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ADAPTIVE SOLAR-POWERED SMART STREET LIGHTING SYSTEM WITH MOTION INTELLIGENCE, SOS EMERGENCY SIGNALING, AND INTEGRATED EV CHARGING INFRASTRUCTURE

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INTRODUCTION

Urban Areas Need Urbanisation & Intelligent Street Lights

Urbanisation has increased dramatically in the last few decades and has changed how urban economies, societies and the built environment function all over the world. Over a third of the population lives in urban areas today, and the UN estimates this percentage will grow dramatically in the coming years (United Nations, 2019). The rapid growth of cities has led to a higher demand for common urban infrastructures such as transportation systems, power supply networks and utility services for public safety and other necessary public services. Within this collection of urban infrastructures, street lights represent one example of a high-demand urban infrastructure because street lighting consumes significant amounts of electricity.

Street Lighting Provides Fundamental Life Requirements and Safety

Street lights improve visibility at night, therefore reducing the number of automobile accidents. They enhance the mobility of pedestrians and increase both the perceived and actual safety of a community's street environment. Although street lighting serves as a tool to promote public safety by reducing automobile crashes, studies have shown that adequate street-lit environments reduce fear of crime (Painter and Farrington, 1999), partly by promoting situational awareness and deterring potentially criminal behaviour. Street lighting systems in cities today still use legacy operation systems that do not adequately adapt to current demands and/or conditions.

Street lighting has historically been governed by fixed operating schedules and uniform lighting levels, with no regard for pedestrian traffic volume or the environmental conditions surrounding them. As a result, the current streetlights continue to consume energy in times of low activity such as later on in the evening or in areas with a sparse population. The need for cities to be more sustainable, energy-efficient, and to operate in a more intelligent manner has brought to light the limitations of traditional streetlight systems (Garg & Kumar, 2020), thus creating a need for a re-imagining of streetlights as intelligent adaptive and multifunctional urban systems.

The High Energy Demand for Streetlights Relative to Sustainable Energy Usage

The streetlight system can account for a large percentage of total municipal electricity use typically between 15% and 40% of all public sector electricity use based on region and level of urbanization (Kyba et al., 2017), resulting in costly operational expenses for local governments and increased carbon emissions in locations where electricity is produced primarily from fossil fuels. A significant problem with streetlights that are not operated correctly is their effect on the environment beyond their function of providing light. Poorly designed and installed street lights produce too much light (light pollution), which is a known factor in the breakdown of ecosystems, disruption of human circadian rhythms, and decrease in the visibility of the night sky. (Falchi et al., 2016) The global movement towards Sustainable Development has been encouraging cities to use renewable sources of energy and to implement energy efficient technology in Public Infrastructure. Solar street lights have emerged as an alternative to grid-dependent street lights, offering significant benefits including reduction of operations costs, independence from a centralized electricity network, and lower impact to the environment (Sharma & Singh, 2018). While solar street lights have been installed, most are not connected or controlled through intelligent systems, limiting the effectiveness and flexibility of the installations. Without intelligent management, solar systems have the potential to be inefficient in their use of batteries and will have reduced reliability during periods of long term low-light availability.

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Emergence of Smart and Adaptive Street Lighting Systems

The advancement of sensing technologies, embedded systems, and wireless technology has opened up new opportunities for creating smart street light systems that can overcome the limitations of traditional street lighting infrastructure. Smart street light systems are most commonly used for adaptive street light performance that uses intelligent capabilities and data-driven decision-making. Motion-based adaptive street lighting systems have become a popular option for smart street lights, with the use of motion-detecting sensors to adjust the amount of light produced in response to detected movement. Passive infrared (PIR) and microwave sensors are commonly used technologies for determining the presence of pedestrians and/or vehicles and adjusting street lighting accordingly. By only providing sufficient light when people or vehicles are present, motion-based adaptive street lighting can eliminate the need for high energy consumption lighting when no one is in the vicinity, so that they provide significant energy savings while also ensuring the safety of their users. Many traditional motion detection-based lighting systems are built on simple binary logic, and use one method of action (as if motion was the same for every type). They simply detect the presence of motion and turn on lights at either a low or high level of brightness according to how their manufacturer designates these levels. Motion detection methods like this do not allow for the consideration of other contextual features of the movement, including speed, type of movement, and directionality, and these contextual features of the movement can be important to maximize energy savings and the safety of users. Growing interest is developing in illuminated motion-intelligent systems that expand beyond just detecting motion, and to systems that think contextually about illuminated responses to motion.

