Priority By Design:

Advancing Emergency Mobility with Cellular Vehicle-to-Everything (C-V2X) in Telangana & India

Futures Report

November 2025

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A Futures Report By

ITS INDIA
Shaping the Future of Mobility

OMI FOUNDATION

ITS India Forum & OMI Foundation Trust

President's Message

Akhilesh Srivastava
President,
ITS India Forum

India's transportation future must be one where **emergencies are never delayed by design flaws**, but instead **cleared by design intelligence**. At a time when we lose thousands of lives each year to delayed emergency care, the deployment of connected and cooperative mobility technologies is no longer optional. It is a moral and national imperative. This Futures Report, ***Priority by Design: Advancing Emergency Mobility with Cellular Vehicle-to-Everything (C-V2X) in Telangana & India***, is a timely and strategic contribution to that imperative.

Jointly authored by **ITS India Forum** and **OMI Foundation**, the report demonstrates how India can harness the full potential of C-V2X to make emergency vehicle prioritization fast, reliable, and scalable - beginning with Hyderabad, and expanding across states and corridors.

The insights here reaffirm a central truth: **intelligent systems can save lives**. With over **95% 5G signal readiness and adaptive signal control already deployed at 70% of key intersections**, **Hyderabad** offers a uniquely fertile ground for **real-time, AI-powered emergency mobility**. This report identifies **potential travel time reductions of 25-47%** and an **annual societal return of ₹1,500 crore from lives saved alone**, demonstrating that this is not just feasible, it is urgent. It proposes clear **national pathways**: *mandating OBUs in all emergency fleets, upgrading legacy traffic controllers, integrating ICCCs with green-wave logic, and establishing a national task force to define standards and audit impact*.

Equally important is the vision this report sets for **Telangana to emerge as a national and global model**. With a vibrant *tech ecosystem*, *world-class testing infrastructure* at *IIT Hyderabad's TiHAN*, and *strong institutional leadership*, the state is well-positioned to demonstrate that emergency mobility doesn't just need reform; it needs a complete redesign powered by C-V2X, tailored to Indian urban and peri-urban realities.

As President of ITS India Forum, I am proud that our network of technologists, administrators, and mobility practitioners is shaping this vision with urgency and precision. We believe C-V2X is not merely a technology; it is a **civic commitment**. Its deployment must be **interoperable, outcome-driven, and rooted in public purpose**.

We urge state and national governments to take forward the roadmap presented in this report. Let this be the decade where **India's digital public infrastructure transforms how we respond to emergencies**. Let this be the decade where ambulances don't wait, but move with priority, by design.

Foreword

Dr R.S.Sharma IAS (Retd.)
Former Chairman,
TRAI
Govt. of India

The rapid evolution of digital technologies presents India with an unprecedented opportunity to redefine public service delivery, enhance institutional efficiency, and improve the quality of life for every citizen. Artificial Intelligence is no longer a future aspiration; it is already reshaping critical sectors such as healthcare, education, agriculture, mobility, and public safety. Guided by a forward-looking policy vision, India has placed strong emphasis on the responsible and inclusive adoption of emerging technologies to advance governance and drive equitable development.

The Telecom Regulatory Authority of India (TRAI) has played a pivotal role in enabling this transformation. By expanding broadband access, accelerating 5G deployment, and fostering innovation in AI-driven telecom networks, DoT is strengthening the nation's digital backbone. Its support for IoT-enabled mobility systems, real-time data platforms, and intelligent transport networks has laid the groundwork for smarter, safer, and more resilient cities. Through clear regulatory direction, public-private collaboration, and an innovation-friendly ecosystem, India is positioning itself at the forefront of next-generation digital infrastructure.

This report, *Priority by Design: Advancing Emergency Mobility with Cellular Vehicle-to-Everything (C-V2X) in Telangana*, reflects that vision. By enabling low-latency, AI-augmented communication between vehicles and infrastructure, the initiative demonstrates how C-V2X can prioritize emergency vehicles at intersections and significantly reduce ambulance travel times—a life-saving innovation validated by pilots in Telangana and Bengaluru.

More than a technology deployment, this effort represents a model for future public digital systems—where research, policy, and industry collaboration converge to deliver measurable outcomes. As India advances its digital public infrastructure and AI strategy, such initiatives reaffirm our commitment to ensuring technology serves every citizen, strengthens institutional capacity, and builds a safer and more resilient nation.

Foreword

Shri Giridhar Aramane, IAS (Retd.)
Former Secretary, Defence and Ministry of Road Transport and Highways
Govt. of India

Effective governance is measured by the ability of institutions to anticipate challenges and deliver timely, equitable solutions to citizens. Across India, technology-driven public systems are redefining the way services are delivered, and nowhere is this more evident than in the domain of mobility and emergency response.

Emergency medical response, represents one of the most critical tests of governance. While Indian cities have made significant strides in traffic management and Intelligent Transport Systems, ensuring that ambulances navigate dense corridors rapidly remains a continuing priority. Addressing this requires a blend of advanced technology, coordinated governance, and operational excellence.

This report, **Priority by Design: Advancing Emergency Mobility with Cellular Vehicle-to-Everything (C-V2X) in Telangana,** showcases a forward-looking model aligned with India's vision for smart, responsive, and citizen-centric infrastructure. By leveraging AI-enabled, low-latency, and interoperable communication systems, C-V2X enables priority passage for emergency vehicles at traffic intersections. The demonstrated reduction of up to 38% in ambulance travel time during peak hours is a testament to the transformative potential of such solutions in saving lives and improving urban resilience.

Importantly, this initiative reflects a governance culture where technology, institutional collaboration, and on-ground execution converge to deliver measurable public impact. Telangana's efforts in building strong digital infrastructure, nurturing an AI ecosystem, and piloting scalable mobility innovations offer a compelling example for cities across India.

As the nation advances toward a more connected and intelligent mobility landscape, initiatives like this illustrate what is possible when vision is matched with execution. C-V2X is not merely a technological innovation, it represents a new paradigm in governance, where emerging technologies strengthen the social fabric and enable faster, safer, and more inclusive access to essential services

Foreword

Shri Rohit Kumar Singh IAS (Retd.)
Former Secretary, Ministry of Consumer Affairs; and Member, National Consumer Dispute Redressal Commission Govt. of India

India's growth story is being reimagined through the intelligent convergence of infrastructure, innovation, and intent. Across every sector, technology is not just an enabler it is the foundation upon which we are building an inclusive and resilient future. Under the Ministry of Electronics and Information Technology, initiatives such as Digital India, Make in India, and the IndiaAI Mission are transforming how citizens connect, how industries evolve, and how governance responds with empathy and precision.

As we enter an age where vehicles, roads, and digital networks communicate in real time, the possibilities before us are extraordinary. Technologies like Cellular Vehicle-to-Everything (C-V2X) are redefining mobility, not as a product of convenience, but as a public service rooted in safety, efficiency, and care. When an ambulance can speak to a traffic light, and a city anticipates the movement of its people, innovation becomes profoundly human. It becomes the embodiment of India's vision, technology with a purpose, progress with compassion.

The report ***Priority by Design: Advancing Emergency Mobility with Cellular Vehicle-to-Everything (C-V2X) in Telangana*** reflects this new imagination for India's cities. It demonstrates how research, policy, and industry collaboration can converge to create urban ecosystems that are not only connected but designed for human impact. The work done in Telangana is a step toward a future where the "golden hour" is safeguarded by design, not circumstance.

As 5G, AI, and edge computing mature across India, our task is to embed them in governance frameworks that prioritize citizens above systems. C-V2X is one such example of how next-generation connectivity can translate directly into public value - saving lives, improving efficiency, and reducing emissions.

As India charts its course toward becoming a global leader in intelligent and sustainable mobility, our vision must remain anchored in inclusivity and purpose. Through innovation anchored in empathy, we are shaping a more connected, responsive, and resilient India.

Foreword

Ambassador (Retd.) Gautam Bambawale
Managing Trustee,
OMI Foundation

Harish Abichandani
First Trustee,
OMI Foundation

Emergencies test the resilience of cities - not just through the strength of their institutions, but the speed of their response. In those critical moments - the so-called "golden hour" - every second counts. For India to be future-ready, it must ensure that life-saving services are not delayed by traffic lights, bottlenecks, or infrastructure inertia.

This report, *Priority By Design*, comes at a defining moment. India is scaling its digital public infrastructure, deploying 5G at unprecedented speed, and embracing frontier mobility technologies. It is in this context that Cellular Vehicle-to-Everything (C-V2X) emerges not merely as a technological upgrade - but as a **societal imperative**. By enabling real-time coordination between ambulances, traffic signals, and command centers, C-V2X has the potential to transform urban governance, emergency healthcare, and citizen trust in public systems.

Co-authored with the ITS India Forum, this report is both a **technical roadmap and a policy blueprint**. It presents the case for India - and Telangana in particular - to become a global exemplar in connected emergency mobility. Drawing on global case studies, stakeholder consultations, and rigorous modelling, it shows how cities like Hyderabad can lead the way with deliberate infrastructure investments, institutional innovation, and multi-agency coordination.

As Trustees of OMI Foundation, we see this report not just as a document, but as a call to action. It aligns with our broader belief that **technology transitions must centre human lives, safety, and dignity**. We hope this Futures Report will catalyze government missions, academic research, industry pilots, and public dialogue - towards the vision of an India where emergency mobility is smarter, faster, and truly inclusive.

Let this be the decade where India moves with purpose, responds with speed, and prioritizes by design.

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Executive Summary

Priority By Design: Advancing Emergency Mobility with Cellular Vehicle-to-Everything (C-V2X) in Telangana and India is a pioneering effort to chart a technically grounded, economically sound, and institutionally actionable roadmap for deploying C-V2X to improve emergency medical response in urban India. Focused on Hyderabad and the rest of Telangana, this report lays the foundation for prioritizing ambulances at traffic intersections using low-latency, AI-enabled, and interoperable signal systems, ensuring timely access to critical care.

