WiSH Hardware Track G-20

DESIGN THINKING PROJECT

SMART STREETLIGHT DIMMER BASED ON TRAFFIC FLOW

Glow on the Go:

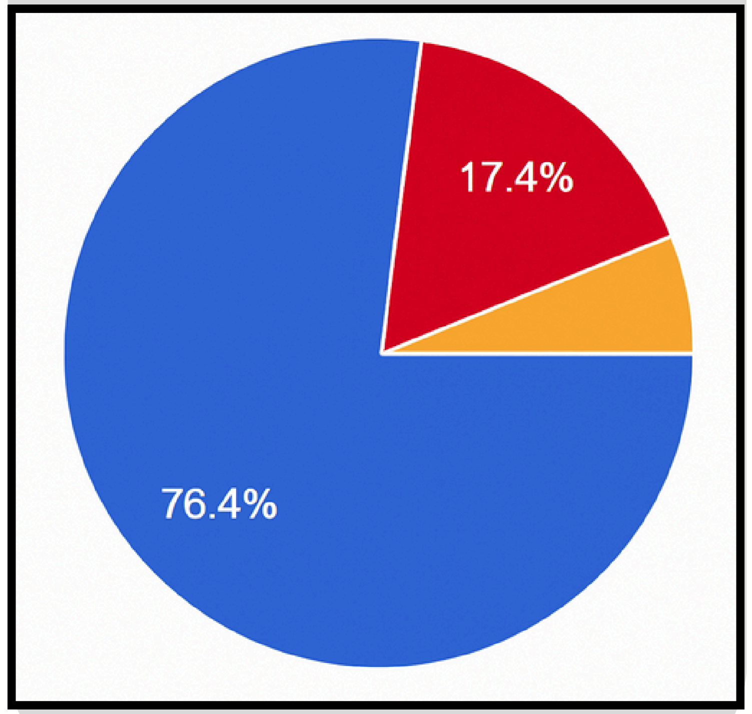
Intelligent Streetlights That Follow the Flow

YOUKTA — RASHMI — SUPRAJA — SWASTI — SHWETA

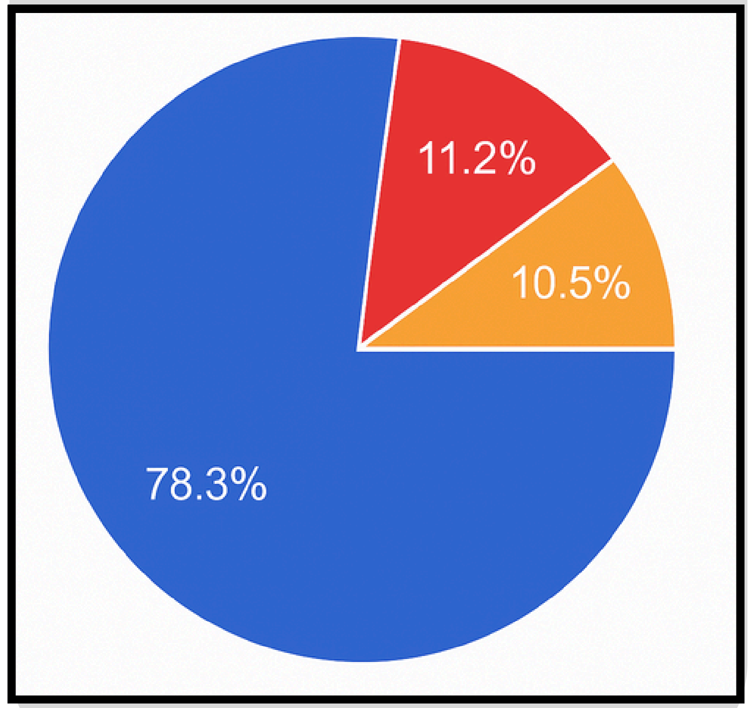
UNDERSTANDING REAL NEEDS: OUR EMPATHY-DRIVEN APPROACH

📊 Shared Google Form survey with 140+ responses
📚 Researched energy usage reports and smart lighting studies in Indian cities

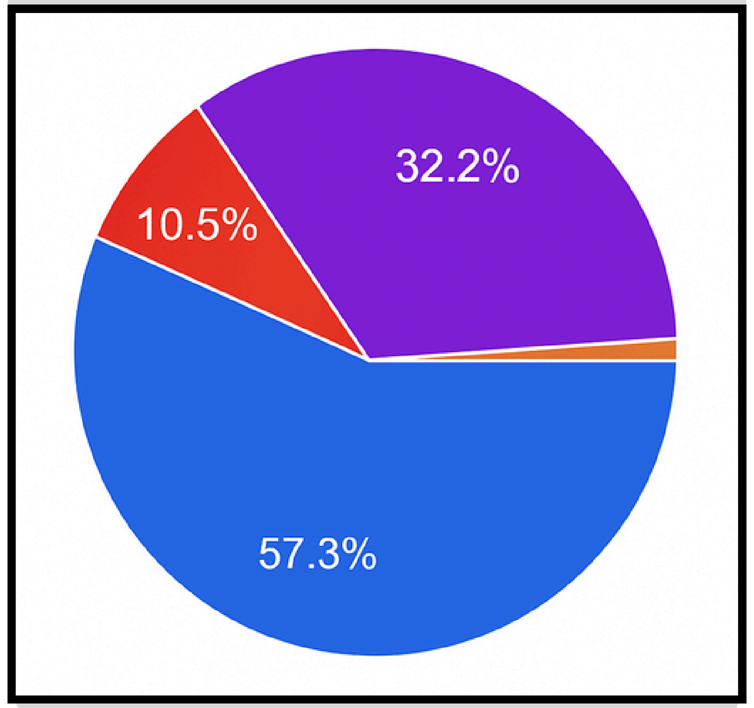
Are streetlights in your area ON all night?



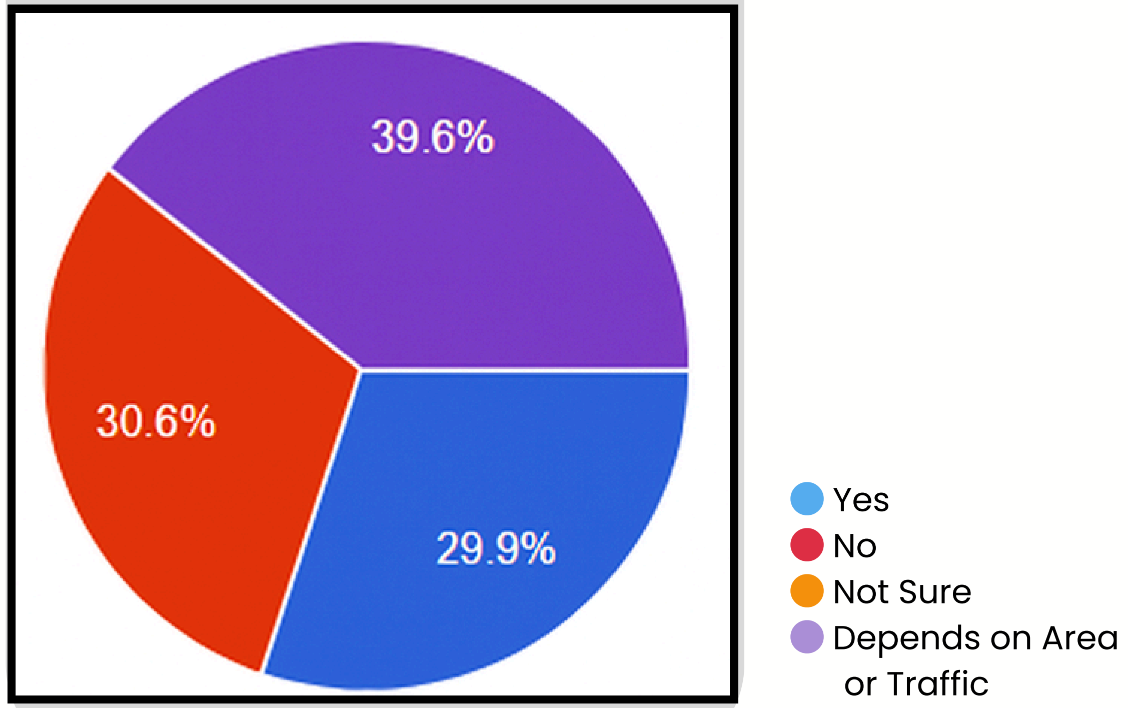
Are you comfortable with the use of motion sensors (eg. infrared, mmWave radar) to detect nearby movement?