Motion Intelligence & Contextual Awareness in Illumination

Motion intelligence is the ability for a system to assess the characteristics associated with movement, including speed, frequency, and pattern of movement, rather than just simply detecting that motion was present. In street lighting, motion intelligence allows the use of different types of illumination response based on the real-world scenarios of how the street is being used. For instance, in the case of a fast-moving vehicle, the longer length of road that the vehicle may travel will require greater total illumination than in the case of a slow-moving pedestrian, who will benefit from being illuminated in localized or direct manner (Li et al., 2019). Lighting systems, which adjust their intensity and distribution based upon their usage or function, may significantly reduce energy use and improve safety in an urban setting. By adjusting the amount of light available for each type of user on an urban street, these systems can provide adequate illumination for pedestrians, cyclists, vehicles, and other road users, while eliminating excess use of electricity through unnecessary yellow light illumination.

Studies demonstrate that using adaptive street lighting that responds to the volume and speed of traffic can produce savings of up to 60% in energy use compared to traditional electric lighting systems (Yoomak et al., 2018). However, there are many challenges that need to be addressed regarding the adoption and implementation of intelligent systems for street lighting, including: complexity in the operation of a system and how to manage multiple layers of interference over time; high initial costs of installing new technology; and difficulties in integrating new systems into existing street-lighting networks. There are still a large number of adaptive street lighting projects that are either still in the design phase or being tested in research or pilot programs with very little applied use of the technology (e.g., Yoomak et al., 2018). Therefore, there is an urgent need to create technologies that can be scaled up to meet the needs of both urban areas and their residents at a price that is affordable. In doing this, we hope to create solutions that balance both technological sophistication and ease of use.

Public Safety Issues and Urban Street Lighting.

Public safety is a primary concern in many urban areas, especially during the late-night hours. When there are no street lights, pedestrians can be at greater risk for being hit by vehicles as there is less visibility on the road. Unfortunately, poorly illuminated areas are correlated with higher rates of both traffic fatalities and thefts (Welsh & Farrington, 2008). Vulnerable populations, such as women, children, and the elderly, may be especially at risk when streets are poorly lit (Welsh & Farrington, 2008). Street lights are a critical component of a city, as they make it easier to see at night. However, traditional street lighting units do not provide any active assistance during emergencies. Cities have begun to adopt a new approach that includes integrating safety indications into everyday urban infrastructure. Cities are increasingly seeing the importance of integrating emergency response, surveillance, and communication capability into existing citywide public systems (Batty et al., 2012).

The ability to integrate SOS or distressed signaling into street lights may provide a new means of creating decentralized safety nodes. Street light installations could enable people to trigger a centralized emergency alert system that provides immediate visual signals and allows for prompt assistance from municipal emergency response personnel. Such SOS signaling systems would be of particular benefit to users within regions lacking surveillance or access to timely assistance from emergency services. Integrating SOS functionality into smart street light systems provides a new dimension of function to the public street light systems. An SOS enabled street light serves as an emergency beacon that can offer visual alert and communication capabilities to users in critical situations, including accidents, medical emergencies, and crime-related threats; enhancing the safety of all users by providing timely notification of potentially dangerous or life-threatening incidents (Kumar et al., 2021).

