Review Progress in Betterment of Smart Street Lighting to Save Energy.

Gaurav P. Shriwastava[1], Ganesh P. Kanade[2], Saniya Arnab Sayed Sardar Ali[3], Darshan D. Rathod[4], Sangharsh S. Lohkare[5]

[1]gaurav P. Shriwastava, Dept. Of Mechanical Engineering, Jagadambha College, Maharashtra, India
[2]ganesh P. Kanade, Dept. Of Mechanical Engineering, Jagadambha College, Maharashtra, India
[3]saniya Arnab Sayed Sardar Ali, Dept. Of Mechanical Engineering, Jagadambha College, Maharashtra, India
[4]darshan D. Rathod, Dept. Of Mechanical Engineering, Jagadambha College, Maharashtra, India
[5]sangharsh S. Lohakare, Dept. Of Mechanical Engineering, Jagadambha College, Maharashtra, India

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Abstract- *Smart Street lighting system have emerged as a transformative solution for urban lightning infrastructure offering enhanced efficiency sustainability and intelligent functionalities and smart street lighting has emerged as a promising solution for cost savings and enhanced urban management. This review paper provides a comprehensive analysis of an advancement's challenges, and future directions in the field of smart street lighting. If implemented as part of a sensor based IOT network, smart street lighting systems can collect data about the city which can then be used to respond to various evolving infrastructure challenges as well as create safe and illuminated spaces.*

Key Words: Internet of things, Streetlight, Smart city, Wireless sensor networks, LED, energy conservation, LDR.

1.INTRODUCTION

Nowadays one of the biggest expenditures is on the lighting the streets. The demand of electricity increases day by day. So, energy saving plays a vital role in present scenario. On the national highway there are approximately 500 street lights and each street light consume approx.150W. During night the street light continuously glows till day or sometimes even day time. So, when 500 street lights are considered the energy consumption will increase up to75000W.

LED lights offer superior energy efficiency, longer lifespan, and improved lighting quality compared to traditional lighting technologies. The transition from conventional lighting to LED lighting has resulted in substantial energy savings and reduced maintenance costs.

Furthermore, the integration of smart features has propelled the advancements in smart street lighting. Motion sensors, dimming controls, and adaptive lighting techniques have been implemented to optimize energy consumption based on real-time conditions. By dimming or turning off lights in low-traffic areas or during off-peak hours, energy savings can be maximized without compromising public safety.

Additionally, advancements in connectivity and control systems have contributed to the evolution of smart street lighting. Internet of Things (IoT) technologies enable remote monitoring, control, and management of street lights. This allows for real-time adjustments, proactive maintenance, and the ability to gather valuable data for further analysis and optimization.

Energy Efficiency:

- **LED Technology:** Widely adopted for smart street lighting, LEDs offer energy savings and longer lifespans compared to traditional sources.

Smart Controls and Sensors:

- **Remote Monitoring:** Equipped with sensors, smart lights enable real-time management, optimizing energy consumption.

- **Motion Sensors:** Dynamic light adjustments based on pedestrian or vehicle presence reduce energy waste.

Connected Systems:

- **IoT Integration:** Interconnected Street lights with centralized control enhance scheduling efficiency.

Data Analytics:

- **Usage Patterns:** Advanced analytics inform resource deployment decisions, minimizing unnecessary energy consumption.

Solar Integration:

- **Renewable Energy:** Some systems integrate solar panels, contributing to sustainable and grid-independent solutions.

Cost Savings:

- **Maintenance Reduction:** Proactive maintenance through real-time fault detection reduces downtime and manual inspections.

Environmental Impact:

- **Carbon Footprint:** Energy-efficient lighting and smart controls significantly reduce the carbon footprint, aligning with sustainability goals.

Challenges and Considerations:

- **Initial Costs:** Deployment cost can be a barrier despite long-term savings.

- **Security Concerns:** Ensuring cybersecurity is crucial to prevent unauthorized access.

Future Directions:

- **5G Integration:** Integration of 5G may enhance communication and control capabilities.

- **Advanced Sensors:** Ongoing advancements in sensor technologies can improve real-time responsiveness.

1.1 Here are some key advancements in this area

Energy Usage Optimization: Data analytics can analyze energy consumption patterns and identify areas of inefficiency in smart street lighting systems. By leveraging machine learning algorithms, predictive models can be developed to optimize lighting schedules, dimming levels, and overall energy usage. This ensures that lighting is provided when and where it is needed while minimizing unnecessary energy consumption.