Do you think different areas (eg. highways, residential areas, etc) should have different dimming strategies?



Do you think streetlights should dim/switch off when there is no traffic?



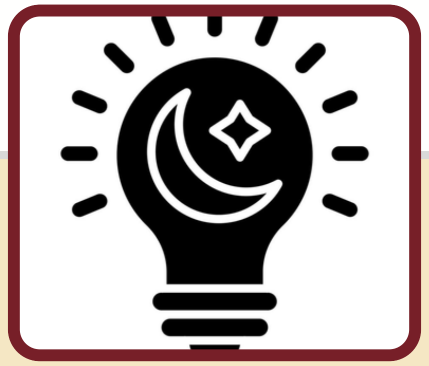
KEY INSIGHTS INFERRED: Dimming strategies should depend on the specific area's needs, not a single policy

Majority favor tailored strategies by area

Strong support for smart/motion-sensing lighting

KEY USER INSIGHTS

User feedback reveals a clear demand for smart, adaptive lighting — with better control, reduced energy waste, improved reliability and context-aware performance.

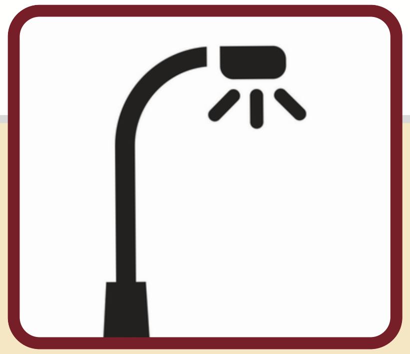


User Habits & Context :

- 🏠 94.3% stay indoors at night
- 💡 75.7% say streetlights stay ON all night

User Preferences :

- ✅ 64.3% support smart dimming
- 📍 46.4% prefer dimming based on location
- 📸 56.9% accept camera-based detection



Main Problems :

- ⚠️ Poor maintenance & flickering
- 🌑 Uneven lighting
- 🔌 Energy wastage
- 🌟 Excessive brightness & light pollution

What Users Want :

- ✅ Safe, reliable lighting
- 🌱 Smart, energy-saving systems
- 🚫 No sudden light changes
- 🛠️ Better maintenance

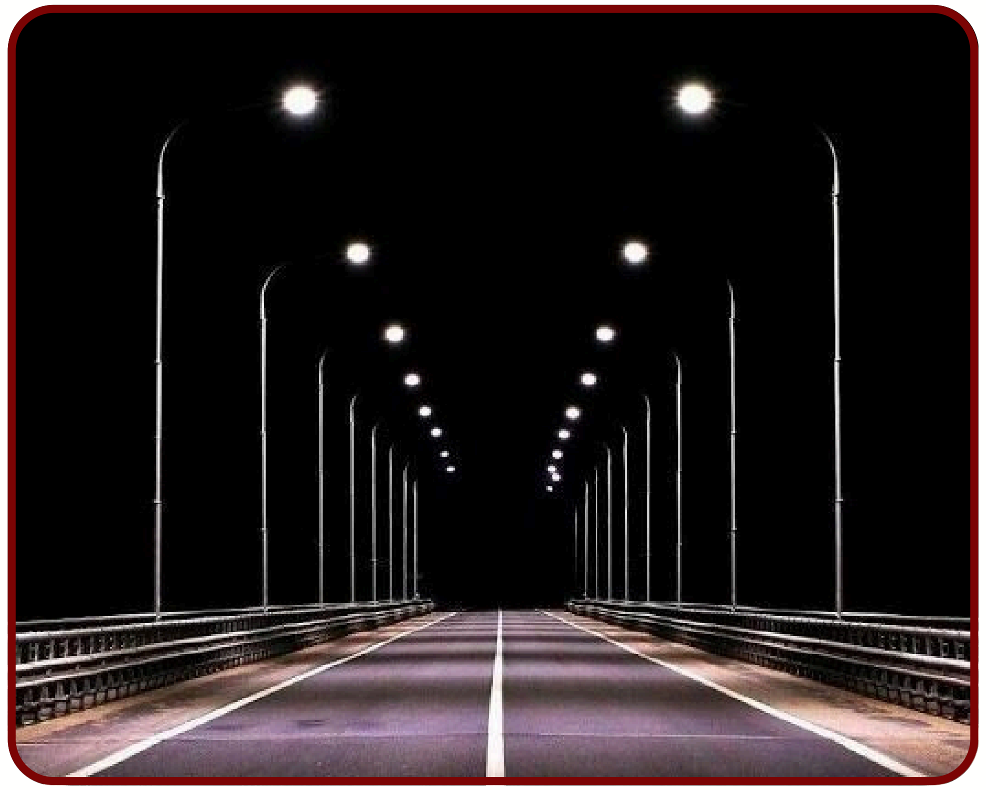
DEFINE

Framing the Core Problem

How might we save energy by adapting streetlight brightness to actual traffic, without compromising safety?

Pain Points Identified :

- Streetlights stay ON even on empty roads
- Poor maintenance & delayed repairs (flickering, outages)
- Uneven lighting across zones – some streets stay dark
- No feedback or alert system for streetlight failures
- Dim or non-functioning streetlights make pedestrians feel unsafe at night
- No zoning strategy – highways, colonies, and parks use same lighting pattern



Empty roads, fully lit – but at what cost?

IDEATE

Brainstorming potential solutions

Core Objectives:

- Achieve energy efficiency, cost-effectiveness, and smart adaptability based on real-time motion and ambient light conditions.

Sensor Optimization:

- PIR Sensors for low-cost motion detection at each pole.
- 1 mmWave Radar per 15 streetlights to detect vehicle speed & direction across zones.
- Ambient Light Sensors to auto-adjust brightness during low-light conditions only.

Smart Operating Modes:

- Timer Mode – Fixed schedule lighting (basic).
- Zone Pulse Mode – Lights in a zone respond to mmWave-triggered motion.
- Urban Wave Mode – Lighting follows the vehicle path dynamically.

Power-Saving Strategy:

- Dimming to 40% when no activity is detected—ensuring energy conservation while maintaining visibility.

Through targeted ideation, we achieved a smart and scalable streetlighting system by combining shared sensing, energy-saving dimming, and renewable power, tailored to real-world traffic dynamics and cost constraints

THREE MAIN MODES OF OUR SOLUTION

TIME BASED MODE

Lighting follows a fixed schedule based on time (e.g. peak hours = full brightness).

ZONE PULSE MODE

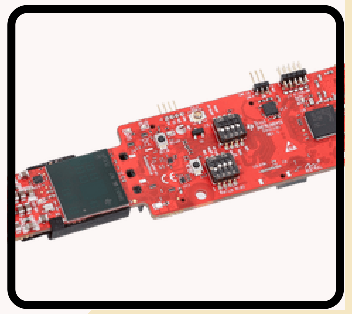
Lights stay dim until motion is detected. It will increase brightness in a pulse like manner.

URBAN WAVE MODE

As soon as motion is detected, the entire row of lights using communication module switch on.

CORE COMPONENTS OF OUR SYSTEM

From precise motion detection to solar-powered autonomy and seamless pole-to-pole communication, each module plays a vital role in making the system adaptive, cost-effective, and ready for the future of smart cities.

