca, Marrakech, Rabat, Tangier, Ifrane, and Fez. Morocco wishes to create a new model of urban management at lower cost, improve the efficiency of urban planning, and achieve sustainable social development meeting the needs of citizens in terms of transport, energy, green economy, security, and housing. Among the cities mentioned, we are interested in the city of Ifrane with the project to implement intelligent public lighting.

Figure 1. Mass view of the intelligent LED street lighting implementation project of the city of Ifrane with the remote management system. (Source: NABILUM Group)

https://doi.org/10.56294/sctconf20241012

The figure shows the installation area of intelligent street lighting in the city of Ifrane which hosts 84 luminaires with a remote management system. The analysis of the case is made based on a documentary study communicated by the NABILUM group, which specializes in the design and implementation of street lighting and urban furniture projects. The simulation results were obtained on 13 February 2024 and were communicated by engineers from the NABILUM group, specialists in smart lighting, who provided information on the savings made using the EXEDRA remote management solution developed by SCHRÉDER.

To evaluate the ROI, we analyzed on the first level the street lighting without the use of smart solutions by evaluating the general performance in terms of power, power demand, unit price, the cost per hour, and we analyzed the estimated cost for 84 public lighting luminaires without the use of smart solutions. In the second level of the study, we analyzed the street lighting with the use of smart remote management solutions and we established a comparison between the cost of the intelligent street lighting solution and the traditional lighting for a quantity of 84 luminaires of 110 W. The data was provided by the company NABILUM Group, and we conducted a descriptive analysis.

RESULTS AND DISCUSSION

Before the implementation of the smart street lighting solution, a study was carried out to study the state of consumption of traditional street lighting in the area concerned.

The study initially identified the 84 lighting fixtures which will be replaced by the intelligent solution with a remote management system. The table below shows the collected results by the company NABILUM.

Table 1. Street lighting without the use of smart solutions (Source: NABILUM Group)

Hours	Luminaire	Quantity of project lighting	Active power in %	Power demand in W	Unit price including tax - ONEE	Cost/hours
18h00	110	84	100 %	9 240	1,36	12,57
19h00	110	84	100 %	9 240	1,36	12,57
20h00	110	84	100 %	9 240	1,36	12,57
21h00	110	84	100 %	9 240	1,36	12,57
22h00	110	84	100 %	9 240	1,36	12,57
23h00	110	84	100 %	9 240	1,36	12,57
00h00	110	84	100 %	9 240	1,36	12,57
01h00	110	84	100 %	9 240	1,36	12,57
02h00	110	84	100 %	9 240	1,36	12,57
03h00	110	84	100 %	9 240	1,36	12,57
04h00	110	84	100 %	9 240	1,36	12,57
05h00	110	84	100 %	9 240	1,36	12,57
06h00	110	84	100 %	9 240	1,36	12,57

We note that the traditional street lighting solution does not provide the possibility of adjusting the brightness according to weather conditions and human activity because the solution is not equipped with the remote management solution which allows optimal management street lighting network.

Table 2. Estimated cost for 84 street lighting luminaires without the use of smart solutions (Source: NABILUM group)

Désignation	Numbers
Total power demand in w	120 120,00
Total cost per night in Dhs	163,36
Cost per month in Dhs	4 900,90
Cost per year in Dhs	58 810,75

This table presents the financial cost of 84 traditional street lighting fixtures which amounts to 58 810,75 Dhs.

The smart street lighting solution using a remote management system makes it possible to make automatic adjustments across the entire lighting network with the possibility of managing each light point separately, according to a well-studied need. The remote management solution is used in smart cities to save money and

https://doi.org/10.56294/sctconf20241012

reduce the high costs of street lighting. Considering that cities may spend as much as 40 % of their allotted funds on expenses, it is advantageous for cities to emphasize that smart street lights may reduce costs.

Table 3. Street lighting with use of smart remote management solutions (Source: NABILUM group)

Hours	Luminaire	Quantity of project lighting	Active power in %	Power demand in W	Unit price including tax - ONEE	Cost/h
18h00	110	84	90 %	8 316	1,36	11,31
19h00	110	84	90 %	8 316	1,36	11,31
20h00	110	84	90 %	8 316	1,36	11,31
21h00	110	84	70 %	6 468	1,36	8,8
22h00	110	84	60 %	5 544	1,36	7,54
23h00	110	84	50 %	4 620	1,36	6,28
00h00	110	84	50 %	4 620	1,36	6,28
01h00	110	84	40 %	3 696	1,36	5,03
02h00	110	84	30 %	2 772	1,36	3,77
03h00	110	84	30 %	2 772	1,36	3,77
04h00	110	84	30 %	2 772	1,36	3,77
05h00	110	84	30 %	2 772	1,36	3,77
06h00	110	84	60 %	5 544	1,36	7,54