Predictive Maintenance: Data collected from sensors can be used to monitor the health and performance of street lighting infrastructure. By analyzing this data in real-time and applying predictive analytics techniques, it becomes possible to identify potential faults or maintenance needs before they lead to complete failures. This allows for proactive maintenance, reducing downtime and optimizing resource allocation.

Adaptive Lighting Strategies: Data analytics and artificial intelligence enable the implementation of adaptive lighting strategies. By analyzing data such as traffic patterns, pedestrian activity, and ambient light levels, smart street lighting systems can dynamically adjust lighting levels in real-time. This ensures optimal visibility and safety while minimizing energy waste during low-activity periods.

Data-Driven Decision Making: The vast amount of data collected from smart street lighting systems can be analyzed to gain valuable insights for decision making. By applying data analytics techniques, city planners and policymakers can make informed decisions regarding infrastructure expansion, energy management strategies, and resource allocation. This data-driven approach helps optimize the overall performance of smart street lighting systems.

Integration with Smart City Initiatives: Data analytics and artificial intelligence allow for the integration of smart street lighting with broader smart city initiatives. By combining data from various urban systems such as transportation, weather, and public safety, advanced analytics can provide valuable insights and enable more efficient and coordinated urban management. For example, real-time traffic data can inform lighting adjustments to improve traffic flow and reduce congestion.

Overall, advancements in data analytics and artificial intelligence have revolutionized smart street lighting systems. By leveraging the power of data, these technologies enable optimized energy usage, proactive maintenance, adaptive lighting strategies, and data-driven decision making, leading to more efficient and sustainable urban lighting environments.

Smart street lighting has emerged as a transformative technology with a focus on energy efficiency. Here's a review highlighting its key aspects:

Energy Efficiency: Smart street lighting leverages LED technology, a game-changer in energy efficiency. The widespread adoption of LEDs significantly reduces energy consumption compared to traditional lighting sources. LEDs not only consume less energy but also boast a longer lifespan, contributing to sustainability efforts.

Smart Controls and Sensors: The integration of smart controls and sensors is a hallmark of modern street lighting. Remote monitoring capabilities empower municipalities to manage and control lighting levels in real-time, ensuring optimal energy consumption. Motion sensors further enhance efficiency by dynamically adjusting light intensity based on the presence of pedestrians or vehicles, minimizing unnecessary energy use.

Connected Systems: The incorporation of Internet of Things (IoT) technology facilitates the interconnectivity of street lights. Centralized control systems enable efficient monitoring and management of entire networks, allowing for strategic scheduling and operation. This

interconnectedness enhances the overall intelligence of street lighting infrastructure.

Data Analytics: Advanced analytics play a pivotal role in optimizing energy usage. Insights into usage patterns enable municipalities to make informed decisions about the deployment of lighting resources. By identifying low-traffic periods, these systems reduce unnecessary energy consumption, contributing to both cost savings and energy efficiency.

Solar Integration: Smart street lighting systems often integrate solar panels, tapping into renewable energy sources. This integration not only reduces dependency on the grid but also aligns with sustainability goals. Solar-powered Street lights offer a greener and more eco-friendly solution, especially in areas with abundant sunlight.

Cost Savings: Smart systems contribute to cost savings through proactive maintenance. Real-time detection of faults and issues enables timely intervention, reducing downtime and minimizing the need for frequent manual inspections. While the initial deployment cost can be a challenge, the long-term savings justify the investment.

Environmental Impact: The adoption of energy-efficient lighting, coupled with smart controls, significantly reduces the carbon footprint associated with street lighting. By aligning with global sustainability efforts, smart street lighting contributes to mitigating climate change and promoting environmentally conscious practices.

Challenges and Considerations: Despite its benefits, the initial costs of deploying smart street lighting systems can be a barrier for some municipalities. Additionally, ensuring the cybersecurity of connected systems is crucial to prevent unauthorized access and potential disruptions.

Future Directions: The integration of 5G technology holds promise for even more advanced communication and control capabilities. Continued advancements in sensor technologies are expected to further enhance the responsiveness of smart street lights to real-time environmental conditions.

Challenges and Considerations in Smart Street Lighting Implementation:

1) **Initial Costs:**

   Challenge: The upfront investment for deploying smart street lighting systems, including sensors and connectivity infrastructure, can be a barrier for some municipalities.