In combination with adaptive lighting systems, SOS capabilities create increased awareness of the location of emergency situations by increasing the brightness of surrounding ambient light and notifying nearby lights of an emergency situation. This generates a localized safety corridor that provides increased visibility and brings attention to the emergency location. While combining SOS

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with street lighting has many potential advantages, there has not been significant research on the implementation of SOS features in street lighting, with most emergency/SOS solutions utilizing standalone emergency devices and/or cell phone apps.The incorporation of SOS features directly into street lighting infrastructure provides numerous advantages, including availability 24/7, strategic location within public venues, and less dependence on cell phones. Incorporating these types of systems requires the careful management of several elements such as energy management, reliability, and access for users, especially in solar-powered systems.

Solar Energy Integration and Intelligent Energy Management

Due to their sustainability and capability to operate in off-grid or energy-constrained regions, solar-powered street lighting systems have been growing in popularity. Recent technological advancements in photovoltaic systems and battery storage have enhanced the reliability and performance of solar lighting installations (Messenger & Ventre, 2010). Nevertheless, despite the advances in technology concerning photovoltaic systems and/or battery storage, the successful energy management of the system is an ongoing problem, notably for systems that use additional features (adaptive control and emergency signaling).Effective use of energy management strategies is critical to maintaining the ability to conduct essential functions (e.g., Activation of SOS) even when solar resources are either unavailable or limited. Intelligent energy management systems use adaptive methodologies to optimize how & when they consume energy with respect to their operating context, providing energy to their Illumination, Sensing & Communications components based on the relative importance of the task at hand. Research shows that by employing intelligent prioritization of energy throughout the system, the overall reliability and longevity of any given system has been increased significantly (see also Singh et al., 2020).

LITERATURE REVIEW

The authors Dabhade and co-authors (2024) conduct an analysis of a smart street lighting structure based on the Internet of Things (IoT) to provide a variable level of light according to the ambient environment and the activity of humans. Their findings indicate that by deploying sensor-based real-time monitoring systems into the design of a smart street lighting structure, optimisation of lighting dimming strategies can achieve energy savings of up to one-half when compared to conventional street lighting. The authors conclude that this type of adaptive control system is capable of reducing electricity consumption and thus carbon emissions, illustrating the importance of the IoT in developing more sustainable urban infrastructures.

Khemakhem and Krichen (2024) have provided a thorough overview of IoT-based public lighting systems via their work on this subject. They look primarily at how LED technology and sensor networks work together to increase energy efficiency, and how adjustments made to dynamic light levels can improve the sustainability of smart cities. They discuss challenges related to communication protocols and cybersecurity issues as well. They believe that although there are still technical limitations with IoT-enabled lighting systems, these systems have great potential for reducing an urban area's energy consumption and environmental impact.

Nur (2025) analyses IoT platforms using LED lighting technology for urban infrastructure energy efficiency improvement. The result of his research is that leveraging intelligent sensors with LED lights will create significant reductions in electricity use and operational costs. Therefore, the synergy of IoT and LED technologies gives a cost-effective and scalable option for future sustainable lighting systems.

Bhavadharani and colleagues (2025) studied a sensor driven street lighting system utilizing both IoT technologies and renewable sources for power generation. The researchers developed a system with motion-activated and ambient light sensors to vary brightness levels to optimize energy efficiency and provide reliable service. These findings indicate that utilizing renewable energy sources with smart lighting will increase sustainability and decrease reliance on grid generated electricity.

Intelligent Street Lighting with a Cloud Based System – Umar et al. (2020) Umar & al. designed a smart street light application that is activated and controlled via a cloud based architecture using sensors. The cloud based infrastructure allows for centralized monitoring of the street lighting system leading to a dramatic reduction in energy consumption. The authors also show that as a result of using these types of systems, cities can significantly decrease CO_2 emissions; thereby, assisting in achieving sustainable goals for the smart city.