The Emergency Mobility Imperative

In dense Indian cities, ambulance delays of 20-30 minutes across 10 km stretches are common - costing lives and leading to long-term complications in trauma, cardiac, and stroke cases. Even with upgrades in adaptive signaling and centralized traffic control, current systems lack real-time emergency vehicle prioritization. **Cellular Vehicle-to-Everything (C-V2X)** provides a transformative solution - enabling ambulances to pre-empt red lights automatically and safely through secure communication with traffic infrastructure.

Methodology and Approach

This report is **designed as a readiness blueprint** and **implementation proposal**. It outlines the technological, economic, and policy considerations for C-V2X adoption in Telangana.

Key components of the methodology include:

- **Secondary analysis** of C-V2X pilots across 9 Indian and 10 global cities
- **Technical mapping** of Hyderabad's 5G infrastructure, adaptive traffic signal coverage, and integrated command control systems (ICCC)
- **Institutional analysis** of stakeholders involved in emergency mobility - including GHMC, EMRI 108, IIT-Hyderabad/TiHAN, Hyderabad Police, and telcos
- **Cost estimation** based on global benchmarks for RSUs, OBUs, AI middleware, and MEC infrastructure
- **Preliminary return on investment (RoI) modeling** using publicly available datasets from ICMR, WHO, MoHFW, Ministry of Petroleum & Natural Gas, and NITI Aayog

Future phases of work will involve:

- Accessing and analyzing **12-month EMRI dispatch data**, **traffic sensor feeds**, and **5G performance logs**
- **Simulations using TiHAN's national C-V2X testbed** at IIT Hyderabad
- **Stakeholder validation workshops** under the aegis of ITS India Forum and Telangana Government, among others

Hyderabad's Implementation Readiness

Hyderabad offers ideal conditions for a state-led C-V2X pilot:

- **>95% RSRP (Reference Signal Received Power) 5G Coverage** across urban zones, supported by Jio, Airtel, and BSNL
- **400+ upgraded junctions** under GHMC's Adaptive Traffic Control System (ATCS) rollout
- **TiHAN at IIT-Hyderabad** as the national anchor for V2X simulation and edge testing
- **ICCC architecture** capable of signal override and integration with dispatch logic
- **Institutional convergence** among GHMC, Telangana Police, EMRI, IIT-H, and national ministries

Pilot Design and Citywide Rollout

The proposed **9.5 km pilot corridor** between Apollo Hospital (Jubilee Hills) and Continental Hospital (Financial District) via AIG Gachibowli is marked by:

- High congestion (average peak speed: ~17 km/h)
- Dense hospital clustering
- Pre-existing ATCS junctions and 5G strength

Technological stack includes:

- OBUs in 100+ ambulances
- RSUs at 17 key intersections
- MEC nodes for signal override
- AI models for ETA prediction and green wave optimization

By 2027, this model can be scaled across **800+ intersections** under GHMC, with institutional support from EMRI, IIT-Hyderabad, and Telangana's Emerging Technologies Wing.

Potential Benefits

A 25-30% travel time reduction is projected based on global benchmarks and signal simulation models.

With over **95% 5G coverage** and **ATCS readiness** already in place, a **citywide EVP rollout** backed by **C-V2X Strategy 2030** can deliver up to **47% faster response times**, **10-20% lower emissions**, and **₹1,500 crore in annual lives-saved impact** - making Hyderabad a national model for replication.

Cost and Returns

The total CAPEX for a citywide rollout is estimated at **₹54.5-63 crore**, including RSUs, OBUs, AI software, and quality assurance mechanisms. This constitutes less than 1% of GHMC's three-year smart mobility budget.

Estimated Returns:

- ₹1,500 crore/year from lives saved (ICMR DALY model)
- ₹60-75 crore/year from congestion and fuel savings
- ₹200 crore/year from improved health outcomes
- <4-year payback period

Policy Recommendations

For Telangana:

- Develop a **C-V2X Telangana Strategy 2030**
- Fast-track approvals for signal infrastructure and firmware
- Mandate OBU installation in all EMRI and hospital ambulances
- Institutionalize a **Program Management Secretariat** co-led by ITS India Forum and OMI Foundation

For Government of India:

- Establish a **joint national task force** (MoHUA-MoRTH-MeitY) to define uniform standards and rollout plans for Emergency Vehicle Priority (EVP) across Indian cities.
- Launch a **national V2X sandbox** under MeitY and MoHFW
- Mandate the installation of **On-Board Units (OBUs)** in all EMRI-108 ambulances, fire brigades, and police vehicles by 2027 to ensure universal signal clearance readiness.
- Extend EVP and C-V2X pilots beyond metro cities to **national highways and rural corridors**, targeting areas with the highest emergency response delays.
- Upgrade outdated signal controllers in Tier-2 and Tier-3 cities to support **adaptive signaling and RSU-based communication** for scalable C-V2X deployment. Standardize signal controller protocols and cybersecurity requirements.
- Encourage **PPP-based funding models** involving telecom operators, city SPVs, and private hospitals for sustainable C-V2X infrastructure deployment.

Hyderabad has the ingredients to become India's first truly connected city for emergency mobility. But beyond Hyderabad, **India has the opportunity to lead the Global South in deploying C-V2X for public good** - from faster ambulance response in dense metros to connected safety networks across rural highways. With the right policy signals, funding pathways, and institutional coordination, C-V2X can move from blueprint to deployment - **saving lives, reducing congestion, and setting a replicable, sovereign model for the world**.


INDIA
P.S.
T.MARG

1. Introduction

Cities are the engines of economic growth, innovation, and social progress. Their ability to move people, goods, and services efficiently underpins not only productivity but also the safety and well-being of their citizens. Among the most critical functions of any city is its capacity to respond swiftly to emergencies - be it medical, fire, or law enforcement. In this context, urban mobility is not just an economic necessity but a public good.

Hyderabad, like many fast-growing Indian metros, faces mounting urban mobility challenges. Rapid population growth, increasing motorization, and spatial sprawl have led to severe congestion, particularly on arterial roads and near critical infrastructure such as hospitals. These mobility constraints have direct, life-threatening consequences - emergency vehicles are routinely delayed by traffic bottlenecks, undermining timely medical intervention and emergency care.

Amid these constraints, new technologies offer hope. **Cellular Vehicle-to-Everything (C-V2X)** is an emerging wireless communication platform that enables real-time interaction between vehicles, traffic infrastructure, and pedestrians. When applied to emergency vehicle movement, C-V2X can dynamically coordinate traffic signals, prioritize ambulances at intersections, and reduce average response times substantially, as global pilots have demonstrated.

With near-universal 5G coverage, ongoing traffic signal modernization, and a world-class C-V2X research testbed at TiHAN-IIT Hyderabad, Telangana is uniquely positioned to lead India's connected mobility revolution. Hyderabad, in particular, presents an ideal launchpad to deploy citywide C-V2X-based emergency vehicle priority (EVP) by 2027.

This Futures Report outlines how **Telangana** - **starting with Hyderabad and expanding statewide thereafter** - can design and implement a scalable, cost-effective EVP system powered by C-V2X. Through evidence from global and Indian pilots, a lifecycle deployment roadmap, and clearly defined institutional roles, it lays out how cities can systematically move from pilots to real-world transformation.

Importantly, this is not just a roadmap for Hyderabad or even Telangana. Drawing from national policy priorities, international case studies, and local implementation pathways, this paper also offers a **strategic blueprint for India**. It presents a set of targeted recommendations for the Government of India to scale C-V2X adoption across cities, highways, and rural corridors - positioning India as a global leader in connected emergency mobility.

Ultimately, this report argues that priority must be built by design, not left to chance - through infrastructure, coordination, and technology working in tandem to save lives, reduce delays, and build public trust in 21st-century urban governance.

2. The Need for Smarter Emergency Services

Timely emergency medical response is a critical determinant of survival and recovery in life-threatening situations such as cardiac arrests, strokes, trauma, or road accidents. The **first 60 minutes - commonly referred to as the "golden hour" - can mean the difference between life and death**, permanent disability and full recovery. For trauma cases, every minute of delay in reaching care increases mortality risk by 1% to 2% (MacKenzie EJ et al., 2007)

2.1. Hyderabad's Emergency Response Bottlenecks

In a rapidly urbanizing city like Hyderabad, where the vehicle population reached 85 lakh as of March 2025, road congestion poses a formidable barrier to effective emergency response (Telangana Transport Department, Vehicle Registration Dashboard, 2024). GPS-based data from the Greater Hyderabad Municipal Corporation (GHMC) and Telangana's EMRI-108 service shows that **ambulances can take up to 12-18 minutes to reach critical destinations** during peak hours, even within a 6-8 km radius (EMRI-108 Dispatch Logs, Telangana State Health Department, 2023-24 (internal, cited by CARE Ratings, 2025)).

These delays are most acute along high-density medical corridors such as the stretch between Apollo Hospitals (Jubilee Hills), AIG Hospitals (Gachibowli), and Continental Hospitals, where average peak-hour travel speeds hover around **17 km/h** - well below the minimum operating threshold for timely emergency response vehicles (GHMC Traffic Speed Monitoring Report - Jubilee Hills to Gachibowli Corridor, Q1 2024).

In cities with high congestion, emergency vehicles are often forced to rely on suboptimal routing, sirens that drivers cannot hear over traffic noise, or ad hoc manual signal overrides, which are neither scalable nor reliable. This results in erratic travel times and inconsistent levels of care across patient demographics and geographies.

2.2. Public Health and Safety Consequences

The broader public health impact of delayed emergency care is profound. A study by the Indian Council of Medical Research (ICMR) found that trauma accounts for **10% of all deaths in urban India**, with delayed ambulance access contributing significantly to this figure (ICMR-INCLEN National Trauma Registry Report, 2022). Furthermore, high congestion correlates with **increased stress levels among emergency responders**, reduced operational efficiency of EMRI fleet logistics, and lost critical minutes during disaster response events such as floods or building collapses.

For a city like Hyderabad that is well on its path to be a global innovation hub, emergency response systems must be future-ready. Smarter mobility must serve not just daily commuters but the most time-sensitive, life-critical journeys.