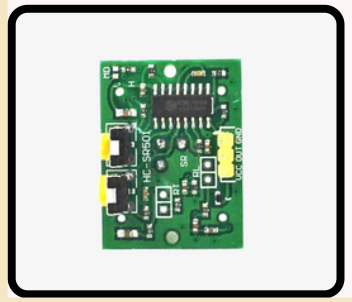


mmWave Radar (IWR6843AOP)

Long-range radar with speed, distance, and direction

PIR Sensor(HC-SR501)

Detect nearby human motion

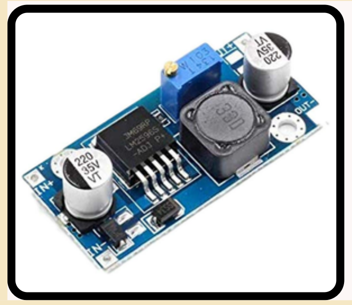


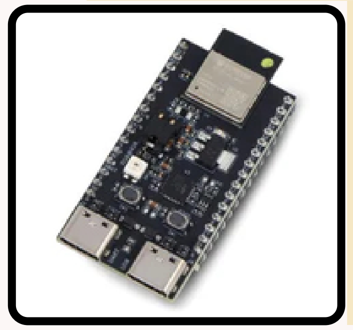
Ambient Light (BH1750)

For auto-dimming based on daylight

Buck Convertor

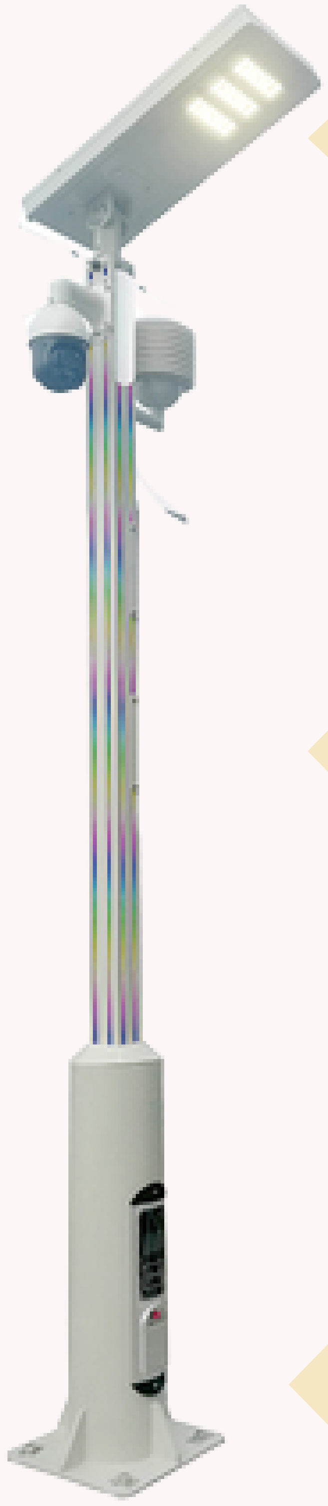
efficiently lowers voltage for safe component power.





ESP32-H2 MCU & GSM Module

Central control unit that handles data processing and communication & sends SMS alerts



100W LED

Used for street illumination

100W LED Driver

Powers 100W LED safely at constant

Solar Panel

Renewable Power source

12V 70Ah Lead-Acid Battery

reliably powers streetlights overnight

12V 10A Charge Controller

Manages charging and discharging

Where is it used?

- Offices, commercial buildings, schools, public parks.
- Ideal for environments where lightning requirements are consistent and can be predetermined

Technology Used

- Real time clock module or time clock controller to maintain accurate on/off schedules.
- User interface, can be integrated with IoT platforms.

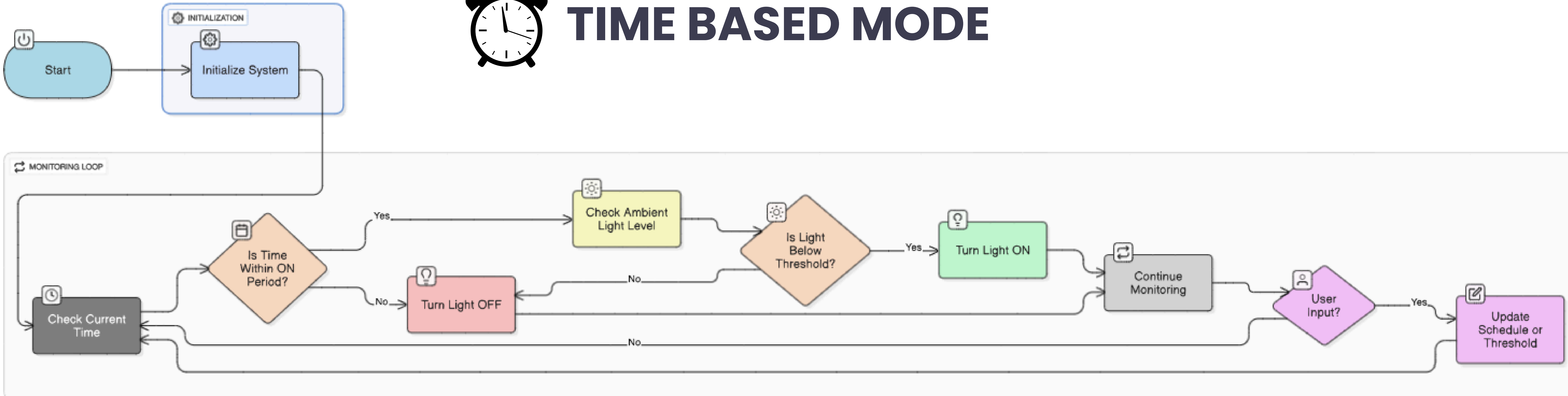
Target Audience

- Facility and building managers, school authorities, and commercial property owners.
- Best suited for institutions and semi-public spaces.

Why use it?

- Provides a predictable consistent lighting schedule.
- Highly Energy efficient
- Enhances comfort and safety by ensuring spaces are lit only when needed, according to operational hours

TIME BASED MODE



Where is it used?

- Gated campuses, societies, hostels, parks, and low-traffic zones.
- Ideal for controlled environments with predictable human movement.

Technology Used

- PIR and ambient light sensors with a local microcontroller.
- Powered by solar panels and battery; no network needed.

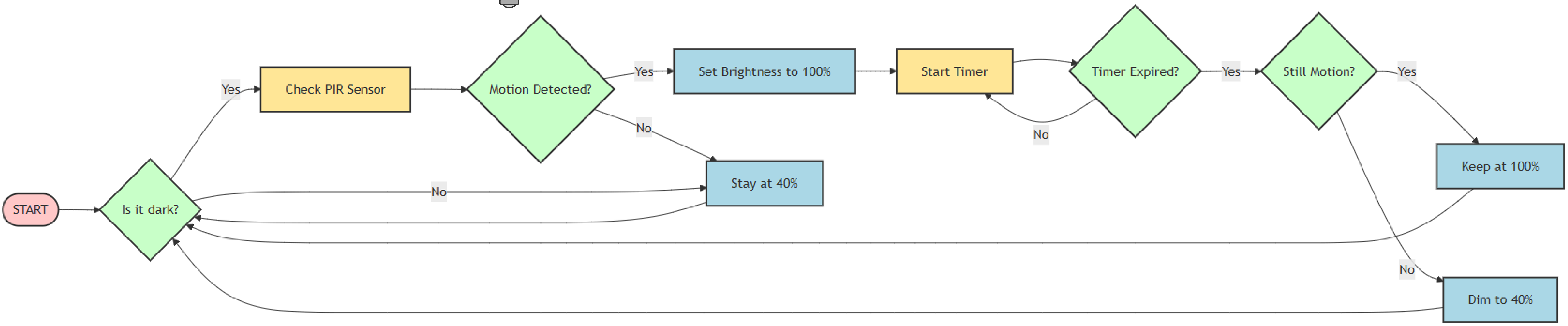
Target Audience

- Facility managers, RWAs, urban planners, and CSR teams.
- Best suited for institutions and semi-public spaces.

Why use it?

- Simple, cost-effective, and highly energy-efficient.
- Auto-brightens on motion; default dim saves 60%+ power.

ZONE PULSE MODE



Where is it used?

- Designed for urban streets, highways, and smart city roads.
- Handles unpredictable, high-speed vehicular movement efficiently.

Technology Used

- Smart city planners, municipal bodies, and highway authorities.
- Ideal for regions focusing on intelligent infrastructure.