Consideration: Exploring financing options, partnerships, or government incentives can help alleviate initial cost challenges.

2) **Security Concerns:**

   Challenge: Ensuring the cybersecurity of connected systems is crucial to prevent unauthorized access and potential disruptions.

   Consideration: Implementing robust cybersecurity measures, encryption protocols, and regular system audits are essential to safeguard against cyber threats.

3) **Integration with Existing Infrastructure:**

   Challenge: Retrofitting existing street lighting infrastructure with smart technologies may pose challenges due to compatibility issues.

   Consideration: Conducting thorough assessments and planning seamless integration strategies can help mitigate compatibility issues.

4) **Maintenance and Upkeep:**

   Challenge: While smart systems can reduce maintenance needs through proactive fault detection, ensuring ongoing upkeep remains essential.

   Consideration: Establishing regular maintenance protocols and training personnel for efficient system management is crucial for sustained performance.

5) **Data Privacy:**

   Challenge: Gathering and analysing data from smart street lights raise concerns about individual privacy.

   Consideration: Implementing transparent data collection policies, anonymizing data, and adhering to privacy regulations are imperative to address these concerns.

6) **Interoperability:**

   Challenge: Ensuring interoperability between different smart street lighting components and systems is crucial for seamless operation.

   Consideration: Adopting industry standards and fostering collaboration between technology providers can enhance interoperability.

7) **Community Engagement:**

Challenge: Successful implementation requires community acceptance and engagement.

Consideration: Conducting awareness campaigns, seeking public input, and addressing concerns proactively can foster community support.

8) **Reliability and Downtime:**

Challenge: Dependence on technology can result in downtime if not properly managed.

Consideration: Implementing redundant systems, regular testing, and quick response protocols can minimize downtime risks.

9) **Energy Source Dependency:**

Challenge: Solar-powered smart street lights may face challenges in areas with limited sunlight.

Consideration: Evaluating local conditions and supplementing solar with alternative energy sources can address energy source dependencies.

10) **Scalability:**

Challenge: Scaling smart street lighting systems for larger urban areas may pose logistical challenges.

Consideration: Planning for scalability from the outset and adopting modular solutions can facilitate smooth expansion.

Navigating these challenges requires a comprehensive approach, involving collaboration between stakeholders, adherence to standards, and a commitment to addressing both technical and social considerations for the successful deployment of smart street lighting systems.

Environmental Impact Review on Smart Street Lighting for Energy Savings:

1. **Reduced Carbon Footprint:**

Positive Impact: The adoption of energy-efficient LED lighting and smart controls significantly reduces the carbon footprint associated with street lighting. This aligns with global efforts to mitigate climate change.

2. **Energy Efficiency:**

Positive Impact: The use of LED technology and smart controls leads to substantial energy savings. By optimizing lighting levels based on real-time needs and using energy-efficient sources, smart street lighting contributes to overall energy efficiency.

3. **Renewable Energy Integration:**

Positive Impact: Some smart street lighting systems incorporate solar panels, tapping into renewable energy sources. This integration further reduces reliance on conventional grid power and promotes eco-friendly practices.

4. **Optimized Resource Utilization:**

Positive Impact: Data analytics provide insights into usage patterns, allowing municipalities to make informed decisions about when and where to deploy lighting resources. This optimization reduces unnecessary energy consumption during low-traffic periods.

5. **Sustainable Practices:**

Positive Impact: The integration of solar panels, energy-efficient lighting, and smart controls showcases a commitment to sustainable practices in urban infrastructure. This not only reduces environmental impact but also sets an example for other municipalities.

6. **Reduced Light Pollution:**

Positive Impact: Smart controls enable precise adjustment of light intensity, minimizing light spill and reducing light pollution. This has positive implications for preserving natural habitats and promoting biodiversity.

7. **Longer Lifespan of LED Technology:**

Positive Impact: The longer lifespan of LED technology compared to traditional lighting sources reduces the frequency of replacements, leading to less material waste and a more sustainable approach to street lighting.

8. **Awareness and Education:**

Positive Impact: The deployment of smart street lighting often comes with awareness campaigns about energy conservation and environmental impact. This educational aspect contributes to a broader understanding of sustainable practices in the community.

9. **Adaptation to Local Conditions:**

Positive Impact: Some smart street lighting systems adapt to local conditions, dimming or

adjusting lighting levels based on environmental factors. This adaptability minimizes energy waste and contributes to a more environmentally conscious operation.