2.3. Systemic Gaps in Current Emergency Vehicle Routing

Despite advances in integrated traffic command centers, most emergency response systems in Indian cities still lack dynamic coordination with traffic signals or predictive routing powered by real-time data. Hyderabad's existing infrastructure, including the GHMC Adaptive Traffic Control System (ATCS) and EMRI-108 network, **operates largely in silos**, limiting system-wide optimization. Manual traffic clearing, police escorts, or dependence on public cooperation remain the primary tools for enabling faster emergency movement.

In the absence of **automated, AI-driven signal pre-emption or vehicle prioritization**, ambulances are subject to the same delays as any private vehicle, undermining the entire premise of emergency response infrastructure.

3. Understanding C-V2X Technology

Cellular Vehicle-to-Everything (C-V2X) is a next-generation communication technology that enables vehicles to interact in real-time with their surroundings - including other vehicles, road infrastructure, pedestrians, and cellular networks. Built to operate over both **short-range direct communication** and **long-range cellular networks (4G/5G)**, C-V2X forms the foundation of a connected, cooperative, and automated mobility ecosystem.

3.1. Core Communication Modes of C-V2X

C-V2X enables four primary modes of communication, each contributing to safer and more efficient transportation:

1. **Vehicle-to-Vehicle (V2V):** Enables direct exchange of speed, location, and direction data between vehicles. Prevents collisions and enables cooperative driving (e.g., platooning).
2. **Vehicle-to-Infrastructure (V2I):** Facilitates real-time communication between vehicles and road infrastructure such as traffic signals and road-side units (RSUs). Enables dynamic signal priority for emergency vehicles, congestion management, and safer intersection handling.
3. **Vehicle-to-Pedestrian (V2P):** Allows vehicles to receive alerts from pedestrians or cyclists carrying smartphones or wearable devices, enhancing safety for vulnerable road users.
4. **Vehicle-to-Network (V2N):** Uses cellular networks (4G/5G) to connect vehicles to broader systems such as traffic management centers, cloud servers, or public safety databases for real-time updates, OTA firmware, and predictive routing.

3.2. Key Functionalities for Emergency Mobility

C-V2X's appeal lies in its **low-latency, high-reliability** capabilities - particularly relevant for critical applications such as emergency vehicle movement. Key features include:

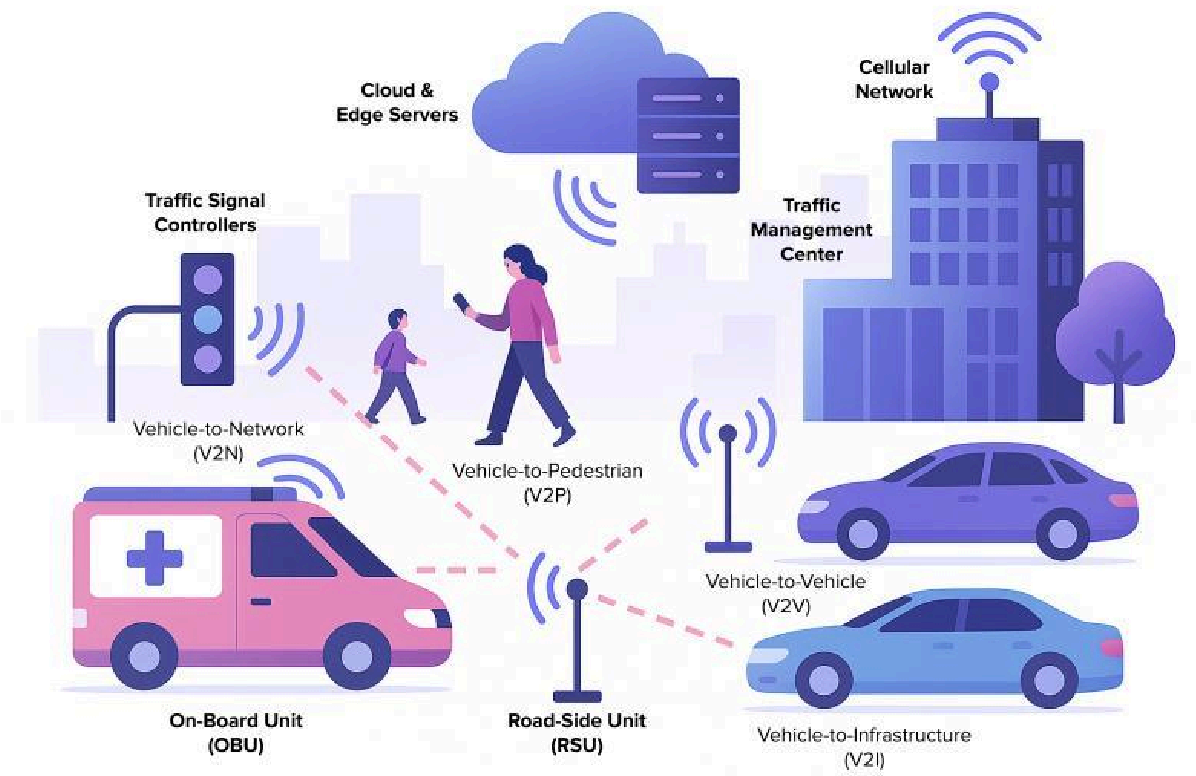
1. **Low Latency (as low as 10-20 ms):** Crucial for real-time response at intersections.
2. **Dynamic Signal Prioritization:** Enables green-light preemption for ambulances without manual intervention.
3. **Real-Time Alerts and Routing Adjustments:** Vehicles and infrastructure adapt based on changing road and emergency conditions.
4. **Secure and Scalable Communication:** Built to meet ISO 26262 and data privacy standards.

3.3. Technical Architecture

The C-V2X system relies on a distributed yet interoperable set of components:

1. **On-Board Units (OBUs):** Installed in vehicles (e.g., ambulances), these communicate with both other vehicles and infrastructure.
2. **Road-Side Units (RSUs):** Installed at traffic junctions, these act as edge nodes to receive and process messages from OBUs.
3. **Traffic Signal Controllers:** Interfaces with RSUs to adjust signal timing in real time.
4. **Traffic Management Center (TMC):** Integrates data from RSUs and vehicle networks; powered by AI models to optimize signal scheduling and traffic flow.
5. **Cloud and Edge Servers:** Used for long-term analytics, firmware updates (Firmware Over-The-Air - FOTA), and predictive optimization.

Figure 1: Diagram illustrating the C-V2X ecosystem



Source: Authors; AI-generated image.

Table 1: C-V2X at a glance

Dimension	Description
What	Cellular Vehicle-to-Everything (C-V2X) enables real-time communication among vehicles, infrastructure, pedestrians, and networks using 4G/5G and direct links.
Why	Reduces emergency response time by up to 47%, improves safety, cuts emissions through smoother traffic flow.
How	Via OBUs in vehicles, RSUs at intersections, signal controllers, and cloud-based AI traffic orchestration.
Where	Urban areas with signalized intersections, high-density corridors, and established cellular coverage.
When	Deployed globally in 2024-25 pilots; scalable in India from 2025-2027 with ongoing 5G expansion.

4. Global Benchmarks and Use Cases

Across the world, countries are integrating C-V2X (Cellular Vehicle-to-Everything) technology into their urban transport systems to improve road safety, emergency responsiveness, and overall traffic efficiency. These initiatives serve as critical benchmarks for India's own ambitions. From large-scale deployments to focused emergency vehicle priority pilots, global experiences offer valuable lessons in spectrum policy, infrastructure planning, and institutional coordination.

4.1. United States

The U.S. has taken significant steps toward scaling C-V2X infrastructure nationwide:

1. **Spectrum Allocation:** In 2020, the **Federal Communications Commission (FCC)** designated the **5.9 GHz band** for C-V2X communications, transitioning away from legacy DSRC systems. By **November 2024**, final spectrum rules were published, allowing C-V2X operation while phasing out DSRC within two years (Federal Communications Commission (FCC), 2020; FCC, 2024).
2. **National V2X Deployment Plan:** In **August 2024**, the **U.S. Department of Transportation (USDOT)** released a national plan that includes short-, medium-, and long-term targets for C-V2X adoption. It emphasizes **emergency vehicle signal pre-emption**, interoperability, cybersecurity protocols, and public-private pilot coordination (U.S. Department of Transportation (USDOT), 2024).
3. **City-level pilots:** Cities such as **Ann Arbor (Michigan)** and **Las Vegas (Nevada)** have conducted V2X trials showing up to **40% faster emergency vehicle routing** and improved intersection safety (Mcity, 2023).

4.2. Europe

The **European Union (EU)** has led C-V2X adoption through a coordinated regulatory and technical approach:

1. **EU C-ITS Corridor:** The **Cooperative Intelligent Transport Systems (C-ITS)** corridor spans from **Netherlands to Germany and Austria**, with RSUs deployed along major highways and arterial roads. Vehicles receive real-time hazard warnings and dynamic signal information (C-Roads Platform, 2023).
2. **Urban Deployments:** Cities like **Amsterdam** and **Berlin** are piloting **signal prioritization for emergency vehicles**, public transport, and cyclists using C-V2X messages over both short-range and cellular links. Integration with urban control centers has demonstrated a **25-35% improvement in emergency response times** during pilot phases (City of Amsterdam, 2019).
3. **Legal Mandates:** The **EU Delegated Regulation (2019/1784)** mandates interoperability across member states, ensuring standardization of SPaT/MAP messages and ISO-based safety compliance (European Commission, 2019).

4.3. China

China is executing one of the world's most ambitious V2X deployments, with strong government support:

1. **Massive Urban Pilots:** Cities like **Shenzhen** and **Wuxi** have installed **thousands of RSUs** and onboard V2X units in taxis, ambulances, and buses. These systems use **5G NR (New Radio)** to enable ultra-low-latency communication.
2. **Emergency Prioritization:** In **Wuxi's Connected Transport Zone**, emergency vehicles use V2X to trigger green-light corridors, resulting in **response time reductions of 30-50%**, as reported by the Ministry of Transport (5G Automotive Association, 2025).
3. **Ecosystem Integration:** Chinese OEMs (e.g., Huawei, Baidu Apollo, SAIC Motor) are producing V2X-enabled vehicles at scale, combining AI-based traffic prediction with V2X decisioning engines.