Integration of LoRaWAN and IoT Technology – Discover IoT (2025) In this study, the authors present an adaptive brightness controlled street lighting system that utilizes IoT enabled technologies along with wireless LoRaWAN communications. By using long-range wireless connectivity in combination with renewable energy sources, the study showed that electric use and emissions could be greatly reduced. Furthermore, the author shows that the framework is designed for scalable deployment within urban areas. Sensor Controlled Automatic Street Lighting Systems – Kodag et al. (n.d.) Kodag et al developed an automatic street lighting system utilizing light-dependent resistors (LDRs), motion sensors and an autonomous control logic. The experimental data collected by the authors demonstrated that by implementing sensor based automation of street lighting would provide up to 50% energy savings. This study supports the effectiveness of utilizing sensor control technology for the purpose of sustainable urban planning.

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The study conducted by Saputra and Surapati (2024) utilized statistical methods to examine the effectiveness of IoT-based lighting controls in terms of their ability to improve the flexibility of the system and reduce energy usage by making use of remote management of the platform itself. This research utilizes quantitative data to validate the operational performance of IoT-enabled fixtures through analysis.

Mahoor (2020) provided a review of the current state-of-the-art technologies that are being used to create smart street lighting systems, including sensor networks, control algorithms, and communication architectures that make up a complete smart street lighting system. Additionally, it provides an overview of trends in global research on the topic and highlights the importance of intelligent lighting systems in minimizing energy waste and emissions.

Studies that were conducted on lighting systems that are enabled with wireless sensor networks (WSN) show that real-time monitoring of ambient conditions and human movement significantly improve the energy efficiency of these lighting systems. Additionally, the incorporation of these lighting systems into sustainable urban lighting strategies enhances the reliability of their operation.

In 2025, Bian and Yang presented a multi-criteria framework used to assess the integration of renewable energy technologies in streetlighting. Bian and Yang's research also shows the ways hybrid renewable energy technologies enhance sustainability and effectively fulfill carbon reduction goals.

Examples from Pratishthan College demonstrate how IoT-enabled street lighting systems have been developed to adjust to traffic and environmental conditions. The document includes various examples of outdoor lighting systems and their corresponding results, including lower energy use and reduced carbon emissions in real-world examples.

As per the ResearchGate report, data-driven adaptive lighting controls can generate significant energy savings in urban areas. The research associates intelligent management of outdoor lighting with reduced negative effects on the environment.

Kabir (2023) designed and implemented an intelligent lighting management system that utilizes IoT technology to reduce energy consumption by as much as 80%. The research demonstrated that using remote monitoring and adaptive control mechanisms can maximize the energy savings of intelligent lighting systems.

The IEEE review looks at how smart streetlights can be used to improve grid resilience and urban connectivity. The report also states that smart streetlights indirectly support emission reductions by being part of an integrated smart city ecosystem.

Lau et al. demonstrate in their case study a type of lighting control based on traffic density using distributed sensor networks. The team showed an energy savings of up to 82% based on traffic intensity.

Research on solar integrated automatic lighting systems indicates that the combination of solar energy with sensor automation increases the efficiency of using energy and decreases the need for grid electrical power.

According to the IJRASCT report, IoT enabled lighting will continue to positively affect the environment and contribute to the goals of environmental sustainability by improving the efficiency of energy use through the elimination of the waste of energy.

Nikpour et al. identify intelligent sensor networks providing dynamic dimming and failure detection enhances operations, as well as decreases energy consumption.

In addition to street lighting, IoT based energy management frameworks within smart cities have demonstrated how integrated sensor systems can support the overall goal of reducing emissions.

RESEARCH GAP

The literature that pertains to smart street lighting has an essential knowledge gap when it comes to IoT-enabled adaptive lighting as well as renewable energy integration. Most of the research is currently focused only on helping to improve energy efficiency, through such things as rudimentary motion detection, LED optimization and solar energy systems; however, very few have researched how to combine context-aware motion intelligence (which can discriminate between different types and speeds of movement), with intelligent solar energy management as one framework. Additionally, the integration of SOS-based emergency communications into the street lighting system is largely unexplored, as most of the safety solutions currently found in the literature are based on utilizing separate emergency devices and/or smart mobile apps. There are also only a handful of studies that investigate how to optimally use energy between lighting, sensors, and emergency functions (particularly under the constraints of solar energy use) using multifunctional systems. The smarter street lighting architecture within which these multifunctional systems would be deployed is missing conceptual models that would address the three topics mentioned - energy efficiency/sustainability/public safety

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- simultaneously. This indicates that the design of a holistic framework that incorporates adaptive motion intelligence, solar optimization, and integrated SOS capabilities for smart city applications is an important and largely underdeveloped area of research.