10. **Contribution to Smart Cities:**

Positive Impact: Smart street lighting is a component of the broader smart city concept. As cities embrace interconnected and sustainable technologies, the overall environmental impact becomes more significant.

While the environmental impact of smart street lighting is predominantly positive, considerations should be given to the production and disposal of electronic components.

2. Objectives of the paper review on smart street light

- Understanding the concept of smart street lights

- Identifying technological advancements

- Assessing energy efficiency and environmental impact.

- Evaluating cost-effectiveness and economic considerations.

- Examining smart street lighting deployments and case studies.

- Identifying research gaps and future directions.

- The main objective of this project is to implement an IoT based Automatic Street Lightning System.

Overall, the objective of a literature review on smart street lights is to synthesize existing knowledge, provide an overview of the field, and contribute to a deeper understanding of the subject matter while identifying areas for future research and development.

3. Literature survey smart street lighting

1)After going through the research paper of Paritosh Chamola and Arti Noor [1], come to know that they designed the smart street light in such a way that the cost should be minimum and carbon footprint by integrating LED with a wireless technology. They used LDR sensors for changing its resistivity according to the spectrum of light which fall on it. It's working is like that in the absence of light resistance is more and in the presence of light its less. To improve its performance they added Motion Sensors, Arduino UNO, Current Sensor and the Blynk IOT app. The system also utilizes Blynk to enable remote monitoring of the data.

And finally declared that, by using smart lights we can have 58.74 % of power saving.

2) In the research paper of Shweta D1, Shruthi M2, Shreya A3, Shwetha B4, Sujay M5, Asst. Prof. Chaitanya K J2 [2], they used two techniques in order to minimize the power consumption. In first technique they used IR Sensors, the vehicle navigation on the National Highways can be sensed and accordingly the street light glows. Thus, the power consumption reduces considerably up to 30%. %. And the second technique is by using LDR'S this detects the light and the light doesn't glow during the day time. This reduces power consumption by 20%. Thus, by these techniques 50% of power consumption is reduced.

3)Chetna Badgaiyan1, Palak Sehgal2[3] used very different method, they used Wireless ZigBee Network and Wireless Sensor Network. ZigBee is wireless communication technology for communication among multiple devices in a WPAN. The maximum data transfer rate of Zigbee devices is 250 Kbps with a 2.4 GHz oscillator. Wireless Sensor Network is a set of small electronic devices which comprises of a microcontroller, an RF transceiver and sensors. They also used Light Sensor, Supervision module, control unit, Measuring Stations and detectors so that street light become highly efficient, low power consuming street light systems. There is ease of maintenance and high transmission rate of information from device to device in the systems explained.

4) Lakshmiprasad1, Keerthana2[4] used two types of modes. First one is Auto mode and second is Manual mode. In auto mode, according to the light intensity, slot of times and also monitoring the weather conditions the nodes are being switched on/off. It monitors the complete locality and thus saving power. Whereas in manual mode, system stores the parameters in computer about changes in environmental conditions continuously like heavy rain visibility, faults, more or less traffic congestion or during foggy conditions. User can manually define each node with specific intensity factor as per the requirement and can take any suitable corrective measure. And found that the maximum energy saving is done with this technology such as 97% saving at the time of dusk say from 7pm to 8pm and 96% savings at the time of dusk, say from 6am to 7am.

5) M. Abhishek et al [5] have implemented design of traffic flow-based street light control system with effective utilization of solar energy in the year 2015. They used the renewable source of energy i.e., the solar power for street lighting. They have also used 8052 series microcontroller and is developed by replacing the normal bulbs with the LEDs due to which the power consumption is reduced by 3 times. Sensors are placed on either side of the road which senses the vehicle movement and sends the commands to the microcontroller to switch ON and OFF the lights. Here all the street lights remain switched off and it glows only when it senses the vehicle

movement. Hence, because of the microcontroller, even when its night the lights are switched off.
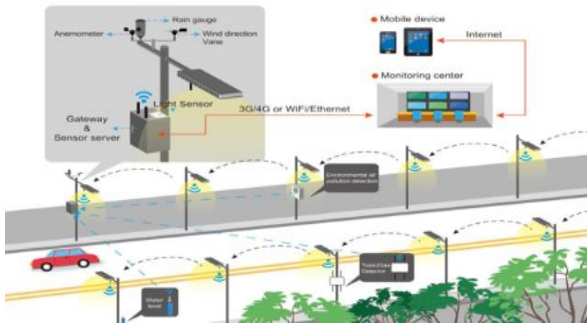

Fig -1: Actual working

Smart Controls and Sensors in Smart Street Lighting:

1. **Remote Monitoring:**

   Functionality: Enables real-time monitoring and management of street lights.