4.4. Japan

Japan's approach emphasizes **standards-based interoperability** and advanced urban testing:

1. **Standardization First:** Japan's V2X policy framework includes **interoperability standards for SPaT, MAP, and BSM messages**, aligned with ISO 26262 and 5GAA protocols.
2. **Urban Pilots:** In Tokyo, coordinated pilots have been run near key hospitals and school zones, combining **V2P safety alerts**, **OBU-equipped emergency vehicles**, and **AI-integrated signal controllers**. These pilots have shown a **20-25% improvement in average intersection clearance times** for ambulances during high-traffic hours (5G Automotive Association, 2023).
3. **Cross-Industry Collaboration:** The **Smart Mobility Challenge** program involves automakers, telcos, urban authorities, and academic researchers to ensure scalable and secure deployments.

4.5. Outcome Metrics from Global C-V2X Pilots

Global deployments of Cellular Vehicle-to-Everything (C-V2X) technology have demonstrated significant improvements across various transportation metrics. These advancements underscore the potential benefits of integrating C-V2X into urban mobility systems.

Table 2: Key Performance Improvements of C-V2X

Metric	Typical Improvement Range	Description
Emergency Response Time Reduction	25% - 47%	Enhanced coordination between emergency vehicles and traffic signals leads to quicker response times.
Fuel Consumption Reduction	8% - 15%	Signal smoothing minimizes stop-and-go traffic, leading to more efficient fuel usage.
Intersection Conflict Reduction	35% - 60%	Improved communication between vehicles and infrastructure reduces near-miss incidents.
Emissions Reduction (CO_2, NOx)	10% - 20%	Smoother traffic flow decreases vehicle emissions in congested areas.
Travel Time Reliability Improvement	20% - 40%	Real-time data exchange enhances predictability and consistency in travel times.

Source: Authors; Compiled from FCC, 2020 & 2024; USDOT, 2024; Mcity, 2023; C-Roads Platform, 2023; City of Amsterdam, 2019; European Commission, 2019; 5G AA, 2025.

5. Indian Pilots and Early Deployments of C-V2X

India's urban centers are actively exploring Cellular Vehicle-to-Everything (C-V2X) technologies to enhance emergency response times and overall traffic management. To assess these diverse deployments systematically, this report applies a standardized 7-point analytical framework. This structure enables consistent comparison across cities, focusing on both technical and institutional dimensions of each pilot.

5.1. Methodology

5.1.1. Analytical Framework for Evaluating C-V2X and Emergency Vehicle Priority (EVP) Pilots

Table 3: 7-Point Assessment Framework for Indian C-V2X Deployments

Category	Description
1. Lead Agencies	Primary government departments, municipal bodies, and/ or private entities leading implementation.
2. Pilot Objectives	Stated goals such as improving emergency response times, reducing congestion, or enhancing signal coordination.
3. Technology Stack	Communication architecture used (e.g., GPS-based routing, AI, C-V2X); hardware components such as OBUs, RSUs, and signal controllers.
4. Geography and Coverage	Specific corridors, junctions, or zones where the pilot has been deployed, including scope and scale.
5. Institutional Design	Inter-agency coordination mechanisms, roles in signal management, data-sharing protocols, and governance models.
6. Outcomes & Metrics	Quantitative and qualitative results - time savings, fuel/ emissions impact, reliability gains, and user feedback.
7. Challenges & Learnings	Barriers encountered in implementation and insights for scaling, including behavioral, technical, or regulatory constraints.

This framework guides the following case studies offering a comparative view of how Indian cities are approaching smart emergency mobility.

5.1.2. Note on City Selection for C-V2X Case Studies

To provide a representative and practical overview of India's early experiences with Cellular Vehicle-to-Everything (C-V2X) and Emergency Vehicle Priority (EVP) deployments, we selected a focused set of urban case studies based on a structured set of criteria. These cities reflect both diversity in geography and maturity in digital mobility infrastructure. Selection was guided by the following parameters:

1. Presence of a documented C-V2X or EVP pilot (government-led or via PPP).
2. Integration with Smart City infrastructure and availability of ICCC facilities.
3. Availability of 5G coverage or proximity to national V2X testbeds.
4. Emphasis on emergency mobility, signal optimization, or traffic decongestion.
5. Openness to innovation, as evidenced by awards, recognitions, or data-sharing initiatives.
6. Regional balance across North, South, East, West, and Central India.

The cities chosen include both metro and non-metro areas to ensure transferability of lessons across urban contexts.

Table 4: Criteria for City Case Study Selection

Criterion	Rationale	Example Cities
Documented C-V2X or EVP pilot	Ensures practical implementation experience	Bengaluru, Coimbatore
Smart City Mission participation	Institutional infrastructure & ICCCs	Pune, Coimbatore
5G/V2X R&D testbed proximity	Technical readiness and ecosystem support	Hyderabad, GIFT City
Emergency services integration	Direct alignment with EVP and response metrics	Delhi, Bengaluru
Open data or ITS recognitions	Signals innovation, replicability	Pune, GIFT City
Regional diversity	Ensures learnings across India's geography	South (Coimbatore), West (GIFT City), North (Lucknow)

5.2. City Case: City Case: Bengaluru - Green Corridors for Emergency Vehicles

The pilot implemented in Bengaluru demonstrated its effectiveness in reducing emergency response times, improving signal clearance, and minimizing disruption to general traffic. Across key intersections, the trial achieved a 38% reduction in emergency vehicle travel time, highlighting the technology's transformative potential to save lives and enhance mobility (Srivastava et al., 2024).

1. **Lead Agencies**
    a. Bengaluru Traffic Police: Supported implementation and monitoring of the green corridor trial.
    b. Danlaw: Managed C-V2X integration, OBU/RSU deployment, vehicle calibration, and system validation.
    c. CDAC: Provided V2X network adapter, technical support, and TSC integration with TiHAN.
    d. Arcadis: Assisted RSU–TSC system integration.
    e. TIHAN – IITH: Conducted interoperability testing of OBU-RSU pairs with CDAC and Danlaw.
    f. Mahindra & Mahindra: Supplied vehicles for OBU integration.
    g. Qualcomm: Supported permissions and licensing for the trial.
2. **Timeline:** October to December 2024.
3. **Pilot Objectives**
    a. Safety: Enable emergency vehicles to pass intersections without stopping or slowing.
    b. Traffic Efficiency: Ensure signal priority reduces congestion and maintains smooth traffic flow during emergency responses.
    c. Public Awareness: Educate authorities and the public on the benefits of C-V2X technology in enhancing emergency response.
4. **Technology Stack**
    a. Signal Request Application for Real-Time Traffic Light Control: Automated Signal Request Application (SRA) in vehicle OBUs uses C-V2X to send Signal Request Messages (SRMs) directly to RSUs for machine-to-machine pre-emption.
    b. Communication Between Vehicle OBU, RSU, and Traffic Controller: End-to-end V2I communication links OBU to RSU to Traffic Controller via SNMP/TSCBM ports, with real-time Signal Status Messages (SSMs) returned to the vehicle.
    c. The vehicle OBU generates SRMs with GPS, speed, heading, and vehicle ID, and receives SSMs from RSUs for fully automated green-corridor activation.
    d. RSU (Roadside Unit) Operations processes SRMs, validates requests, exchanges data with the Traffic Controller through MAP, SNMP, and TSCBM configurations, and relays SSMs back to OBUs.
    e. Traffic Signal Controller (TSC) Operations executes pre-emption commands from RSUs, adjusts green phases, and securely shares live signal status via RSU IP and SNMP configuration.

5. **Geography and Coverage**
    a. The trial was conducted at four major Bengaluru junctions, selected based on emergency vehicle routes, traffic congestion patterns, and proximity to key hospitals, to evaluate C-V2X-based signal control under varying traffic conditions. The locations included: BTP110: Bharathi Nursing Home; BTP112: 14th Cross, KR Road; BTP114: KR Road Junction; BTP113: 27th Cross, Pai Vista
6. **Pilot Design**
    a. An emergency vehicle, equipped with an On-Board Unit (OBU), enters the vicinity of the intersection.
    b. The OBU sends an emergency signal to the Road-Side Unit (RSU) connected to the traffic signal controller.
    c. Upon detecting the emergency signal, the RSU communicates with the traffic controller to change the signal to green for the lane in which the emergency vehicle is approaching.
    d. Once the vehicle clears the intersection, the OBU sends an "exit" signal, and the RSU cancels the emergency mode, resuming normal signal operations.
7. **Outcomes & Metrics**
    a. Emergency Vehicle Travel Time: C-V2X-enabled vehicles reduced travel time by 38%, shortening an 8-minute journey to 5 minutes during non-peak hours, also lowering CO_2 emissions.
    b. Signal Clearance Efficiency: Signals turned green in an average of 7 seconds after receiving a Signal Request Message (SRM).
    c. Preemption Success Rate: 100% of test cases (10/10 trials) successfully granted signal preemption.
    d. Traffic Impact: Minimal disruption to non-emergency vehicles, with normal traffic flow resuming immediately after the emergency vehicle passed.
    e. RSU Coverage: Each RSU provided effective coverage of approximately 300 meters per intersection.
    f. Stakeholder Demonstration: A live system demonstration was conducted for the Joint Commissioner of Police (Traffic) and other stakeholders.
8. **Challenges & Learnings**
    a. Connectivity Challenges: Junctions spaced over 800 meters require intermediate RSUs to maintain seamless coverage.
    b. Signal Interference: Structures like metro pillars create shadow zones, necessitating multiple RSUs at critical junctions.
    c. Scalability: Citywide deployment requires significant additional infrastructure investment.
    d. Traffic Management Integration: Integrating with existing traffic management systems can optimize signal coordination, traffic flow, and commute times
    e. Green Corridor Coordination: Signals along the corridor must communicate to ensure a continuous green path for emergency vehicles.
    f. TSC Integration: Connecting C-V2X with existing Traffic Signal Controllers demands substantial investment and technical effort.