OBJECTIVES OF THE RESEARCH

1. To analyze the limitations of conventional street lighting systems with respect to energy efficiency, adaptability, and public safety in urban environments.
2. To conceptually propose an adaptive solar street lighting framework that employs motion intelligence for demand-based illumination.
3. To examine the potential benefits of motion-intelligent lighting in optimizing energy usage while maintaining adequate visibility for different urban road users.
4. To explore the integration of SOS-based emergency signaling within street lighting infrastructure as a decentralized public safety enhancement.
5. To evaluate the relevance of the proposed concept for smart city development, focusing on sustainability, energy conservation, and improved urban safety.

RESEARCH METHODOLOGY

Research Design: This is a conceptual and exploratory research design study, with an intention of proposing and analyzing a new adaptive solar street lighting concept integrated with motion intelligence and SOS functionalities. Not intending design of a system, prototype, or experimentation for validation; instead, it focuses on theoretical development and analytical evaluation of the proposed idea within the context of smart cities' infrastructures.

Nature of the Study: The nature of the study is qualitative and analytical in nature, focusing on concept-based reasoning more than quantitative measures. For example, it will include analyzing the existing problems associated with conventional street lighting and investigating adaptive and intelligent features, with a focus on addressing the problems of energy efficiency and public safety.

Data Sources: The study will entirely depend on secondary data sources including peer-reviewed journals, conference proceedings, government reports as well as other publications on smart street lighting, renewable energy systems, motion-based control, and urban safety mechanisms. These sources form the theoretical basis for developing and validating the proposed concept.

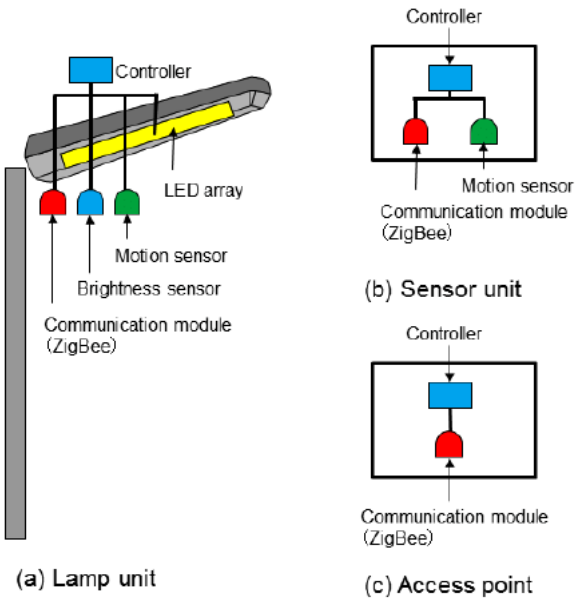
Method of Evaluation: The existing models regarding street lighting and the smart lighting frameworks are analyzed through a qualitative comparative analysis method. The broad parameters for comparison with respect to proposed adaptive solar street lighting systems depend on aspects like energy efficiency, adaptiveness, sustainability, and safety functionality.

Framework of Concepts Development: A conceptual framework is proffered on the basis of literature analysis, showing the functional integration of motion intelligence, adaptive illumination, considerable use of solar energy, and SOS-based emergency signaling. This framework includes logical interactions of system components without hardware architecture or implementation details for the framework.

Scope of Study: The study is restricted to a conceptual proposal and analytical evaluation of adaptive solar street lighting in urban and semi-urban settings. It does not include technical designs, cost modeling, field performance tests, or actual deployment aspects.

