ABSTRACT

Standardized street lighting plays a vital role in economic growth, safety, and human well-being in developing nations like India. The rise of power LEDs has transformed street lighting due to their controllability, low energy use, long life, and improved lighting parameters like CCT, CRI, and flicker control. These advancements have replaced older light sources and opened research opportunities exploring how lighting affects both visual and non-visual human responses, particularly with the discovery of ipRGCs and their impact on circadian rhythms.

This thesis focuses on developing a smart, energy-efficient, human-centric street lighting system for India by analyzing how varying CCT and flicker influence object detection. Initial studies evaluated drivers' reaction times under different CCTs and peripheral lighting, finding that 4000K offered the best results without peripheral light, while 5000K (main) and 6000K (peripheral) proved optimal overall. Flickering peripheral LEDs were found to delay reactions, suggesting the need for stable, flicker-free lighting.

Further, dimming techniques like Beam Angle Switching (BAS) and Pulse Width Modulation (PWM) were tested for energy savings. BAS was found not to impact lumen output or heat dissipation, and its use in Jadavpur University reduced energy use by 55.52%, saving 53.14 tons of CO_2 annually. Combining BAS with PWM offered additional savings without affecting CCT.

In the final phase, EEG and GSR studies assessed brain responses to varied lighting scenes. Results showed that CCTs between 4500K–5000K optimized object recognition and brain activity. A scoring method for lighting scenes was also developed to evaluate human-centrism. Finally, a tunable smart luminaire and a low-cost RGB sensor-based CCT monitoring device were built.

Overall, the research offers actionable solutions for safer, human-focused, and energy-efficient street lighting in urban India.