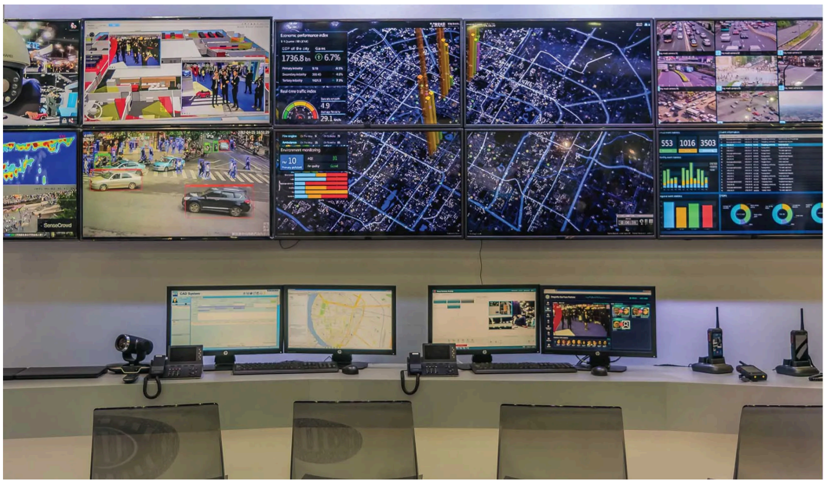
5.3. City Case: Pune - Smart Signal Integration and ICCC-Led Traffic Management

Pune has deployed adaptive traffic signal systems and integrated emergency services into its Integrated Command and Control Centre (ICCC). While C-V2X has not yet been formally deployed, the city's ICCC architecture, corridor-level analytics, and AI-based adaptive signaling establish foundational readiness for future V2X-enabled emergency response solutions (Pune Smart City, 2021; Indian Express, 2023; Economic Times CIO, 2022).

1. **Lead Agencies**
    a. Pune Smart City Development Corporation Ltd. (PSCDCL): Urban innovation SPV responsible for ICCC and traffic modernization.
    b. Pune Municipal Corporation (PMC): Local traffic signal and road infrastructure authority.
    c. Pune Traffic Police: Implementation and coordination of emergency vehicle routing protocols.
    d. Private ITS Partners: Vendors for Adaptive Traffic Management System (ATMS), including L&T, Tech Mahindra, and others involved in smart signal upgrades.
    e. EMRI-108 Fleet (State Health Department): Emergency dispatch partner with GPS-enabled fleet.
2. **Pilot Objectives**
    a. Improve overall traffic efficiency through adaptive signal control.
    b. Enable real-time traffic monitoring and dynamic signal phasing.
    c. Lay digital and institutional foundations for future emergency vehicle priority systems.
    d. Integrate multiple city services into a unified ICCC platform with future-facing mobility use cases.
3. **Pilot Timeline**
    a. Adaptive Traffic Management Phase I began in March 2023, with 95 junctions operational by December 2023.
    b. ICCC-EMRI integration planning began in early 2024 under Smart City Phase II.
4. **Technology Stack**
    a. Adaptive Traffic Management System (ATMS): Software-driven dynamic signal optimization based on real-time vehicle flow.
    b. ANPR & Traffic Cameras: Automated Number Plate Recognition and congestion monitoring at key intersections.
    c. ICCC Integration: Real-time dashboards combine feeds from ambulances, CCTV, and traffic signals.
    d. Emergency Dispatch Coordination: EMRI fleet locations are monitored within the ICCC interface for potential green-corridor support (manual override if required).
    e. No RSU/OBU or C-V2X infrastructure yet; however, Pune's ATMS architecture is compatible with future C-V2X layer via SPaT/MAP messaging standards.
5. **Geography and Coverage**

a. Phase I (2023-24): Covered 95 traffic junctions across city's high-density areas, including:
    i. Shivajinagar
    ii. Deccan Gymkhana
    iii. Swargate
    iv. Hadapsar
    v. Aundh-Baner corridor
b. Coverage Expansion: Additional 100+ junctions planned in ATMS Phase II rollout under PMC's Smart City roadmap.

6. **Institutional Design**
    a. ICCC as Central Nerve Center: Aggregates traffic flow data, video surveillance, and emergency fleet locations.
    b. PMC + Traffic Police Coordination: Signal control is shared; manual intervention possible for emergency prioritization.
    c. Health Department Linkage (Exploratory): State-level MoUs being explored for EMRI-ICCC integration to enable auto-alerts and route planning.
    d. Vendor-Neutral Signal System: Hardware and software can support modular V2X layering in future.
7. **Outcomes & Metrics**
    a. Reduced Congestion: 2023 pilot data indicates a 15-20% improvement in traffic flow efficiency at pilot junctions.
    b. Improved Signal Reliability: Signal downtime fell by over 35% after ATMS and ICCC coordination.
    c. Public Safety Response Time: Limited but improving; time-stamped ICCC data now allows faster signal override by operators during emergencies.
    d. Institutional Readiness: Pune among top-ranked cities for ICCC maturity in India.
8. **Challenges & Learnings**
    a. No Formal EVP System Yet: While technologically feasible, Pune has yet to implement real-time ambulance signal pre-emption or V2X protocols.
    b. Cross-Agency Integration Lag: Health and traffic systems operate under different dashboards; efforts are underway for unification.



    c. Signal Hardware Variability: Legacy intersections still require upgrade to intelligent controllers.
    d. Scaling Needs Funding: Further junction upgrades and V2X-capable retrofits depend on capex from state/ central funding or public-private partnerships (Tele.net, 2019).

5.4. City Case: Delhi - AI-Enabled Emergency Response and Signal Integration

Delhi is advancing emergency vehicle coordination through a new fleet of 5G-enabled ambulances and AI-driven signal optimization (via Google's Project Green Light), while building institutional systems that can support future V2X deployments (Business Standard, 2025; Google Research, 2023; Rothenberg, 2024).

1. **Lead Agencies**
    a. Delhi Traffic Police: Manages signal systems and ambulance coordination.
    b. EMRI-108 / Zenzo Ambulance Services: 5G-enabled fleet provider.
    c. Google Research: Developer of AI-driven traffic optimization tools under Project Green Light.
    d. Delhi Government / NCR Authorities: Facilitate policy, infrastructure deployment, and oversight.
2. **Pilot Objectives**
    a. Integrate 5G-enabled ambulances into real-time traffic and emergency response systems.
    b. Optimize signals using AI to minimize delay and improve flow across intersections.
    c. Lay groundwork for future signal pre-emption and dynamic routing, akin to C-V2X implementations.
3. **Pilot Timeline**
    a. Project Green Light pilot commenced in October 2023, with 5G ambulance rollout announced in January 2024.
    b. Signal coordination and AI-enabled ETA models tested through Q1-Q2 2024.
4. **Technology Stack**
    a. 5G-enabled ambulances for real-time telemetry and remote patient monitoring
    b. AI-based signal optimization using Google Maps data (Project Green Light) to reduce stop-and-go emissions and improve flow
    c. GPS-driven ambulance location tracking integrated with Traffic Police dashboards via ICCC and control rooms.
    d. No active C-V2X RSU/OBU infrastructure, though the existing signal network and GPS tracking layer could evolve to support full V2X.
5. **Geography and Coverage**
    a. Ambulance Fleet: 671 5G-enabled ambulances operating across Delhi-NCR
    b. Project Green Light: Currently active at ~70 intersections globally; Delhi is part of the ongoing pilot network
6. **Institutional Design**
    a. Traffic Police and EMRI Coordination: Ambulance routes and signal override requests are routed via police control systems.
    b. Joint Pilot with Google: Project Green Light provides AI-generated "green wave" timing suggestions via traffic engineers.
    c. Disaster and Highway Control Integration: Ambulance tracking links with RCC (Regional Control Center) for triaging major events.

7. **Outcomes & Metrics**
    a. Fleet Modernization: Launch of 671 5G ambulances aimed at reducing emergency response time and enabling remote patient care
    b. Traffic Signal Improvement: Project Green Light trials demonstrate up to 30% fewer stops and 10% emissions reduction at optimized intersections
    c. Preliminary Route Efficiency: Subjectively improved ambulance travel, though detailed response-time audits are pending.
8. **Challenges & Learnings**
    a. Fragmented Signal Ecosystem: Mixed signal standards and equipment across Delhi impede unified deployment.
    b. Lack of V2X Hardware: No active RSU or OBU installations impede end-to-end automation.
    c. Data and Coordination Complexity: Integrating 5G signals, emergency dispatch, and AI models across agencies remains challenging.
    d. Potential to Scale: Institutional interest and technological groundwork present a strong path toward C-V2X readiness if combined with edge infrastructure.

City Case: Delhi - AI-Enabled Emergency Response and Signal Integration.

Source: Hindustan Times, 2019.

City Case: Bengaluru - Emergency Vehicle Priority (EVP) and Signal Optimization.

Source: Bangalore Mirror, 2024.

5.5. City Case: GIFT City (Gujarat) - 5G C-V2X Corridor Pilot for Urban Innovation

GIFT City is hosting one of India's most advanced C-V2X pilots, developed through a collaboration between C-DAC Bengaluru and TiHAN-IIT Hyderabad under the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) (C-DAC, 2023; TiHAN Foundation, 2023). The corridor supports real-time V2V, V2I, and V2N communication using 5G and dedicated short-range communication (DSRC).