DISCUSSION

Energy Efficiency and Adaptive Illumination



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This study´s major incentive is the high energy use rate of typical streetlights. The off-timing and the uniformly lit lighting systems allow continuous energy use no matter how much an area is used. The inconsistency of the use of energy to how much it's constantly needed has been shown to be one of the most significant factors of an unnecessarily high level of energy cost on the part of municipalities (Kyba, 2017). The proposed adaptive solar street lighting concept eliminates this by enabling demand-based lighting through the use of motion intelligence.

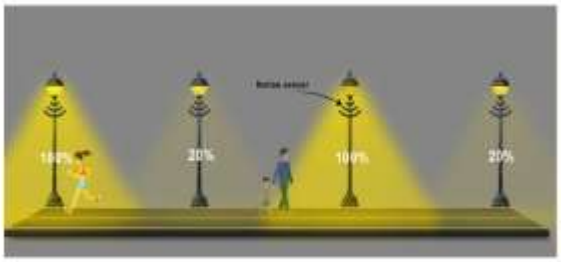
The proposed framework allows for motion intelligent usual on/off (or low/high) results in a higher theoretical potential for energy conservation because increases in energy use can be projected to be used only when and where they are needed as determined by motion of the pedestrian and/or (vehicle) frequency of movement and speed at the time. Previous studies indicate there is a potential for adaptive street lighting systems whereby barrier-free traffic responds to the actual amount of traffic may use up to 40% less energy (Yoomak, 2018). The present concept will build upon this by incorporating an awareness of context, rather than merely sensing that something is present, therefore enabling the realization of a greater level of conservation through accurate correspondence of streetlights to street activity level.

The use of solar energy also increases the sustainability component for the proposed system by decreasing the overall fossil-fuel reliance for grid electricity, especially in areas where there is inadequate infrastructure to supply dependable electricity to support lighting (Sharma & Singh 2018). While adaptive control creates a methodology for utilizing solar energy to power lighting systems allowing for reduced operational costs and a lower environmental impact. Together, with the use of both adaptive control (intelligent energy use) and renewable (solar) energy, the proposed system provides conceptual support for energy-efficient infrastructure through integrated combining (not relying exclusively) on renewable energy resources and intelligent (adaptive) strategies.

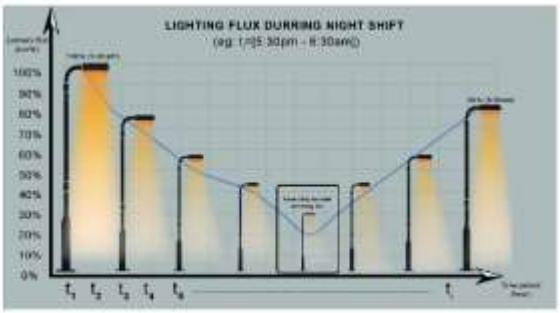
Motion Intelligence as a Functional Advancement



(a)



(b)



(c)



(d)

Motion intelligence represents an additional functional development in addition to existing (traditional) methods for motion detection. Traditional systems rely on simply registering motion and do not take into consideration how that motion occurs. Lack of consideration for the type of motion occurring results in providing one lighting level regardless of whether it is created by a pedestrian, cyclist or motor vehicle thus decreasing adaptive lighting's ability to efficiently and functionally meet the needs of the individual road users.

The proposed system is consistent in that it is responsive to how people use the streetlight system (Li et al., 2019). For example, vehicles go through different velocity levels, however vehicles are typically driven much faster than pedestrians and will therefore require lights to provide broader and brighter coverage along longer stretches of roadway, whereas a slower moving pedestrian will typically require a more localized source of light. The proposed system has addressed the distinction of providing this more closely matching the safety needs in the real world when compared with providing excessive amounts of lighting in locations where lighting is not necessary. Therefore, this suggests that future development of adaptive lighting systems should be based upon the use of intelligent decision-making capabilities, which consider context-based decisions, rather than rely solely on fixed thresholds.

