Solution Brief

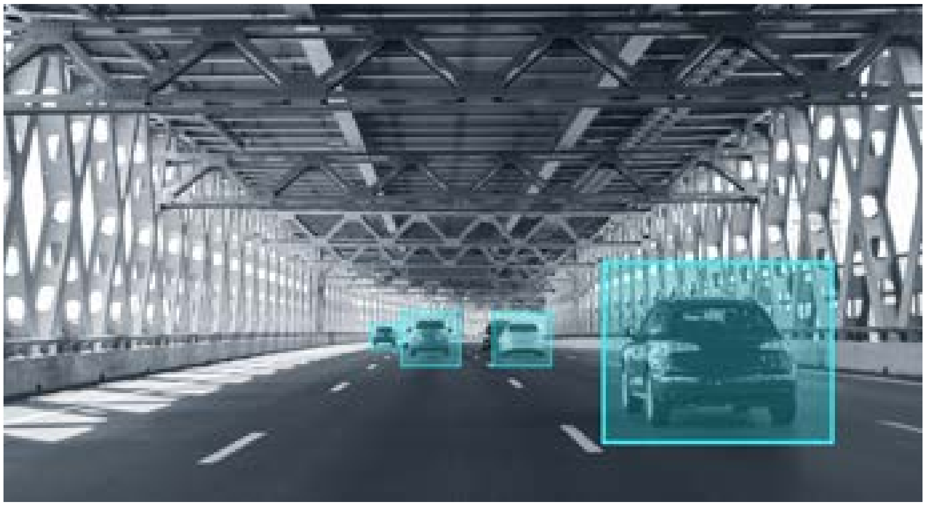
LATTICE SENSAI™ MULTI-OBJECT DETECTION FOR TRAFFIC DATA COLLECTION SYSTEMS

Deterministic, Low Power Edge AI for Accurate, Real-time Traffic Volume Measurement

Introduction

Traffic agencies and urban planners increasingly rely on high-accuracy, video-based detection to analyze roadway usage, multimodal activity, congestion, and safety risks, as traditional sensing methods such as induction loops, pneumatic tubes, and basic cameras lack the multimodal accuracy and real-time responsiveness required for modern traffic studies. Deep learning–based vision systems now enable reliable detection and classification of vehicles and other road users, even under challenging lighting, occlusion, and environmental conditions. The Lattice sensAI multi-object detection (MOD) solution brings this capability directly to the edge using low power FPGAs, delivering deterministic real-time perception without the cost, bandwidth, or privacy concerns of cloud processing, and enabling compact, energy-efficient traffic data collection systems with accurate, high-frequency, privacy-preserving analytics through on-device intelligence. See Figure 1.

Figure 1: Edge AI Multi-object Detection in Real-World Traffic



Object-detection Pipeline: Reliable Traffic Perception

Modern traffic data collection has evolved beyond vehicle counts to include multimodal analytics such as vehicle classification, pedestrian and cyclist activity, turning movements, queue lengths, occupancy, speed estimation, and long-term congestion trends. Research in multi-object tracking (MOT) and multi-target multi-camera (MTMC) perception consistently shows that high-quality, per-frame object detection is the foundation for reliable traffic analysis. Anchor-free, multi-scale detectors and refined non-maximum suppression techniques improve performance in dense traffic, occluded scenes, and situations involving small or distant objects. The Lattice sensAI solution stack implements these capabilities through its Generic MOD and Automotive MOD models, which use anchor-free, multi-scale architectures paired with fixed resolution RGB inputs optimized for FPGA execution. These models enable near-sensor deployment in intersection cameras, midblock monitoring nodes, and portable traffic study units, delivering per frame detection across varying lighting, weather, and scene complexity.

Challenges

Modern traffic data collection systems face several technical and environmental challenges that directly affect the reliability, accuracy, and consistency of MOD performance in real-world roadway conditions.