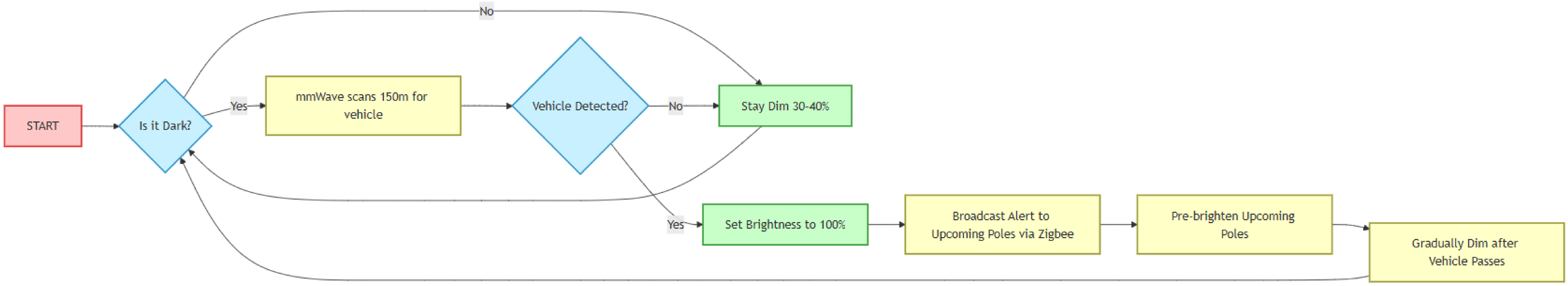
Target Audience

- Uses mmWave radar, PIR, ambient light sensors, and GPS.
- Zigbee enables pole-to-pole communication for seamless control.

Why use it?

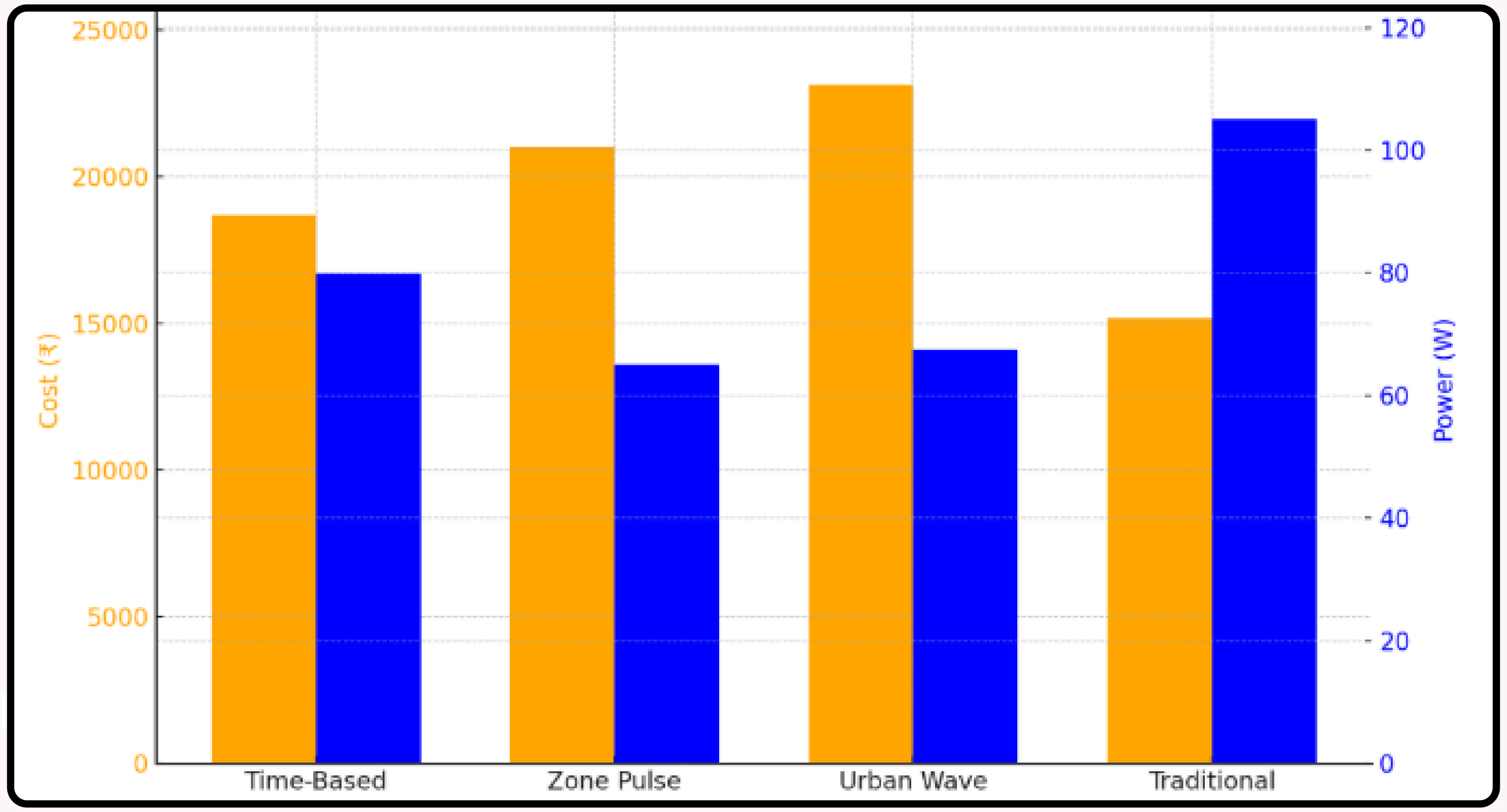
- Enables real-time response to traffic and reduces energy waste.
- Supports gradual dimming and predictive lighting via GPS & sensor fusion.

URBAN WAVE MODE



COST AND POWER

Component	Cost (₹)	Avg Power Consumption
mmWave Radar	1750 (for 15 poles)	2.5 W
PIR Sensor	130	0.15 mW
Ambient Light Sensor	100	0.002 W
Buck Converter	229	370 mW(load)
ESP32-H2 MCU	350	1.5 W - 2 W
GSM Module	180	8 W(peak) ; 4 mW(sleep mode)
100W LED	2,190	100 W (or 40 W when dimmed)
100W LED Driver	300	5 W
12V 70Ah Battery	5,500	– (energy storage)
PWM Charge Controller	840	0.48 W
Solar Panel	7000	– (energy source)



⏰ TIME BASED MODE

Total Cost: 18490
Total Power: 79.85 W

(Ambient Light, Buck Convertor, ESP32, GSM Module, 100W LED, 100W LED Driver,Solar Panel, Battery, Charge controller)

💡 ZONE PULSE MODE

Total Cost: 20820
Total Power: 64.98 W

(Ambient Light, Buck Convertor, ESP32, GSM Module, 100W LED, 100W LED Driver,Solar Panel, Battery, Charge controller, PIR Sensor)

📡 URBAN WAVE MODE

Total Cost: 22935
Total Power: 67.48 W

(Ambient Light, Buck Convertor, ESP32-H2, GSM Module, 100W LED, 100W LED Driver, Solar Panel, Battery, Charge controller, PIR Sensor, mmWave Radar Sensor)

🔋 Note: Solar panels increase initial cost but eliminate electricity bills.
💰 Investment is recovered in 3 years, making the system cost-effective long-term.
📡 Only 1 mmWave radar is used per 15 poles, reducing cost while ensuring accurate detection.

🌃 Traditional Streetlight:
Cost: ₹15,000 (approx.)
Power Consumption: 105 W (constant full brightness)

AREA-WISE **DIVISION**

Not all areas have the same traffic pattern, activity level, or infrastructure support.

Hence, using one fixed streetlight logic everywhere is inefficient and costly.