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Therefore, it should be understood that the functional adaptability of street lighting is influenced by how streetlight systems adapt to provide effective performance for users. For instance, when a user is travelling at high speeds in a vehicle at night, streetlights must provide adequate illumination, meanwhile users at low speeds who are walking may need illumination that is geared towards providing sufficient visibility along the side of the street. Consequently, the development of streetlight systems to provide intelligent systems in the future will be similar to how the smart infrastructure industry is moving towards developing systems that respond to changes in user demand by using more adaptive methods of providing services.

Public Safety Enhancement through SOS Integration

Street lighting has long been recognized as a contributor to public safety by improving visibility and reducing fear of crime (Painter & Farrington, 1999). In traditional systems, an emergency response is not typically implemented in a proactive manner. With the integration of SOS within street lighting systems, street lights can now function as decentralized safety hubs instead of simply lighting up the road.

By establishing street lights as SOS-enabled beacons that can send an SOS for numerous situations of distress (i.e. accident, medical emergency, personal safety) (Kumar et al., 2021), street lights can now be considered as active participants within the urban safety network. Increasing illumination at the specific location of the emergency will help bystanders and emergency response units find the critical location.

This integration improves upon the limitations of using mobile devices to provide an SOS function, where the user must have access to their device, where the battery has sufficient power, and where the network is available. On the other hand, street lighting systems are permanent installations in public areas accessible by everyone. In addition, the continuous nature and strategic location of SOS-enabled street lights provides an additional advantage. In this way, SOS-enabled street lights provide another way in which to provide essential safety services without relying exclusively on using personal mobile devices.

Contribution to Smart City and Sustainable Development Goals

This new idea is in line with the goals of smart cities, which include sustainability, efficiency, and benevolence to a city's citizens. Smart cities are using digital intelligence on physical structures to deliver better services and manage resources (Batty et al., 2012). A prime example of this would be changing streetlights into SMART streetlights since they are already prevalent and operate night and day in urban areas.

By implementing renewable energy, adaptive control and emergency functionality in one unified system, the overall design of the proposed system uses the multi-functional concept of the infrastructure design. This is consistent with smart systems being designed not as stand-alone systems, but rather as providing multiple services to users (Gubbi et al., 2013). From a sustainability point of view, this concept contributes to affordable and clean energy, help develop sustainable cities, and provide a safe community.

In addition, the proposed system illustrates how we can use an existing infrastructure as the foundation to add additional urban services without needing to build new physical installations. This will result in long-term infrastructure savings and hopefully create an environment conducive for financial challenged municipalities to look towards intelligent systems.

Practical Challenges and System Complexity

While the proposed adaptive solar street lighting framework has numerous conceptual advantages, it also presents additional challenges to be fully recognized. The combined use of motion intelligence and SOS operation increases the complexity of the systems and, therefore, has implications for reliability and required maintenance. Previous work has reported that high initial costs and operational complexity are two factors that impede the large-scale deployment of smart lighting systems (Yoomak et al., 2018).

Solar systems are also reliant on their environmental context and energy storage capacity. Extended periods of below-average solar availability may negatively impact the system's effectiveness, especially under conditions where emergency signalling is activated often. This reinforces the necessity for intelligent energy prioritization, as previously identified in research related to adaptive energy management (Singh et al., 2020). While the present investigation does not propose a specific solution to the technical issues related to this study, it will conceptually illustrate the need to balance illumination, sensor use, and emergency operation with limited available energy.

Another challenge is to ensure that users have access to SOS capability during an emergency and can trust the system to work reliably. SOS capability must be easy to discover and to function within various environmental and social contexts for it to fulfil this operational purpose. These practical matters indicate that future research must pay careful attention to how users interact with systems and account for long-term maintenance requirements.

Findings

The conventional type of streetlight (or external lighting) currently used in cities around the world is characterized by several negative aspects that are caused by the limitations of fixed schedule lighting, non-adaptiveness, and no safety performance features. As a result, these limitations lead to excessive energy use, high costs to operate, and a slow response to how street facilities are

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currently being used by people at the moment. From an analysis of these issues conceptually, the researcher found that using adaptive lighting using motion intelligence will lead to more closely matching the level of light needed for the use of a street at the time of its need.