   Benefits: Optimizes energy consumption by adjusting lighting levels based on real-time needs.

2. **Motion Sensors:**

   Functionality: Detects movement, adjusting light intensity accordingly.

   Benefits: Reduces energy waste during low-traffic periods, enhancing efficiency and cost savings.

3. **IoT Integration:**

   Functionality: Connects street lights for centralized control and monitoring.

   Benefits: Facilitates efficient scheduling, operation, and potential predictive maintenance.

4. **Adaptive Lighting:**

   Functionality: Adjusts lighting based on environmental conditions, such as dimming during low-activity hours.

   Benefits: Reduces light pollution, promotes sustainability, and aligns with eco-friendly practices.

5. **Energy Optimization:**

   Functionality: Optimizes energy consumption through dynamic adjustments based on real-time needs.

   Benefits: Significant energy savings and improved cost efficiency.

6. **Customizable Scheduling:**

   Functionality: Allows municipalities to set specific schedules for street lighting.

   Benefits: Flexibility in resource utilization and energy conservation.

7. **Fault Detection and Reporting:**

   Functionality: Detects faults and issues in real-time, enabling proactive maintenance.

   Benefits: Reduces downtime, minimizes manual inspections, and leads to cost savings.

8. **Data Analytics for Usage Patterns:**

   Functionality: Analyses usage patterns to inform resource deployment decisions.

   Benefits: Minimizes unnecessary energy consumption during low-traffic periods.

9. **Responsive to Environmental Conditions:**

   Functionality: Responds to ambient conditions, adjusting lighting levels accordingly.

   Benefits: Enhances energy efficiency by aligning with natural light availability.

10. **Enhanced Public Safety:**

    Functionality: Improves visibility and security through motion sensors and adaptive lighting.

    Benefits: Creates well-lit areas when needed, contributing to public safety.

Smart controls and sensors in smart street lighting not only contribute to energy savings but also enhance operational efficiency, reduce maintenance costs, and create more sustainable and responsive urban environments.

4. Methodology

To make self-dependent street light I used the concept of speed-bump power generators is indeed based on converting the kinetic and potential energies produced by vehicles passing over speed bumps into electric energy and by upgrading this speed-bumpin such a way that the number of counts of vehicle and then it will decide is their rush on the road or not? and then accordingly decide the brightness of street light.

I also use IOT with Wi-Fi connectivity so that we can make flexibility in exception situation. For Example, any criminal gets hide in this region so police will face difficulty in catching criminal, at that time we can on all street light from anywhere due to this there is more visibility on road and officers will catch the criminals easily.

The Streetlight uses advanced AI algorithms to recognize vehicles that illegally drive in yellow lanes or make loadings and unloading's illegally, and automatically cites them for a traffic violation.

White Light Emitting Diodes (LED) replaces conventional HID lamps in street lighting system to include dimming feature.

This project is enhanced by integrating the LDR to follow the switching operation precisely and IOT to display the status of street on web browser and help in controlling it. The basis of the speed bump system is the mechanical mechanism since it dictates the changeable amount of energy. The most common and efficient mechanisms used in speed bumps are the roller, the crack-shaft, the magnetic and the rack-and-pinion.
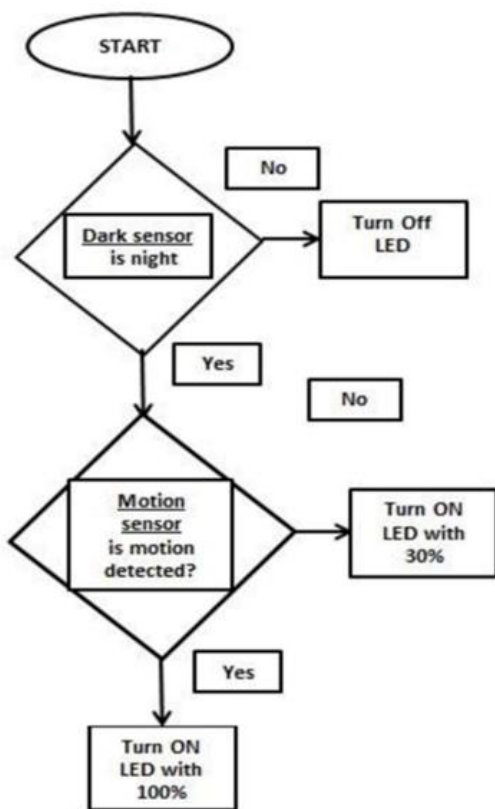

Fig -1: Working technique

Data Analytics in Smart Street Lighting:

1. **Usage Pattern Analysis:**

    Functionality: Utilizes data analytics to analyse usage patterns.