1. **Lead Agencies**
    a. Centre for Development of Advanced Computing (C-DAC), Bengaluru: Lead agency for technical deployment of C-V2X stack.
    b. TiHAN Foundation, IIT Hyderabad: National testbed partner, providing hardware and standards.
    c. Gujarat International Finance Tec-City (GIFT City Authority): Urban planning and mobility governance.
    d. Department of Telecommunications (DoT): Supporting 5G-based ITS testing.
2. **Pilot Objectives**
    a. Create a secure, real-time communication corridor for road safety and connected mobility.
    b. Enable trials for collision avoidance, emergency braking alerts, and green corridor signaling.
    c. Assess performance of C-V2X applications under Indian road, climate, and traffic conditions.
3. **Pilot Timeline**
    a. Corridor deployment began in September 2023.
    b. Full-stack C-V2X trials including RSUs/OBUs and latency testing conducted from November 2023 to March 2024.
4. **Technology Stack**
    a. 5G-Powered C-V2X Infrastructure: Uu and PC5-based communication layers.
    b. RSUs (Road Side Units) deployed along select stretches in GIFT City.
    c. OBUs (On-Board Units) installed on test vehicles, including ambulances and commercial fleet units.
    d. Cloud and Edge-based Processing: Data from RSUs is streamed to a central analytics platform.
    e. Security Stack: PKI and pseudonymization protocols implemented to ensure safe vehicle-to-network messaging.
5. **Geography and Coverage**
    a. Corridor within GIFT City campus, covering approximately 3 km of road infrastructure.
    b. Select intersections outfitted with RSUs and smart signals.
    c. Deployment adjacent to commercial zones and planned residential developments to mimic mixed-use traffic.
6. **Institutional Design**

a. C-DAC leads the platform design, with TiHAN providing simulation, compliance validation, and training.
b. GIFT City authorities support signal integration and physical deployment permissions.
c. Multi-institutional MoUs signed to formalize data sharing, evaluation, and system audits.
d. The pilot is part of C-DAC's larger urban mobility test framework, with potential for replication in other smart cities.

7. **Outcomes & Metrics**
   a. Latency Performance: Initial tests show sub-10ms latency for vehicle alerts under 5G SA conditions.
   b. Scenario Testing: Successful trials for intersection movement assist, forward collision warning, and emergency vehicle proximity alerts.
   c. Readiness Scorecard: GIFT City now considered among the first Indian cities to implement live V2X RSU-OBU signaling at city scale.
8. **Challenges & Learnings**
   a. Real-World Calibration Needed: Testing largely conducted under controlled traffic volumes; real-world congestion trials needed.
   b. Hardware Standardization: Interoperability across vendors and standards requires alignment with international protocols.
   c. Funding for Scale: Expanding beyond the current corridor will require multi-agency capex and operating model clarity.
   d. Skills & Talent Gaps: Need for city-level operational teams trained in V2X management and integration.

City Case: GIFT City (Gujarat) - 5G C-V2X Corridor Pilot for Urban Innovation.
Source: India Today, 2022.

5.5. City Case: Coimbatore - 5G-Enabled Smart Corridor for Traffic and Future EVP Integration

Coimbatore, a Tier-2[1] industrial hub in Tamil Nadu, has launched a pilot for smart traffic signal optimization leveraging 5G connectivity and adaptive signal management. Enabled through infrastructure enhancements under the Smart Cities Mission, the initiative integrates real-time traffic sensor data with a centralized dashboard at the city's Integrated Command and Control Centre (ICCC). While no formal MoU with BSNL has been found in the public domain, 5G trials by BSNL in early 2025 have coincided with the city's digital mobility upgrades, offering a foundation for future emergency vehicle prioritization (EVP) and potential C-V2X deployment. In parallel, Coimbatore's Smart City Vision emphasizes interconnected infrastructure - such as adaptive signals, CCTV networks, and responsive streetlighting - as key enablers of a future-ready, integrated mobility ecosystem (The Hindu, 2019; nPerf, 2025; Coimbatore Smart City Ltd., 2023).

1. **Lead Agencies**
    a. BSNL Tamil Nadu Circle: Provided the 5G infrastructure backbone enabling high-speed, low-latency data transmission between traffic assets.
    b. Coimbatore Smart City Limited (CSCL): Coordinated smart infrastructure development, funded under the Smart Cities Mission.
    c. Private Technology Partners: Involved in deploying adaptive traffic signal controllers, real-time sensor systems, and data analytics dashboards (names not publicly disclosed).
    d. Coimbatore Traffic Police: Operationalized changes in signal behaviour and provided integration support with the city's ICCC.
2. **Pilot Objectives & Technology Stack**
    a. Test 5G-enabled real-time communication to ICCC.
    b. Deploy adaptive signal controllers and traffic-sensor arrays.
    c. Develop cloud-based dashboard monitored by CSCL/Traffic Police.
    d. Note: No OBUs/RSUs yet; EVP/C-V2X integration currently under technical review.
3. **Pilot Timeline**
    a. 5G infrastructure backbone by BSNL completed in January 2025.
    b. Smart signal pilot launched in March 2025.
4. **Geography and Coverage**
    a. The pilot corridor spans 6-8 high-traffic intersections on:
        i. Avinashi Road
        ii. Race Course Road
    b. These locations connect to major hospitals, commercial areas, and public transport nodes.
    c. Additional test zones proposed around Gandhipuram Bus Stand and Town Hall area.

[1] In this report, we adopt the Government of India's HRA classification framework, under which Coimbatore is considered a Tier 2 city. Alternate tiering models based on digital infrastructure or economic activity may vary.

5. **Institutional Design**
    a. Real-time traffic feed shared with CSCL's ICCC.
    b. No formal MoU with BSNL found - coordination appears operational, not contractual.
6. **Outcomes & Metrics**
    a. Average signal wait times down by 15-20%.
    b. Real-time congestion snapshots enable rapid control-room response.
    c. The project demonstrates feasibility of 5G-enabled signal systems, laying groundwork for future EVP readiness.
7. **Challenges & Learnings**
    a. Limited EVP Use: The pilot focused on signal responsiveness, not on emergency vehicle priority.
    b. Fragmented Signal Infrastructure: Legacy controllers in parts of the city limited seamless scaling.
    c. Lack of Unified Data Standards: Data from private partners and public sources lacked interoperability.
    d. Need for Institutional Anchors: Unlike metros, Coimbatore lacks a nodal ITS agency to guide city-wide C-V2X strategy.

City Case: Coimbatore - 5G-Enabled Smart Corridor for Traffic and Future EVP Integration.
Source: The Hindu, 2020.

5.6. City Case: Hyderabad - TiHAN's C-V2X Testbed and Emerging Urban Integration

Hyderabad has emerged as a national leader in the research, development, and demonstration of C-V2X technologies through the TiHAN Testbed at IIT Hyderabad. While city-scale deployment is still in early planning stages, the TiHAN program provides India's most advanced controlled environment for testing V2X scenarios, supported by real-time data, hardware-in-loop simulations, and integrated mobility platforms (Press Information Bureau, 2022; Livemint, 2022; TiHAN Foundation, n.d.; DST, Government of India, 2022).

1. **Lead Agencies**
    a. TiHAN Foundation, IIT Hyderabad: Nodal R&D agency for C-V2X, part of DST-supported NM-ICPS program.
    b. Government of Telangana: Supports smart mobility partnerships and MoUs with TiHAN and startups.
    c. Startups & Private Sector: Partner with TiHAN for pilot technologies (e.g., V2X software, low-latency communication devices).
    d. Hyderabad Traffic Police (under GHMC): Engaged for long-term testing along select corridors such as ORR (Outer Ring Road).
2. **Pilot Objectives**
    a. Build and validate India's first multi-modal CAV testbed for connected and autonomous vehicles.
    b. Test C-V2X use cases such as:
        i. Emergency vehicle prioritization
        ii. Collision warning systems
        iii. Signal pre-emption
        iv. V2P pedestrian alerts
    c. Support startups and automotive OEMs with a plug-and-play testing environment.
3. **Pilot Timeline**
    a. TiHAN's full-stack C-V2X testbed became operational in August 2022.
    b. Urban pilot discussions with Hyderabad city agencies ongoing since mid-2023.
4. **Technology Stack**
    a. Dual Communication Layer:
        i. PC5 Interface for direct short-range communication.
        ii. Uu Interface over 5G for cloud coordination.
    b. V2X Hardware:
        i. Onboard Units (OBUs)
        ii. Roadside Units (RSUs)
        iii. Multi-sensor edge nodes
    c. Simulators & Digital Twins:
        i. Software-in-the-loop (SiL), Hardware-in-the-loop (HiL), and Vehicle-in-the-loop (ViL)
    d. Command Centre:

        i. Real-time dashboard with latency logging, performance benchmarks, and scenario replay tools.

5. **Geography and Coverage**
    a. Located at IIT Hyderabad campus in Kandi, Sangareddy district.
    b. Controlled urban testbed spans:
        i. 2.3 km test track
        ii. Urban intersections, pedestrian crossings, signalised zones
        iii. Dedicated environments for V2P, V2V, and V2I use cases
    c. Proposed extension to urban corridors in Hyderabad (e.g., Outer Ring Road, ISB Gachibowli corridor) under discussion with government partners.
6. **Institutional Design**
    a. Operated as an autonomous Section-8 company under the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS), Department of Science and Technology (DST), Government of India (GoI).
    b. Strong emphasis on startup incubation and OEM-government collaboration.
    c. Coordinates with Telangana ITS and Smart City departments for potential scale-up.
7. **Outcomes & Metrics**
    a. Performance Benchmarks:
        i. Latency: <50ms for PC5, <100ms for Uu (as reported by TiHAN).
        ii. Field-tested emergency response routing via simulated EVPs.
    b. IP & Standardization:
        i. Contributed to India's early work on C-V2X protocol stack and conformance tools.
    c. Startup Impact:
        i. Hosted over 50 startups in mobility, safety, and AI integration.
    d. Readiness Indicators:
        i. Technologically ready for full-stack deployment in live corridors.
8. **Challenges & Learnings**
    a. Testbed-city disconnect: Bridging controlled testbed learnings to complex urban road conditions remains a challenge.

    b. Limited policy frameworks: No clear city-level implementation roadmap for large-scale deployment.
    c. Funding gaps: Pilot-to-deployment transition depends on joint funding models with city and state agencies.
    d. Stakeholder alignment: Need better synergy between academic R&D, municipal corporations, and industry.