KEY CHALLENGES

- Complex, high-traffic environments with overlapping objects including dense traffic, occlusions, and small objects
- Broad range of environmental conditions across day/night transitions, weather, and seasonal changes
- High-accuracy multimodal detection for vehicles, pedestrians, cyclists, and mixed road users
- Power and deployment constraints on low power, thermally limited embedded platforms
- Privacy and connectivity limitations requiring on-device processing and metadata-only output

LATTICE SOLUTION

- Low power, near-sensor intelligence for always-on embedded roadside systems
- Anchor-free, multi-scale detection architecture for robust outdoor object detection
- Deterministic, real-time performance with stable, predictable inference
- Privacy-preserving edge processing with on-device inference and metadata output
- Scalable hardware deployment for compact and pole-mounted Intelligent Transportation System (ITS) designs
- Flexible model and class coverage from automotive to generic object detection
- Easy integration into traffic side processing pipelines with fixed inputs and outputs

- **Complex, High-traffic Environments with Overlapping Objects**
  Urban and suburban traffic environments often contain overlapping vehicles, crossing pedestrians, cyclists weaving between lanes, and vehicles of highly variable size. MOT and intelligent vehicle perception research repeatedly highlight dense occlusion and small object detection as primary causes of missed and false detections. Inadequately optimized detectors struggle to maintain track continuity and accurate counts in these conditions.
- **Broad Range of Environmental Conditions**
  Traffic cameras must maintain consistent detection quality under changing illumination (day/night transitions, shadows, and headlights), adverse weather (rain and fog), and seasonal variations. Embedded traffic surveillance work notes that illumination changes and night/day transitions significantly degrade performance if detectors are not tuned for such scenarios.
- **High-accuracy Multimodal Detection**
  Modern planning and safety initiatives require not only vehicle counts but also multimodal coverage: cars, buses, trucks, motorcycles, bicycles, and pedestrians. Intelligent vehicle and urban MOT studies show that robust multimodal detection is harder than single-class vehicle detection due to different object scales, motion patterns, and occlusion characteristics.
- **Power and Deployment Constraints**
  Portable traffic study systems and pole mounted roadside sensors cannot rely on high power GPUs or large x86 servers. Research on embedded surveillance systems demonstrates that it is feasible to deploy deep detectors on embedded platforms, but power, thermal envelope, and cost must be carefully controlled.
- **Privacy and Connectivity Limitations**
  Transmitting raw video offsite raises privacy concerns and requires stable, high bandwidth connections. Many deployments instead prefer on-device inference, sending only anonymized metadata (counts, classes, and trajectories) to downstream systems.

Edge Intelligence for Smart Traffic Analytics

Lattice addresses the challenges of modern traffic data collection by delivering a low power, near-sensor MOD solution built on the Lattice sensAI solution stack. At the core of this solution is the Lattice sensAI model zoo, which provides two deployment-ready MOD models: the Generic MOD model trained on a large, widely used benchmark dataset covering 80 common object categories and the Automotive MOD model designed specifically for eight traffic-relevant classes. Both models enable efficient, deterministic, and deployment-accurate execution on Lattice CertusPro™-NX FPGAs.

The models are optimized for embedded systems with compact parameter counts and separated class and bounding-box outputs, enabling robust per-frame detection even in dense traffic, occlusions, and varying lighting conditions. The Automotive MOD model has been validated through indoor, outdoor, and hardware-in-the-loop testing on the Lattice CertusPro-NX FPGA (CPNX-100), with reliable detection of vehicles up to 30 meters and strong performance across all eight classes.

By performing inference entirely at the edge, the MOD solution ensures stable, predictable latency and privacy-preserving analytics, since only metadata, not raw video is transmitted downstream. This architecture suits both portable and roadside traffic systems operating under strict power and thermal constraints. With class coverage including person, bicycle, car, motorcycle, bus, truck, traffic light, and stop sign, enabled by the Automotive MOD model, Lattice sensAI delivers accurate, efficient, and scalable edge-based traffic perception without the bandwidth, cost, or thermal requirements of other approaches.