To maximize energy savings, optimize illumination, and adapt to local conditions, we divide use cases into:

Rural Roads / Village Streets
Mode: Zone-pulse
Why:
- Very low night-time activity
- Limited power infrastructure
- Solar-friendly

Urban Residential Streets
Mode: Zone pulse
Why:
-Irregular foot/vehicle traffic
-Needs dim + motion-triggered bright light
-Prioritizes both safety and savings

Highways / Industrial Corridors
Mode: Urban-wave
Why:
-Predictable peak traffic
-Usually AC powered
-Motion sensing unreliable at high speeds

Public Parks / School Campuses
Mode: Zone pulse
Why:
-Low, sporadic movement at night
-Quiet zones benefit from low base lighting
-Ideal for solar-powered setups

Commercial Markets / Shopping Areas
Mode: Time based
Why:
-Fixed business hours
-High lighting demand in evenings
-Efficient via scheduled control

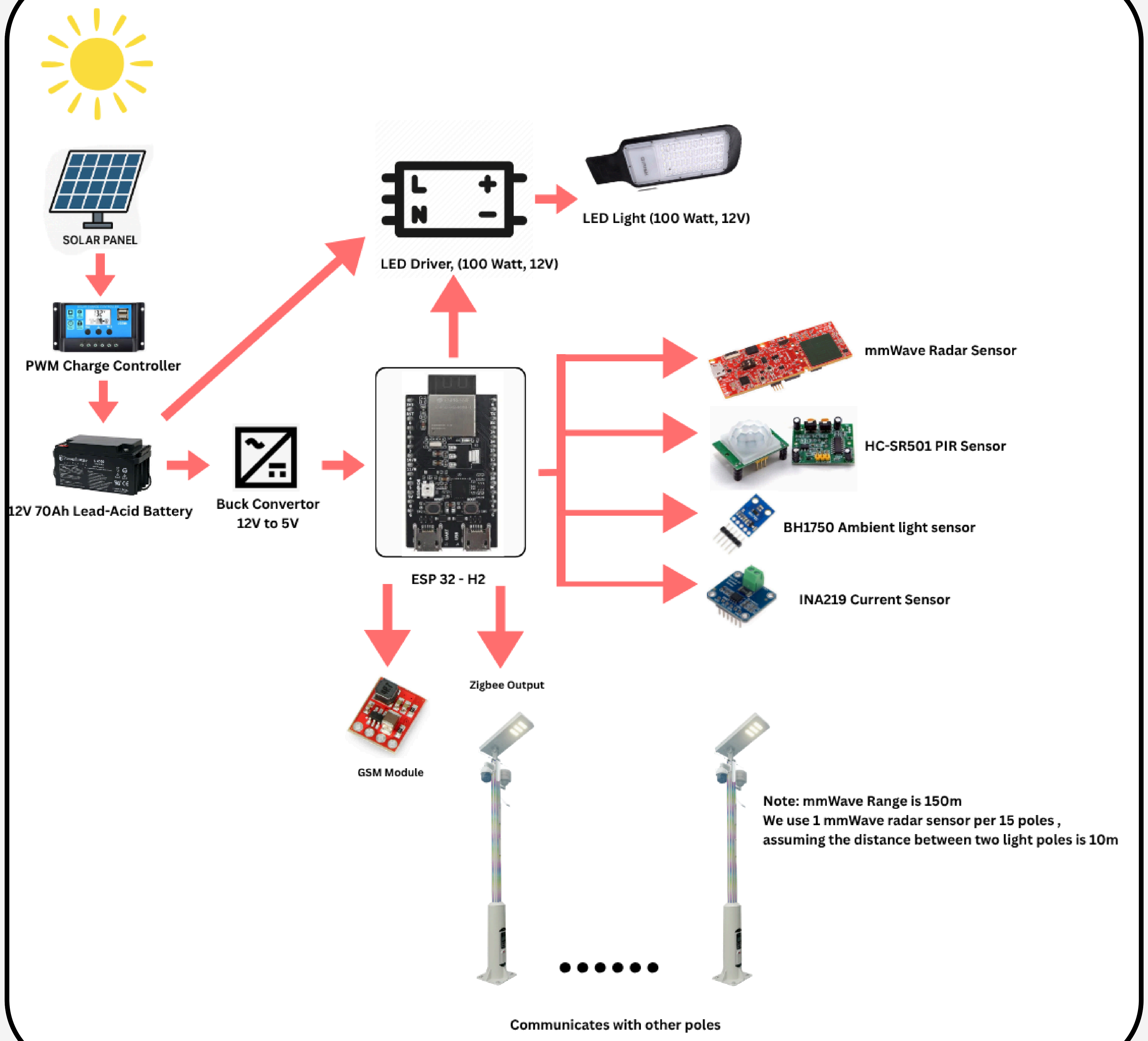
Flyovers / Underpasses
Mode: Urban wave
Why:
-Motion-based boost ensures visibility
-Safer with energy-efficient fallback

Smart City Zones / BRT Corridors
Mode: Urban wave
Why:
-High-tech infrastructure available
-Mixed traffic behavior
-Integrated smart communication preferred

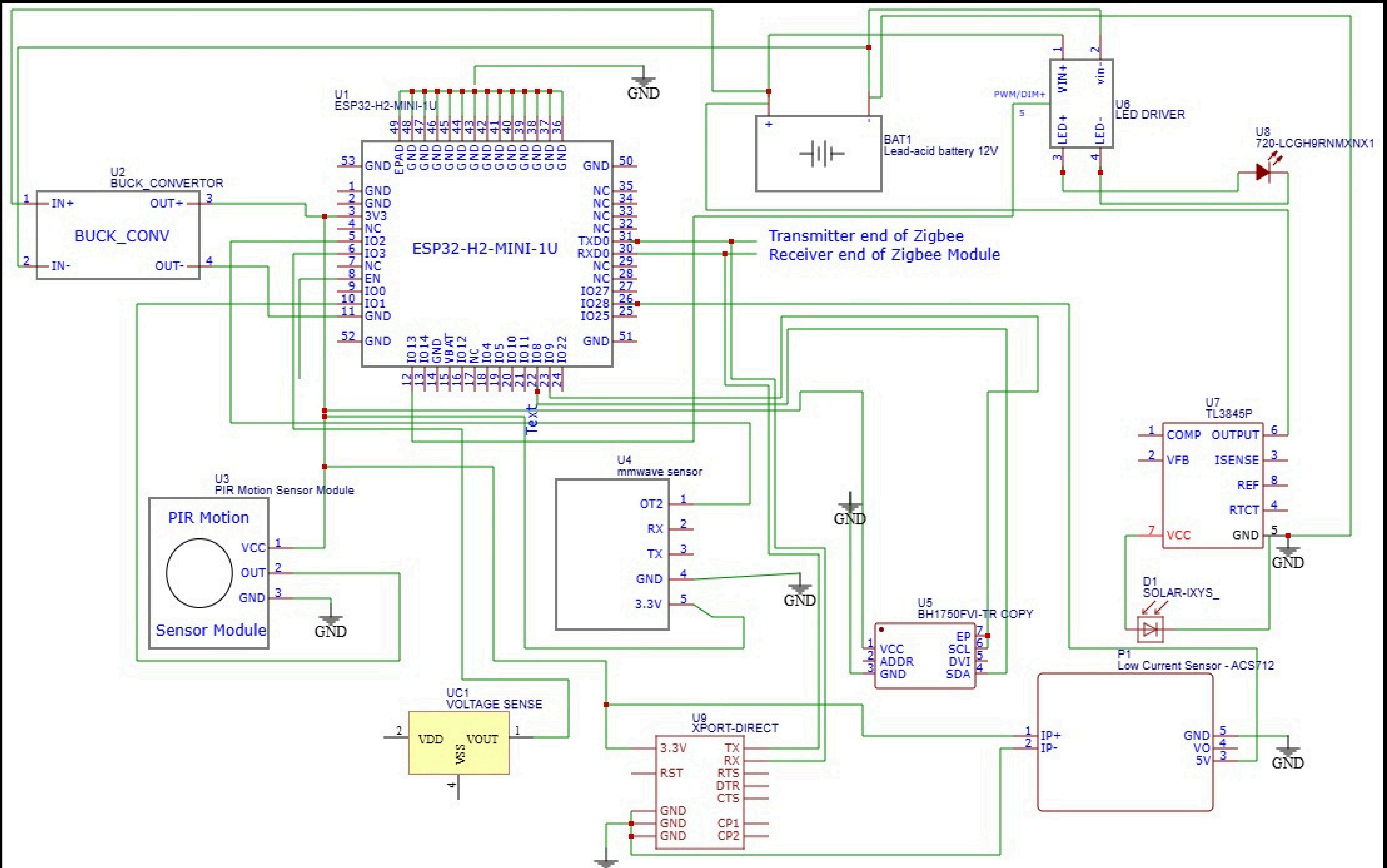
DETAILED COMPARISON OF METRICS IN EACH MODE