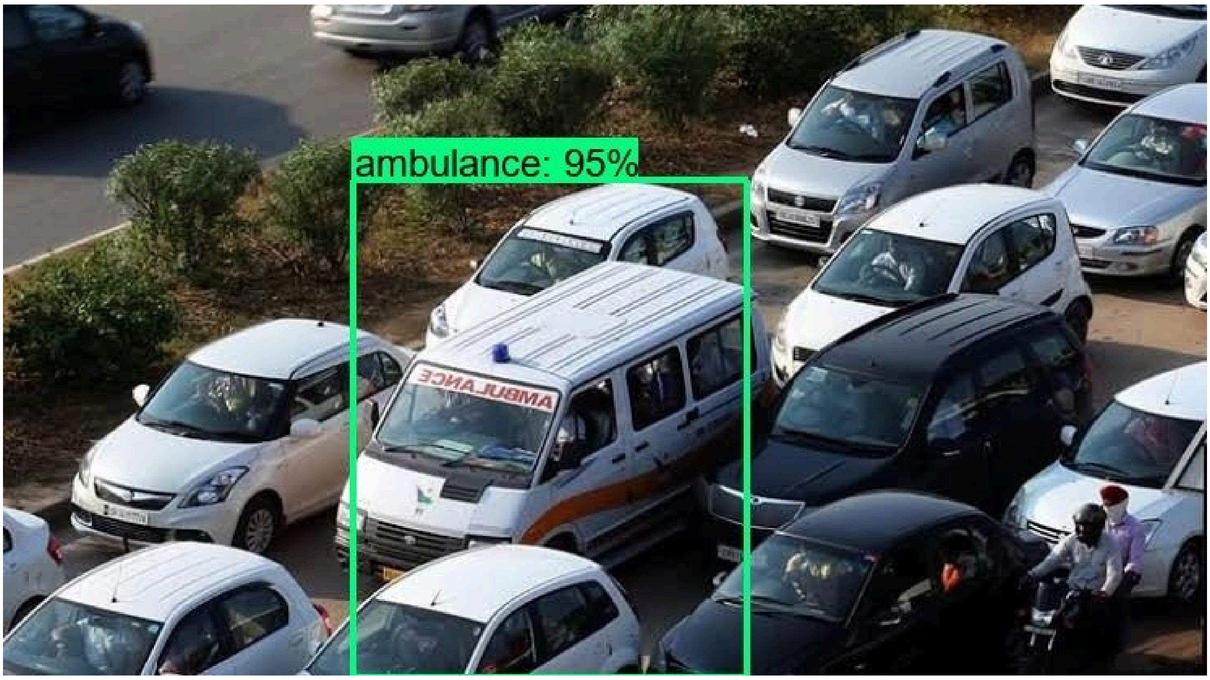
5.7. City Case: Lucknow - AI-Enabled Ambulance Tracking and ICCC-Based Signal Coordination

Lucknow has emerged as a notable example of semi-automated emergency vehicle management in a Tier-2 city[2]. While not a full C-V2X deployment, the city has implemented real-time ambulance tracking integrated into its Integrated Command and Control Centre (ICCC), using AI and GPS analytics to predict arrival times and manually adjust signal flows at critical intersections. This serves as a transitional model for C-V2X readiness (Hindustan Times, 2023; Ministry of Housing and Urban Affairs, 2023; Times of India, 2024).

1. **Lead Agencies**
    a. Lucknow Smart City Limited (LSCL): Lead implementing agency overseeing ICCC infrastructure.
    b. Uttar Pradesh State Road Transport Corporation (UPSRTC) and EMRI-108 Services: Integrated ambulance fleet systems.
    c. UP Traffic Police: Executes manual signal interventions based on alerts from ICCC.
    d. Private Technology Vendors: Provided AI-driven dashboards and GPS integration (e.g., NEC India).
2. **Pilot Objectives**
    a. Reduce emergency response times through better route visibility and signal coordination.
    b. Enable predictive ambulance arrival alerts to ICCC operators.
    c. Build foundational capabilities for eventual C-V2X signal prioritization and automation.
3. **Pilot Timeline**
    a. ICCC-based ambulance integration initiated in July 2023.
    b. Predictive signal coordination piloted during October-December 2023.
4. **Technology Stack**
    a. GPS Tracking: Ambulances fitted with real-time GPS transmitters.
    b. ICCC Dashboard: Visualizes ambulance location, destination, ETA, and congestion status.
    c. AI/ML Layer: Predicts bottlenecks and expected delays along route.
    d. Manual Signal Override System: Alerts sent to traffic police or control rooms for pre-emptive action.
    e. Communication Protocols: Mobile-based alerting with ICCC-field unit links.
5. **Geography and Coverage**
    a. The pilot covered key emergency corridors in central Lucknow:
        i. KGMU (King George's Medical University) zone
        ii. Hazratganj-Aminabad corridor
        iii. SGPGIMS-Shaheed Path route
    b. Integrated with over 50+ signals across the central urban area.

[2] In this report, we adopt the Government of India's HRA classification framework, under which Lucknow is considered a Tier 2 city. Alternate tiering models based on digital infrastructure or economic activity may vary.

6. **Institutional Design**
    a. Real-time coordination between ICCC operators and field traffic staff.
    b. Ambulance ETA estimates used to manually time green-light windows.
    c. SOPs defined for signal override via handheld devices or direct commands to smart signal controllers.
    d. Governed under Lucknow Smart City's digital governance charter.
7. **Outcomes & Metrics**
    a. Response Time Reduction: Ambulance arrival time reduced by 18-25% in select corridors.
    b. Public Awareness: Citizens reported increased compliance with emergency vehicle clearance, supported by VMS and social media campaigns.
    c. Operational Load: Reduced reliance on field spotters due to digital visibility.
    d. EVP Transition Readiness: ICCC architecture now ready to accommodate full-scale C-V2X deployments with OBUs/RSUs.
8. **Challenges & Learnings**
    a. No Full Automation Yet: Absence of OBUs and dynamic vehicle-to-signal interfaces.
    b. Manual Intervention Delays: Some lag due to human-dependent overrides.
    c. Infrastructure Variation: Not all intersections are equipped with smart controllers.
    d. Scalability Issues: Needs state-wide ITS framework for wider rollout.



City Case: Lucknow - AI-Enabled Ambulance Tracking and ICCC-Based Signal Coordination.
Source: Raman, et al., 2020

5.8. City Case: Mumbai - EVP Integration in Mega-Corridors and Multi-Modal ITS Plans

Mumbai, India's financial capital, is leveraging its expansive public transport network and digital governance infrastructure to pilot signal preemption and emergency vehicle routing. While full C-V2X integration is at the planning stage, BEST, MMRDA, and BMC have initiated digital corridor upgrades, with an eye toward integrating emergency vehicle prioritization into broader multi-modal traffic orchestration (Hindustan Times, 2023; Economic Times; 2023).

1. **Lead Agencies**
   a. Brihanmumbai Electric Supply and Transport (BEST): Exploring EVP for e-buses and ambulances in congested corridors.
   b. Mumbai Metropolitan Region Development Authority (MMRDA): Leads corridor digitisation under the Mumbai Metro and smart signal upgrades.
   c. Brihanmumbai Municipal Corporation (BMC): Oversees signal infrastructure and ICCC.
   d. Tech Partners: Engagements with Google Maps, TCS, and Siemens Mobility in advisory or execution roles.
2. **Pilot Objectives**
   a. Enable smoother movement for ambulances, especially along congested hospital corridors and Eastern/Western Expressways.
   b. Digitize and synchronize signals for fleet-based prioritization (ambulances, fire trucks, BEST e-buses).
   c. Integrate mobility data from apps like MumbaiOne with ICCC systems for multimodal coordination.
3. **Pilot Timeline**
   a. Signal modernization Phase I started in November 2023, with ~70 intersections targeted under MMRDA.
   b. EVP pilot design work initiated in February 2024 under coordination with BEST and TCS.
4. **Technology Stack**
   a. Google Maps Live Integration: Ambulance tracking & congestion rerouting.
   b. Smart Signal Controllers: Installed along key arterial routes.
   c. Data Integration: BEST bus movement and traffic sensors being integrated with ICCC.
   d. Planned C-V2X Pilot: Under consideration for Western Express Highway.
5. **Geography and Coverage**
   a. Focus corridors: JJ Hospital-Marine Lines, Bandra-Kurla Complex (BKC), Sion-Chembur Link Road.
   b. Target intersections: 70+ in Phase 1 under MMRDA's signal modernization plan.
6. **Institutional Design**
   a. MMRDA and BMC co-own the signal upgrades; ICCC integration via private vendors.
   b. BEST coordinates fleet movement data sharing with ICCC.

c. Emergency services data (ambulances, fire) to be integrated into predictive signal models.

7. **Outcomes & Metrics**
   a. EVP pilots under design phase, not yet evaluated at scale.
   b. Congestion maps and dwell time analytics show scope for 25-30% improvement in priority vehicle movement.
   c. Multimodal platform integration readiness demonstrated via MumbaiOne trials.
8. **Challenges & Learnings**
   a. Jurisdictional overlap between BMC, MMRDA, and BEST delays tech unification.
   b. Limited RSU/ OBU experimentation yet; C-V2X stack remains untested on ground.
   c. Privacy concerns around ambulance location data integration with third-party systems.

City Case: Mumbai - EVP Integration in Mega-Corridors and Multi-Modal ITS Plans.
Source: The Indian Express, 2017.

5.9. City Case: Chandigarh - 5G-Enabled Smart Traffic & Emergency Response Corridor

Chandigarh, a UT and planned city, has emerged as a smart city innovator by launching a pilot that integrates 5G connectivity with emergency response capabilities. The project uses AI-enhanced smart signal management with scope for future C-V2X upgrades. While EVP is not fully automated, the pilot demonstrates the feasibility of 5G-enabled traffic orchestration (Chandigarh Smart City Ltd., n.d.; Communications Today, 2024; Hindustan Times, 2023; The Tribune, 2025; Bharti Airtel, 2023).