Key Capabilities of Lattice sensAI MOD Models

- **Ultra Low Power, Near-Sensor Intelligence**
  Compact architectures (~2.7M–3.0M parameters) for efficient embedded execution, enabling continuous, always-on detection in roadside and portable systems with tight power budgets.
- **Anchor-free, Multi-scale Detection Architecture**
  YOLO-like, anchor-free design with three detection scales and a fixed 384×288 RGB input, supporting accurate detection of vehicles, pedestrians, bicycles, traffic lights, and other classes in real-world outdoor environments.
- **Deterministic, Real-time Performance**
  The MOD models are optimized for deployment-accurate, fixed-point execution on the Lattice CertusPro-NX FPGA, enabling stable detection across classes and scenes and producing predictable frame-to-frame behavior required for real-time analytics.
- **Privacy Preserving Edge Processing**
  Inference runs entirely on the FPGA, producing only class labels and bounding boxes, matching the model card outputs and avoiding the need to transmit raw video off-device.
- **Scalable Hardware Deployment**
  The lightweight model architectures map cleanly to Lattice CertusPro-NX System on Module (SoM) designs, supporting compact counters, pole-mounted systems, and embedded ITS units without major thermal or hardware redesign.
- **Flexible Model and Class Coverage**
  Integrators can scale from broad object detection to traffic-specific perception without changing hardware.
  - **Automotive MOD:** 8 traffic-critical classes validated through indoor testing, outdoor sunny-day evaluation, and Lattice CertusPro-NX hardware testing, ensuring that real-world behavior aligns with offline metrics measured on standard object-detection benchmarks at multiple localization tolerances (e.g., 8-pixel and 20-pixel mean average precision).
  - **Generic MOD:** 80-class generic based detection for broader or fine-tuned applications.This model provides 80-class coverage for broader or customizable detection needs.
- **Easy Integration into Traffic Side Processing Pipelines**
  Fixed input resolution, predictable timing, and separated outputs simplify integration into typical MIPI-to-FPGA-to-host traffic processing pipelines.
- **Long-lifecycle Flexibility**
  The FPGA architecture enables updates to the model, class set, and processing pipeline through bitstream or firmware changes, supporting long-term ITS deployments without hardware replacement.
- **Unified Toolchain and Development Workflow**
  The Lattice sensAI solution stack (models, quantization tools, compiler, and SoM reference) provides a coherent path for development and deployment, reducing integration complexity compared to fragmented AI hardware ecosystems.

Competitive Analysis

Traffic data collection systems can be implemented using a range of sensing and processing technologies, each with strengths tailored to specific deployment environments. These approaches differ in accuracy, power requirements, thermal limits, system cost, and real-time behavior. The following categories represent the most common solutions used for counting vehicles, classifying road users, and analyzing traffic patterns.