Feature	Time mode	Zone Pulse Mode	Urban Wave mode
Brightness Control	Fixed (based on clock)	Variable (based on detected motion)	Variable (based on detected motion)
Ideal For	Villages, factories, parks in residential areas	Residential areas, tech parks etc	Highways, underpasses, city roads
Energy Efficiency	⭐⭐⭐ (Predictable but rigid)	⭐⭐⭐ (Balance)	⭐⭐⭐⭐ (Best balance)
Safety for Pedestrians	**On but may miss context**	**Responsive + always aware**	**Responsive + always aware**
User Comfort	⭐⭐⭐ ⭐ (Consistent light levels)	⭐⭐⭐⭐ (Consistent light levels)	⭐⭐⭐⭐⭐ (Feels intelligent and human-like)
Responsiveness	Low (changes by clock only)	High (instant + scheduled backup)	High (instant + scheduled backup)
Hardware Cost	Low	Moderate	High (add ZigBee, more logic)
Power Source	Solar or AC (predictable usage)	Solar or AC (predictable usage)	Mostly AC with Solar backup
Setup Complexity	Low (time sync needed)	Moderate	High (network + calibration)
Wireless Comms Needed?	❌ None	❌ None	✅ Yes (ZigBee/LoRa for inter-pole alerts)
Failsafes Needed	RTC must be synced accurately	Sensors must all work	Sensors + Comms must all work
Maintenance Frequency	Moderate	Moderate	Higher (multi-module monitoring)
Network Scalability	⚪ Limited	⚪ Limited	✅ High (Mesh-compatible, clusterable)
Smart City Integration	⚪ Maybe	✅ Good fit	✅✅ Best fit (IoT-ready)
Best For	Schools, shopping complexes, trails	Residential areas, college campuses	Highways, underpasses