    Benefits: Informs municipalities about when and where to deploy lighting resources, minimizing unnecessary energy consumption during low-traffic periods.

2. **Predictive Maintenance:**

    Functionality: Analyses performance data to predict maintenance needs.

    Benefits: Enables proactive maintenance, reducing downtime and minimizing the need for frequent manual inspections.

3. **Energy Consumption Insights:**

    Functionality: Provides detailed insights into energy consumption patterns.

    Benefits: Facilitates optimization strategies, contributing to significant energy savings and cost efficiency.

4. **Customized Scheduling:**

    Functionality: Allows for the creation of customized lighting schedules.

    Benefits: Maximizes efficiency in resource utilization and adapts lighting to specific needs or events.

5. **Real-time Monitoring:**

    Functionality: Monitors street lights in real-time.

    Benefits: Enables immediate response to issues, improving overall system reliability and efficiency.

Solar Integration in Smart Street Lighting:

1. **Solar Panel Integration:**

    Functionality: Incorporates solar panels into street lighting infrastructure.

    Benefits: Harnesses renewable solar energy, reducing dependence on the grid and contributing to eco-friendly practices.

2. **Grid Independence:**

   Functionality: Enables street lights to operate independently from the conventional power grid.

   Benefits: Enhances sustainability by reducing reliance on non-renewable energy sources.

3. **Energy Storage:**

   Functionality: Stores excess solar energy for use during low-light conditions.

   Benefits: Provides consistent illumination, even in periods with limited sunlight.

4. **Reduced Operating Costs:**

   Functionality: Lowers energy costs by utilizing solar power.

   Benefits: Contributes to long-term cost savings, making the system more economically viable.

Cost Savings in Smart Street Lighting:

1. **Maintenance Reduction:**

   Strategy: Proactive maintenance through real-time fault detection.

   Benefits: Reduces downtime, minimizing the need for frequent manual inspections and lowering maintenance costs.

2. **Energy Efficiency:**

   Strategy: Optimization through smart controls and sensors.

   Benefits: Drastically reduces energy consumption, leading to substantial cost savings over time.

3. **Longer Lifespan of LED Technology:**

   Strategy: Adoption of energy-efficient LED lighting.

   Benefits: Extends the lifespan of lighting fixtures, reducing the frequency of replacements and associated costs.

4. **Reduced Light Pollution:**

   Strategy: Precise adjustment of light intensity.

   Benefits: Mitigates light pollution, avoiding unnecessary illumination and potential regulatory fines.

5. **Government Incentives:**

   Strategy: Leveraging incentives for sustainable initiatives.

   Benefits: Reduces the financial burden on municipalities, making the initial investment more attractive.

Incorporating data analytics, solar integration, and cost-saving strategies in smart street lighting not only enhances efficiency but also promotes sustainability, reduces environmental impact, and contributes to long-term economic benefits.

5. CONCLUSIONS

The smart street light project described in the statement offers several valuable features and benefits. By incorporating advanced technologies, such as vehicle speed estimation, number plate recognition, and accident detection, it enhances road safety and overall efficiency. It is stated that this project is not limited to rural areas but also extends its advantages to urban areas. Moreover, as technology continues to advance, the project can adapt to the increasing power demands by utilizing renewable energy resources, which proves to be advantageous in the long run.

Additionally, the integration of smart parking and support for driverless cars further demonstrates the versatility and potential of the proposed system. By leveraging wireless sensor networks and new RF solutions, the project aims to reduce installation costs and promote energy efficiency.

The design model presented in the paper is considered highly valuable, promising to overcome the limitations faced by conventional street lights currently in use. However, it is essential to actualize the system on a larger scale to assess its full impact and benefits.

Overall, the smart street light project offers a comprehensive and innovative solution that addresses key challenges in street lighting and paves the way for a more sustainable and efficient future.

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