Unlike the traditional motion detection systems that equally illuminate a street no matter the speed or type of movement, the adaptive motion intelligence used in adaptive lighting to differentiate between types of movement speeds in improving both energy efficiency and performance in illumination (in addition to energy efficiency). Using the proposed framework to integrate solar energy into the lighting system reduces reliance upon electricity supplied by the grid and lowering greenhouse gas emissions. Additionally, the researcher found that adding SOS functionality to the street lighting infrastructure will allow street lighting to become active safety items (active public safety).

In this way, the SOS streetlights can serve as decentralized sources of emergency beacon light; assisting with answering where an accident has occurred, assisting with responding to a medical emergency, and providing safety for a person while away from home.

In conclusion, the researcher suggests that creating adaptive lighting, using solar energy, and creating emergency signage in the integrated system of city streets will improve how sustainable, efficient and safe city street lighting systems are using this type of streetlight.

Suggestions

Based on the conceptual findings of this study, it is suggested that urban planners and municipal authorities consider the adoption of adaptive street lighting strategies rather than relying solely on fixed or time-based illumination systems. The integration of motion intelligence should be prioritized over simple motion detection to enable context-aware lighting responses that better match real-world usage patterns. Policymakers should also encourage the use of renewable energy sources, particularly solar power, in public lighting infrastructure to support long-term sustainability goals.

It is further suggested that safety features such as SOS-based emergency signaling be incorporated into future smart street lighting initiatives to enhance public safety without requiring additional standalone infrastructure. Awareness programs may be necessary to educate citizens on the availability and proper use of SOS-enabled street lighting systems. Additionally, future smart city projects should focus on developing multifunctional infrastructure solutions that combine energy management, adaptive control, and safety services rather than treating these aspects independently.

CONCLUSION

This research study has proposed a conceptual framework for adaptive solar street lighting that employs motion intelligence and an SOS feature to provide a multi-functional solution for urban infrastructure. The study has explored the limitations of traditional street light systems due to their inherently high levels of energy waste, little flexibility in operation, and very limited support for active public safety. After conducting qualitative and literature reviews related to this concept, it has been shown that motion intelligent street lighting will allow for demand-based lighting, reducing the amount of energy consumed by streetlights and the ability to provide adequate levels of visibility to a variety of users in different contexts.

Further, in addition to providing solar energy as a sustainable means of powering the street lights, the provision of an SOS feature on solar street lighting will enable it to serve as a decentralized public safety hub in urban areas rather than simply providing light to the street. Although the proposed framework is still conceptual, it adds to the body of knowledge regarding smart city infrastructure and demonstrates the manner in which traditional public infrastructure systems can be transformed into adaptive, energy-efficient, and safety-oriented solutions. The study shows that developing motion intelligent adaptive solar street lighting with an SOS feature are some directions for the future of street lighting for cities who want to meet the objectives associated with both smart cities and sustainable development.

Further Scope of Study

This study has focused only on conceptual analysis and has not included the development of a system design, the simulation of system performance, or the validation of the developed concept(s) through experimentation. Future research may include the creation of simulation models to assess the performance of motion-sensitive lighting at different traffic densities and environmental conditions, as well as the assessment of prototype systems for the purpose of measuring actual energy savings, effectiveness of light levels, and response times for SOS activation.

Other research areas could include an analysis of the economic feasibility and costs/benefits associated with implementing adaptive solar street lighting in different urban settings. Further studies could also consider how the adaptive solar street lighting systems can be integrated into larger smart city systems (e.g., traffic management, emergency response networks). Future research will continue to develop and assess user acceptance, accessibility to SOS features, and policy framework requirements for large-scale implementation. These studies will support the transition from the conceptual design phase to the practical implementation phase of motion-sensitive street lighting systems, promoting the development of intelligent and sustainable street lighting systems.

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