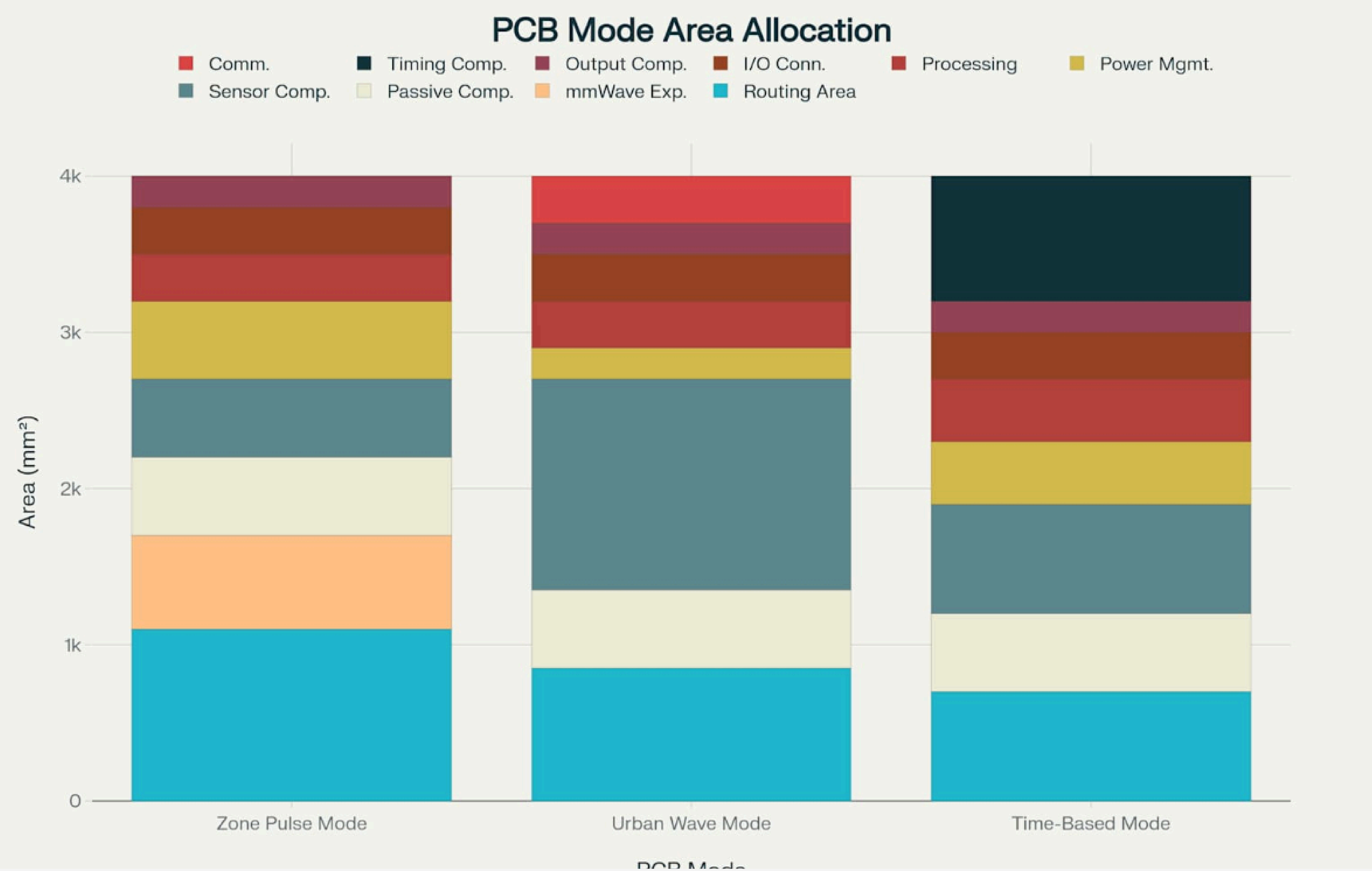
BASIC ARCHITECTURE DIAGRAM



CIRCUIT DIAGRAM



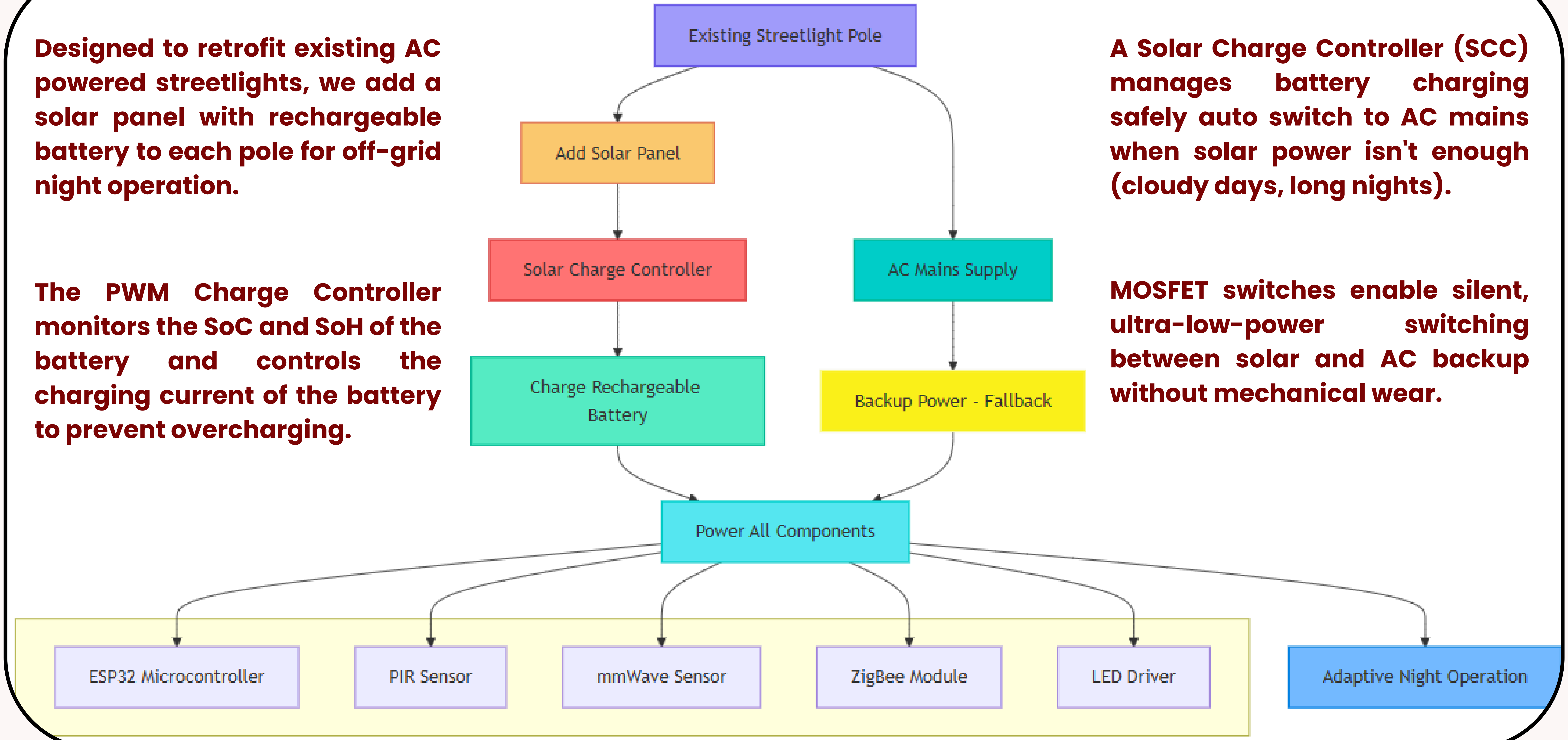
MODE-WISE AREA ANALYSIS



Solar-Based Power Supply for Adaptive Streetlight Operation

Designed to retrofit existing AC powered streetlights, we add a solar panel with rechargeable battery to each pole for off-grid night operation.

The PWM Charge Controller monitors the SoC and SoH of the battery and controls the charging current of the battery to prevent overcharging.



A Solar Charge Controller (SCC) manages battery charging safely auto switch to AC mains when solar power isn't enough (cloudy days, long nights).

MOSFET switches enable silent, ultra-low-power switching between solar and AC backup without mechanical wear.

WHY ZIGBEE?

1. Wireless mesh networking
2. Low latency
3. Built-in security
4. Low power
5. Scalable

SYSTEM COMPONENTS

1. Zigbee module -transciever
2. Microcontroller (MCU/ECU)
3. Power supply and regulators
4. Steering/Brightness Actuator
5. Sensor input (optional)

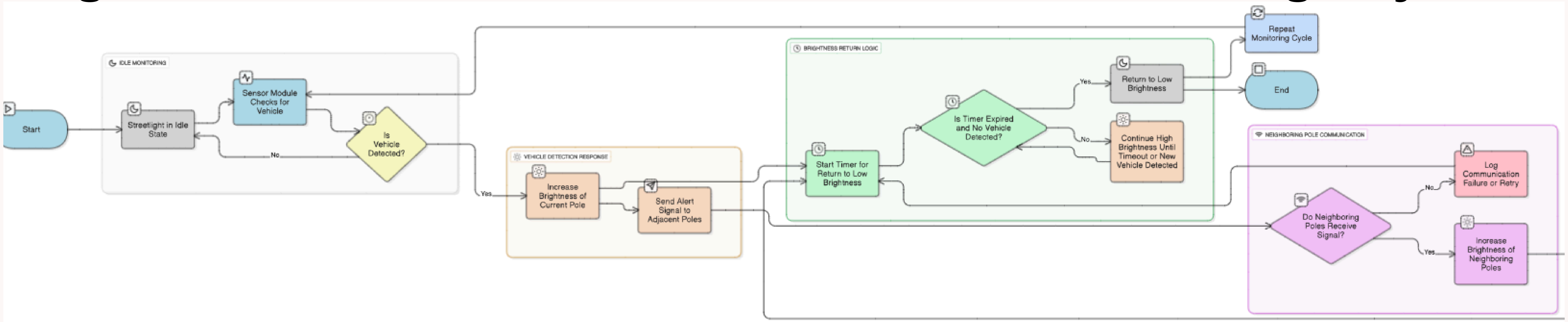
COMMUNICATION FLOW

1. ECU sends zigbee command
2. Zigbee module transmits wirelessly
3. Streetlight module recieves via zigbee
4. Command decoded by MCU
5. Actuator is triggered accordingly

KEY BENEFITS

1. Real time control
2. Fault detection
3. Reduced energy costs
4. Scalable network
5. Improved safety

Zigbee-Based Communication Protocol for Smart Streetlight System



BUILT-IN FAULT DETECTION USING EXISTING COMPONENTS

Component	Possible Fault	Detected By
Solar Panel	Not charging / damaged / shaded	Ambient Light Sensor (BH1750) shows bright + Battery Voltage (via ADC) not rising during day
Battery	Undervoltage / not holding charge / not charging	Battery Voltage (read by ESP32 ADC) stays <11V or doesn’t rise during sun hours
Buck Converter	Not supplying 5V to ESP32	ESP32 goes offline, GSM fails to send daily “All OK” message → Fault inferred after reboot via NVS logs
LED + Driver	No light output, driver not switching	BH1750 detects no brightness even after PWM is sent → LED or driver fault
Ambient Light Sensor	Stuck reading / no variation	BH1750 LUX reading flat across 24h
Passive InfraRed Sensor	No human detection	GPIO input from PIR stays LOW for hours, even in known busy periods
mmWave Sensor	Always 0 or spamming detection	GPIO input from mmWave sensor stays LOW (no detection) or toggles rapidly with no PIR match
ESP32 MCU	Loop freeze / crash / restart	GSM “All OK” message not received → assumed ESP or buck fault
Low Dropout Regulator	All sensors stop responding	All sensors stop responding (BH1750, PIR, mmWave, GSM)
Charge Controller	Not charging battery	Sunlight present (BH1750), but battery voltage stays flat → controller not transferring power

Fault Alerts via Global System for Mobile Communications (GSM)

- **Module: SIM800L (GSM + SMS via AT commands)**
- **Trigger: Any fault detected**
- **Powered by: 5V Buck Converter → LDO (Low Dropout Voltage Regulator) → GSM Module (3.8V)**
- **SMS Power Use:**
  - **Idle: ~4mW**
  - **Peak (sending SMS): 8W**
- **Addition of 1000μF before LDO to survive the sudden burst of power**
- **ESP32 sends AT+CMGS (Command Message Global Send) when faults are flagged**
- **Future Scope: Add web dashboard to log and monitor faults across all poles centrally**

TESTING METHODOLOGY & MARKET RESEARCH

Evaluation module consists of:

- Real-world field testing of all 3 modes
- Power measurement logging
- Fault detection triggers & GSM alert validation
- Zigbee sync latency checks
- A user perception survey
- Post-test analysis (ROI, graphs, failure rate)

Market Opportunity Size

- India has **~3.04 crore** streetlights, most of which are still conventional or basic LEDs.
- Only **11–12%** use adaptive lighting.
- Our system, costing **₹16k–₹18k** per pole with ROI in **2.5–4** years, fits well into government/CSR upgrades.
- Target Market Size Estimate (in ₹):
    - Even if one retrofits 5% of 3 crore poles:
    - 15 lakh × ₹18,000 avg. = **₹2,700 crore opportunity**