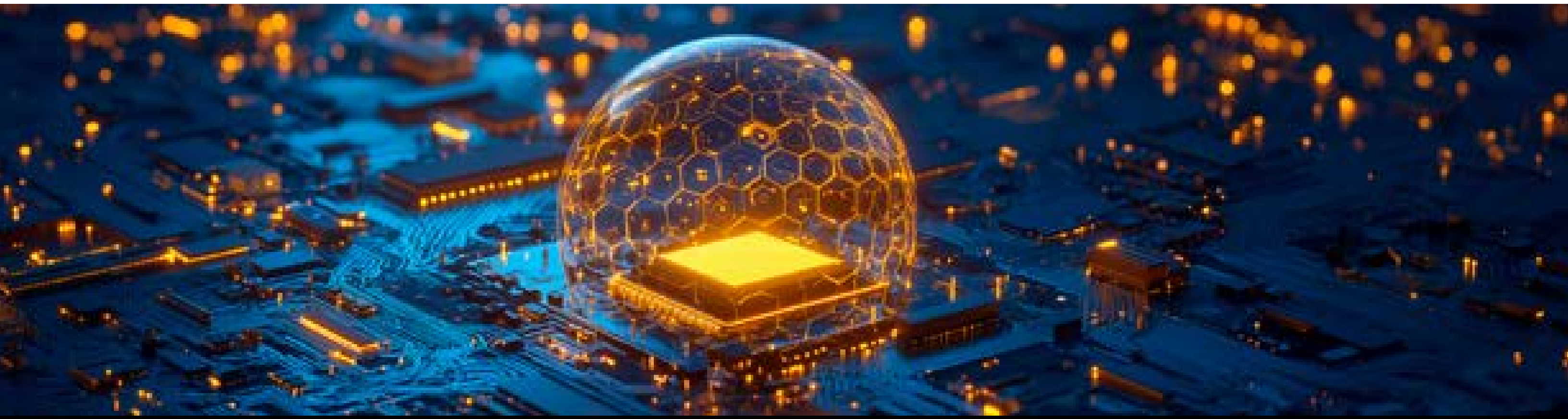
- **Cloud-based Video Analytics**
  Systems that stream raw or compressed video to remote servers for detection and tracking. They offer flexible compute resources and scalability, but they depend on stable high-bandwidth connectivity, introduce network-related latency, and often raise privacy concerns when video must leave the roadside site.
- **GPU/CPU-based Edge Vision Systems**
  Embedded platforms that run deep-learning models locally using high-performance processors are well-suited for complex, multimodel workloads and high-throughput analytics. However, their higher power consumption and heat generation can make them impractical for compact, passively cooled roadside units or portable traffic study devices. In contrast, Lattice sensAI is a lower power alternative for deployments where thermal and power constraints dominate.

- **Traditional Non-vision Sensors (Loops, Tubes, and Radar)**
  Established sensing methods widely used for vehicle counts or speed estimation. While simple and reliable for basic metrics, they cannot provide classification of vulnerable road users, or the spatial context and trajectory information increasingly required by modern planning and safety applications.
- **Generic Embedded Vision Modules**
  Low-cost detectors use general-purpose embedded processors without hardware–model co-design. These solutions may struggle with occlusions, small or distant objects, lighting changes, and maintaining consistent frame-to-frame detection quality in real-world traffic environments.
- **Large Multi-camera Analytics Platforms**
  High-compute systems fuse several camera streams for city-scale tracking and complex flow analysis. While powerful, they require substantial infrastructure, energy availability, and thermal capacity, making them unsuitable for small roadside enclosures or battery-powered field deployments.

Compared with these approaches, the Lattice MOD solution delivers ultra-low power execution, deterministic timing, and edge-only metadata output. This makes Lattice sensAI MOD well suited for portable, battery-operated, and pole-mounted traffic data collection systems that must operate reliably within sub-watt power budgets while still delivering consistent, real-time multimodal insights.

Conclusion

Modern traffic data collection systems require consistent, per-frame detection performance to support multimodal counts, turning-movement studies, and roadway safety analysis. The Lattice sensAI MOD model zoo, featuring the 80-class Generic MOD model and the 8-class Automotive MOD model, provides deployment-accurate perception for these workloads through compact, FPGA-optimized architectures validated under indoor, outdoor, and hardware-in-the-loop testing. By executing inference directly on Lattice CertusPro-NX FPGA devices, it delivers predictable latency, privacy-aligned metadata outputs, and an embedded-efficient compute footprint suited to portable and pole-mounted systems operating within sub-watt power envelopes. This combination provides a reliable technical foundation for modernizing traffic data collection infrastructure across both temporary study units and permanent roadside sensors.



Ready to Learn More?

To learn more about Lattice low power FPGA-based solutions for industrial, automotive, communications, computing, and consumer applications, visit **www.latticesemi.com** or contact us at **sales@latticesemi.com**.