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Case for an Automated Traffic Light Management System with Embedded Image Processing to Reduce Traffic Delays in Kampala.

Problem Statement.

Kampala, Uganda's capital, suffers from severe traffic congestion, with peak-hour delays averaging 20-30 minutes at major intersections like Clock Tower, Wandegeya, and Jinja Road (KCCA, 2022). The city's vehicle population, exceeding 1.5 million and growing at 7% annually (UBOS, 2023), overwhelms fixed-time traffic light systems that fail to adapt to real-time traffic variations. This has led to over reliance on traffic police men who are not very effective due to lack of real-time coordination. Without adaptive, data-driven traffic management, Kampala's congestion will worsen as urbanization accelerates, exacerbating delays and environmental degradation.

Solution: Automated Traffic Light Management System with Embedded Image Processing.

An automated traffic light management system using embedded image processing technology offers a cost-effective, scalable solution to reduce traffic delays in Kampala. By leveraging cameras and micro-controllers to monitor real-time vehicle density, the system dynamically adjusts traffic light timings to optimize flow, prioritizing high-traffic directions and minimizing wait times at key intersections.
System Components and Functionality

1. **Embedded Cameras with Image Processing:**
    - Description: High-resolution cameras (720p or higher, e.g., Raspberry Pi Camera Module or USB webcams) are installed at intersections to capture real-time images or video of traffic.
    - Function: Cameras feed data to an embedded processor running OpenCV or a lightweight YOLOv5-nano model to count vehicles (cars, boda-bodas, trucks) and assess lane density. For example, the system detects if one lane has 10 vehicles while another has 2, allocating it more time to the busier lane.
    - Communication: Cameras connect to a microcontroller via wired (Ethernet) or wireless (Wi-Fi/LoRaWAN) protocols, suitable for Kampala's patchy connectivity. LoRaWAN supports long-range communication (up to 10 km) in urban environments ().

2. **Microcontroller or Single-Board Computer:**
    - Description: A Raspberry Pi 4 (490k) processes image data and controls traffic lights.
    - Function: The microcontroller analyzes vehicle counts and adjusts light timings using predefined logic (e.g., green light for 20 seconds if >5 vehicles detected, 10 seconds if fewer). It prioritizes high-traffic lanes during peak hours (7-9 AM, 5-7 PM).
    - Integration: Interfaces with traffic light controllers via GPIO pins or relay modules for seamless actuation of red, yellow, and green lights.
3. **Traffic Light System:**
    - Description: Existing traffic lights are retrofitted with IoT-enabled controllers, or new LED-based lights ($10-15 per set) are installed for energy efficiency.
    - Function: Lights adjust dynamically based on vehicle density, reducing wait times in congested lanes while maintaining flow in lighter ones.
    - Adaptability: Handles Kampala's mixed traffic (40% boda-bodas) by tuning detection algorithms to recognize smaller vehicles, ensuring flexible timings.
4. **Additional Features:**
    - Solar Power: Solar panels ($100-200 per intersection) ensure reliability amid Kampala's frequent power outages, leveraging Uganda's 5-6 kWh/m^2/day sunlight (UNDP, 2022).
    - Mobile App/SMS Alerts: A simple app or SMS interface (using Uganda's 80% mobile phone penetration, GSMA, 2024) allows traffic managers to monitor congestion and override timings, aligning with your interest in mobile solutions (Feb 28, 2025 conversation).
    - Cloud Integration: Aggregates data from multiple intersections for city-wide optimization, using Kampala's improving 4G coverage.

Benefits for Reducing Traffic Delays

- Reduced Delays: Real-time vehicle detection can cut wait times by 20-30%, as seen in adaptive traffic systems in Nairobi, which reduced delays by 25% in similar urban settings (IBM, 2021). For example, optimizing Jinja Road's green light could save 5-10 minutes per trip.
- Improved Traffic Flow: Dynamic timings increase intersection throughput by 15-20%, based on studies of camera-based traffic systems (), reducing bottlenecks at high-traffic junctions like Nakawa.
- Economic Savings: Reduced delays save $200-300 million annually in fuel and productivity losses, scaled from World Bank estimates (2020).

- Environmental Impact: Shorter idling times cut CO_2 emissions by 10-15%, addressing Kampala’s air pollution, which exceeds WHO limits by 20% during peak hours (UNEP, 2022).
- Scalability: Low-cost components ($500-1,000 per intersection) enable deployment at Kampala’s 100+ signaled intersections, starting with high-priority areas like City Square.
- Labor Efficiency: Automation reduces reliance on traffic police, common at congested junctions, freeing resources for other tasks.

Evidence from Recent Studies

- Delay Reduction: A 2024 study in Nairobi showed camera-based traffic systems reduced delays by 25% (), applicable to Kampala’s similar urban density.
- Vehicle Detection Accuracy: YOLOv5-nano achieves 90% accuracy in detecting mixed traffic (cars, motorcycles) on embedded systems (), suitable for Kampala’s boda-heavy roads.
- Cost-Effectiveness: IoT traffic systems in Indian cities reduced congestion by 15-20% using $1,000 per intersection (), achievable with Kampala’s budget constraints.
- Scalability: LoRaWAN-based systems in Lagos enabled city-wide coordination, cutting congestion by 18% (), a model for Kampala’s sprawling layout.

Cost.

- Raspberry pi : 490,000, Raspberry camera module : 180,000/USB cam: 80,000, USB power adapter for raspberry : 25,000 , toy cars: 50,000

- Total Cost: 700,000 – 800,000 UGX (to be raised by the group members).