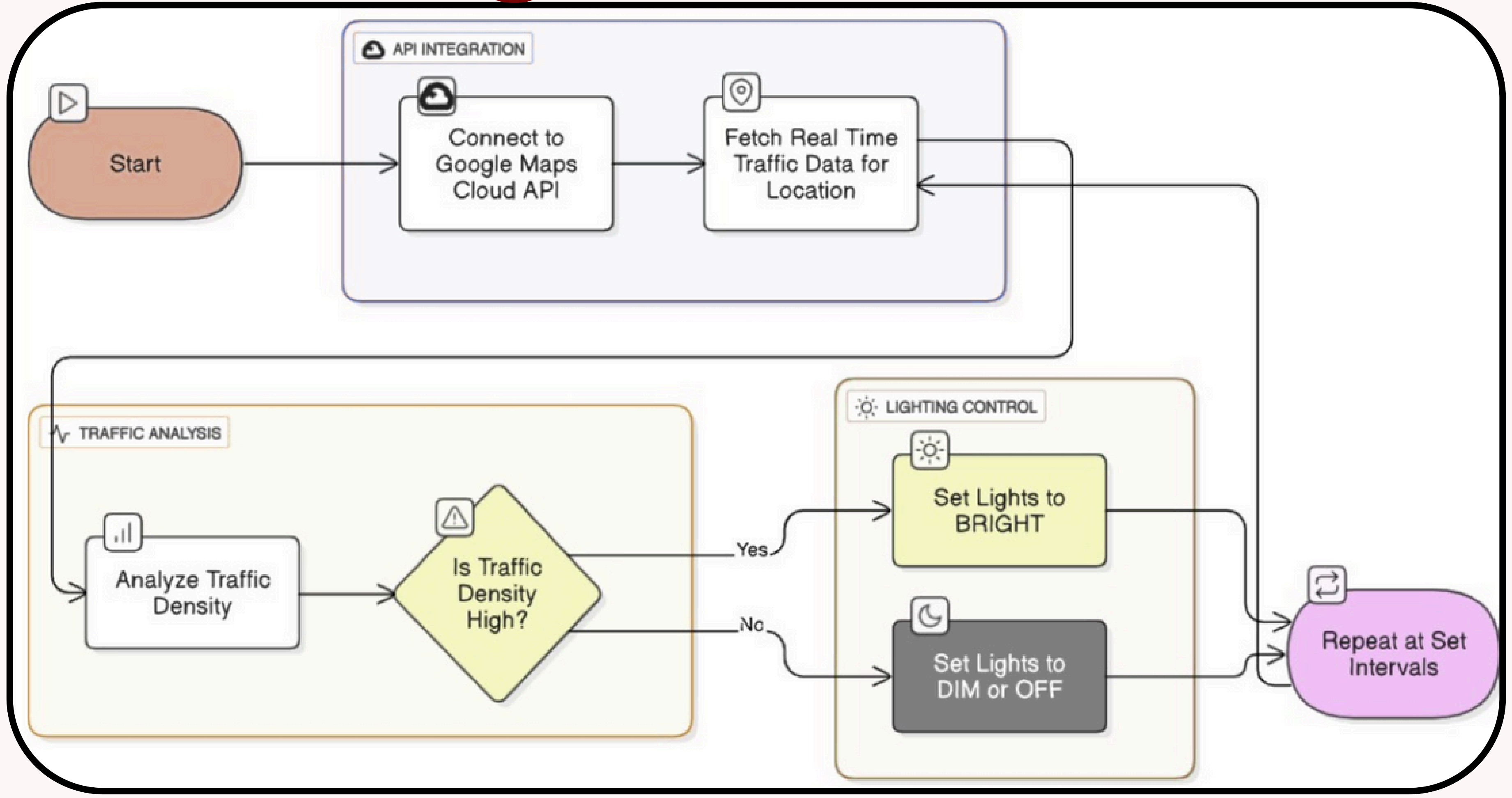
LIMITATIONS

- **High Initial Investment:** Solar panel + sensor hardware = ₹16k–₹20k/pole. Break-even takes ~2.5–4 years.
- **Battery Lifespan & Maintenance:** Lead-acid batteries degrade over time. Frequent SoC/SoH monitoring is needed to avoid power drops.
- **Zigbee Mesh Limitations:** Signal range & interference in dense urban areas may affect pole-to-pole sync.
- **Sensor Accuracy & False Triggers:** PIR may give false detection in high-temperature zones.
- **Complex Setup for Urban-Wave Mode:** Requires Zigbee, and multi-sensor sync → more prone to misalignment without tight calibration.
- **No Field Trial Yet:** System is in prototyping stage. Real-world deployment needed to validate performance + ROI.

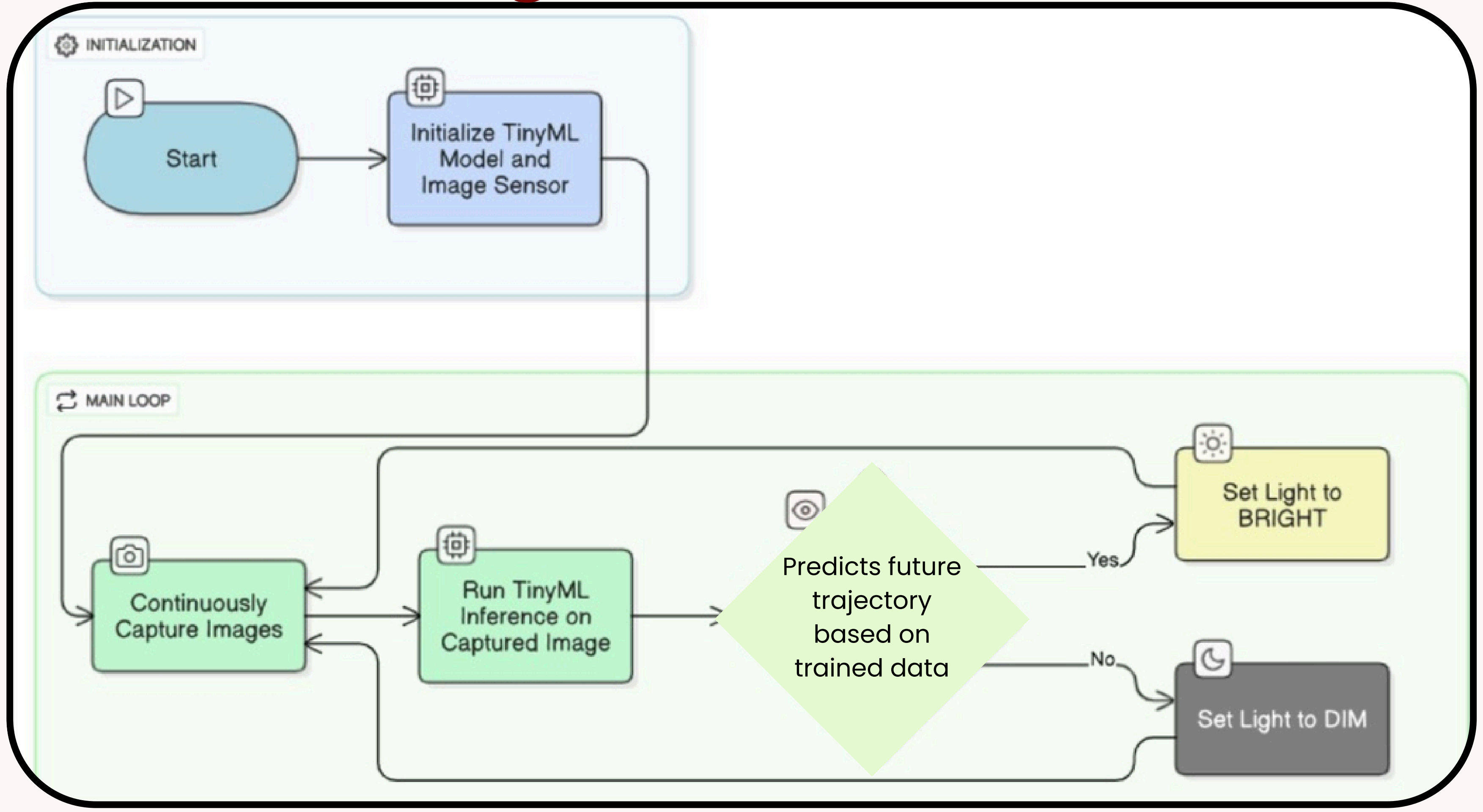
We're aware, and we're building smarter fail-safes, better energy balancing, and future upgrades to overcome these.

FUTURE SCOPE

Google Cloud API



TinyML model



SMARTER. GREENER. SCALABLE.

Powerfully Efficient

- **Large energy** savings using adaptive dimming
- Fully solar-powered — zero grid draw
- mmWave + PIR for precision lighting only when needed
- Gradual dimming and inter-pole sync for seamless drive-through experience across roads
- Zone pulse mode: bright only in presence

Real ROI from Real Intelligence

- **₹16-18k** total cost per smart pole
- Break-even in **2.5-4 years** (depending on the mode) via energy + maintenance savings
- **10,000 poles = huge annual savings**
- Reduces **tons** of CO_2 emissions annually

Engineered for Mass Deployment

- Industrial-grade parts, designed for manufacturing
- Plug-&-play for urban roads, campuses & tech parks

Launch & Scaling

- 100% Solar + Battery
- Smart Sensing (ambient, motion, vehicle detection)
- Eco-Friendly, Low-Maintenance
- Connected (GPS + Zigbee) for Smart Cities

TEXAS INSTRUMENTS WiSH HARDWARE TRACK GROUP - 20

Thank you

References

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