Désignation Smart	Traditional streetlight	Difference lighting	between the two solutions
Total power demand in w	69 300	120 120	50 820
Total cost per night in Dhs	94,25	163,36	69,11
Cost per month in Dhs	2 827,44	4 900,90	2 073,46
Cost per year in Dhs	33 929,28	58 810,75	24 881,47

Table 4. Comparison between the intelligent street lighting solution and traditional lighting for a quantity of 84 110 W luminaires. (Source: NABILUM Group)

The comparison between the two street lighting solutions (smart and traditional) gives a clear image of the importance of the savings achievable in terms of power in general and in terms of cost in particular. The difference between the two solutions is around 50 % in terms of power demand and cost. In this regard, energy consumption reduction is significantly supported by smart lighting control systems. The ability to design modern lighting systems with smart technologies that effectively address the energy savings issue has been made possible by advancements in wired and wireless networks, control technologies, and embedded systems.

The results of the implementation of the smart street lighting solution show the return on investment that the target area will be able to reap. By analyzing the results, the table shows that the city can achieve a saving of 42 % something which is confirmed by the literature which states that the total cost of consumption can be lowered by up to 42 % by using proper maintenance.

https://doi.org/10.56294/sctconf20241012

Hours	Gradation
18h00	90 %
19h00	90 %
20h00	90 %
21h00	70 %
22h00	60 %
23h00	50 %
00h00	50 %
01h00	40 %
02h00	30 %
03h00	30 %
04h00	30 %
05h00	60 %
06h00	60 %
Average	58 %

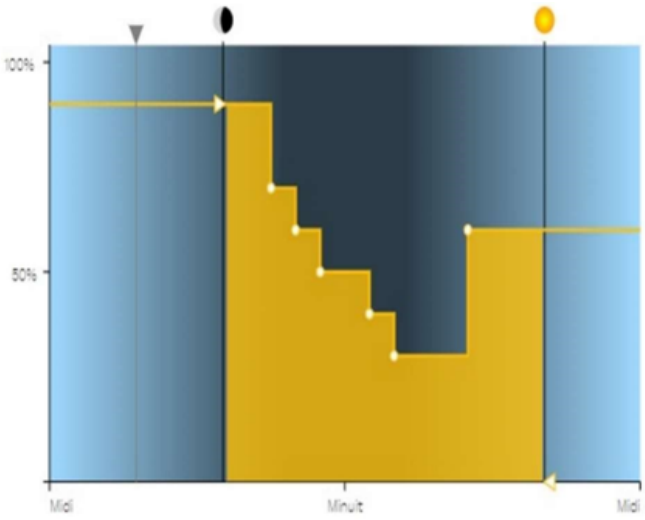

Figure 2. Lighting profile programmed for the city of Ifrane (Source: NABILUM group)

CONCLUSION

Smart lighting is a gateway to smart cities. The luminaires create an ecosystem of sensors and devices allowing municipalities to streamline services to their citizens.

Optimizing energy consumption is in everyone's interest, particularly municipalities in city management and public establishments in general.

The introduction of intelligent street lighting makes it possible to optimize resources and reduce the budget and costs allocated to public lighting as demonstrated in the study, the solution makes it possible to reduce up to 42 % of costs, and a better result can be achieved with better gradation.

We note that smart lighting allows several advantages like real-time energy monitoring, automatic adjustment of brightness according to weather conditions and human activity, and the specific need at the location of the light point.

The evaluation of the ROI in smart lighting projects allows us to shed light on the gain that the municipality could gain in terms of cost savings thanks to the optimization of lighting management.

Local governments and stakeholders must be aware of the expected gain through the optimization of the implementation and management of smart lighting solutions in Morocco for environmental impacts of electricity use and for cost savings.

For future research, we suggest exploring the long-term sustainability and scalability of smart lighting initiatives, evaluating citizen perceptions and acceptance of smart city technologies, and assessing the broader societal impacts of smart city development in Morocco.

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FINANCING

The authors did not receive funding for the development of this research.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

Conceptualization: Asbai Mustapha, Ghilane Hind, Alaoui Lalla Latifa.
Formal analysis: Asbai Mustapha, Ghilane Hind, Alaoui Lalla Latifa.
Research: Asbai Mustapha, Ghilane Hind, Alaoui Lalla Latifa.
Methodology: Asbai Mustapha, Ghilane Hind, Alaoui Lalla Latifa.
Writing - original draft: Asbai Mustapha, Ghilane Hind, Alaoui Lalla Latifa.
Writing - revision and editing: Asbai Mustapha, Ghilane Hind, Alaoui Lalla Latifa.