1. **Lead Agencies**
    a. Chandigarh Smart City Ltd. (CSCL): Lead implementation body.
    b. Airtel & Sterlite Technologies: Provided 5G infrastructure and fiber backbone.
    c. Chandigarh Police: Emergency coordination partner for routing and signal override.
    d. ICCC Operator: Aggregates vehicle, camera, and signal data.
2. **Pilot Objectives**
    a. Use 5G for faster emergency alert transmission and data-heavy CCTV feeds.
    b. Build readiness for dynamic signal prioritization and eventual C-V2X deployment.
    c. Reduce response times for ambulances and fire services in critical corridors.
3. **Pilot Timeline**
    a. Phase 1 pilot with 25 intersections launched in December 2023.
    b. AI-camera integration and real-time ambulance ETA testing conducted from January to April 2024.
4. **Technology Stack**
    a. 5G-Enabled Edge Nodes: Installed at 20+ intersections.
    b. Smart Signal Controllers: Capable of real-time adjustments.
    c. AI Camera Network: Real-time traffic classification and congestion heatmap generation.
    d. Cloud Dashboard: Displays ETA and routing for emergency vehicles.
5. **Geography and Coverage**
    a. Corridors Covered: Sector 17 to PGIMER, Airport Road, ISBT Sector 43.
    b. 25+ junctions covered under Phase 1 with 5G signal infrastructure and CCTV.
6. **Institutional Design**
    a. MoU between CSCL, Airtel, and Chandigarh Administration.
    b. Centralized ICCC with feed from field units and command room alerts.
    c. Coordination protocols tested for ambulance pre-clearance with Sector-wise alerts.
7. **Outcomes & Metrics**
    a. Average ambulance response time reduced by 15-20% in covered zones.
    b. AI-based traffic signal efficiency improvement reported at 18-22%.
    c. Citizen satisfaction on real-time updates and smoother mobility shared in surveys.

8. **Challenges & Learnings**
    a. Not yet a full C-V2X deployment; no OBUs/RSUs tested.
    b. Dependence on Airtel’s coverage means restricted scalability with other vendors.
    c. Signal controller compatibility varies across junctions.

City Case: Chandigarh - 5G-Enabled Smart Traffic & Emergency Response Corridor.
Source: Hindustan Times, 2021.

5.10. Lessons from Indian Pilots

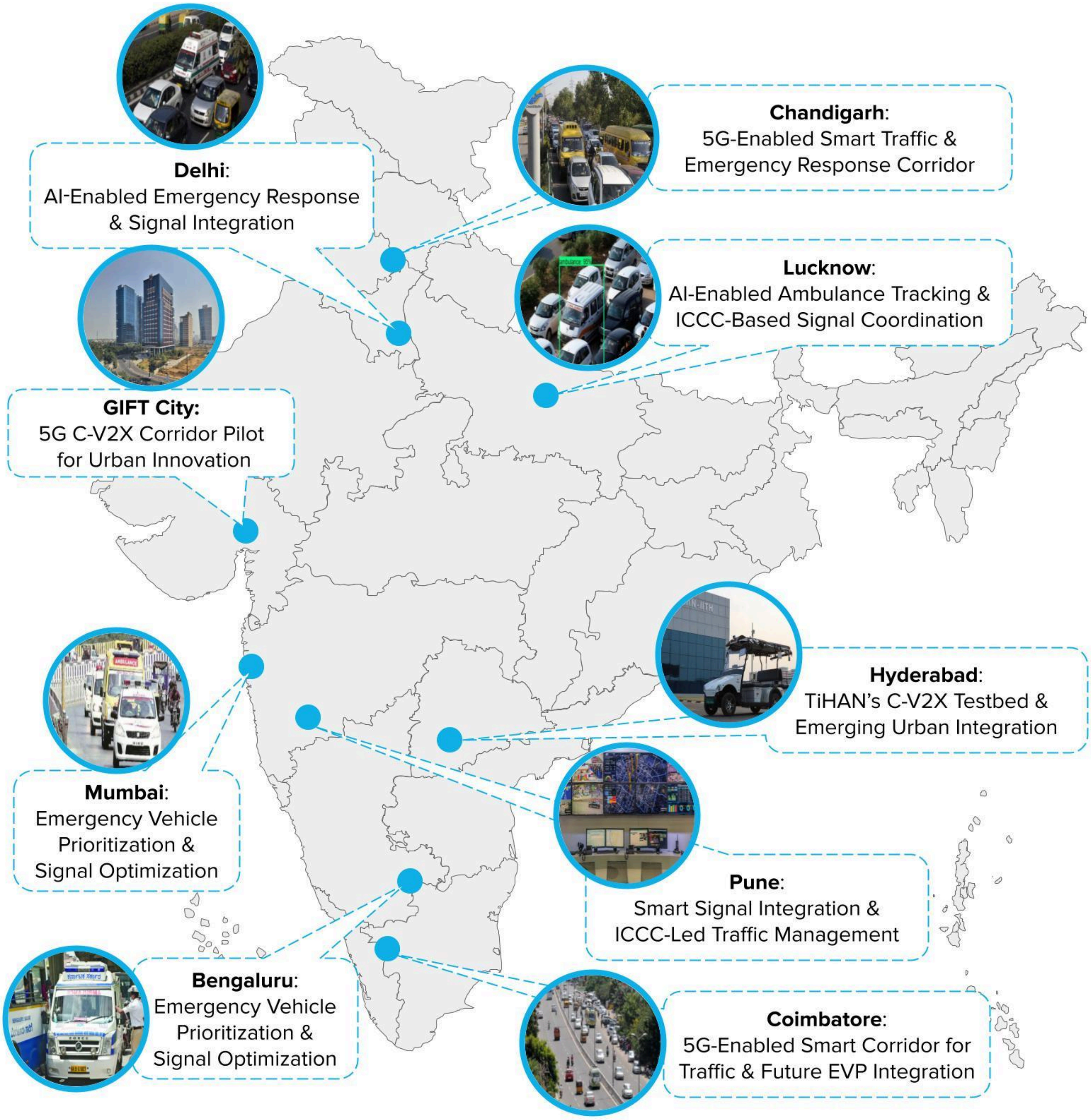
India's diverse urban experiments with emergency vehicle prioritization (EVP) and foundational C-V2X technologies offer valuable insights for future deployment at scale. While cities vary in their infrastructure maturity, institutional design, and adoption of V2X-specific components, several shared lessons and directional trends emerge.

5.10.1. Key Lessons from Indian Pilots

Table 5: Key Lessons from India Pilots on Deployment of C-V2X and EVP Integration

Theme	Insights
1. Tech Readiness vs. C-V2X Maturity	Most cities have achieved partial digitalization (e.g., GPS tracking, AI dashboards), but **few have deployed full C-V2X stacks** (OBUs/RSUs with low-latency communication). Hyderabad (TiHAN) and GIFT City are closest to readiness.
2. Fragmented Institutional Control	Emergency services, traffic signals, and smart infrastructure often lie with different agencies (e.g., traffic police, Smart City SPVs, hospitals), leading to coordination delays and duplicated efforts.
3. ICCC as a Backbone, But Not the Brain	Most ICCCs currently serve as **monitoring hubs**, not dynamic orchestrators. For true EVP, they must be enabled with **real-time signal override, AI-based routing, and automated SOPs**.
4. Manual Overrides Still Dominant	Even in cities like Lucknow and Bengaluru, ambulance priority largely relies on **semi-automated or manual signal interventions**, lacking scalable automation.
5. Public Behavior and Awareness Matter	Cities with **public campaigns (e.g., BTP's awareness drives)** saw better compliance with lane discipline and reduced response times - highlighting the need for behavioral change alongside tech.
6. Vendor Lock-in and Protocol Fragmentation	Pilots often use proprietary stacks with **limited interoperability**. A unified protocol or standards-based approach (e.g., 3GPP's PC5 and Uu layers) is essential.
7. Capacity Gaps in Mid-Tier Cities	Cities like Coimbatore and Chandigarh have **strong intent but limited capacity**, requiring central/state support for tech upgradation, training, and interoperability governance.

Figure 2: Select C-V2X-enabled Emergency Vehicle Prioritization Pilots in India



Note: Map not to scale.

#PriorityByDesign

6. Hyderabad's C-V2X Readiness, and Implementation Roadmap

Hyderabad stands at the forefront of India's urban mobility transformation, offering a promising testbed for C-V2X (Cellular Vehicle-to-Everything) deployment to enable emergency vehicle prioritization (EVP) and real-time traffic management. The city's combination of robust 5G infrastructure, smart traffic control upgrades, and national-level research assets positions it as a strong candidate for rapid-scale implementation.

6.1. Key Enablers of C-V2X in Hyderabad

6.1.1. 5G Coverage and Network Readiness

As of early 2025, Hyderabad boasts over 95% RSRP (Reference Signal Received Power) coverage across major urban zones, supported by Airtel, Jio, and BSNL (Press Information Bureau, 2025; Deccan Chronicle, 2025; nPerf; 2025). This comprehensive footprint is critical for enabling low-latency, ultra-reliable communication between vehicles and infrastructure (V2I), a prerequisite for EVP.

6.1.2. Smart Traffic Infrastructure

The Greater Hyderabad Municipal Corporation (GHMC) has begun upgrading over 400 out of its 1,125 traffic lights (i.e. junctions) with Adaptive Traffic Control Systems (ATCS), forming the physical layer for EVP signal override (The New Indian Express, 2025). Many of these junctions are already integrated into Hyderabad's Integrated Command and Control Center (ICCC), enabling real-time traffic flow monitoring and control (The Times of India, 2025).

6.1.3. TiHAN: India's National Testbed

The Technology Innovation Hub on Autonomous Navigation (TiHAN) at IIT-Hyderabad serves as India's premier testbed for autonomous and connected vehicle systems, including C-V2X. TiHAN has developed and tested PC5 and Uu interface-based V2X stacks and is piloting dynamic signal control, RSU-OBU interoperability, and cyber-physical testing for emergency vehicle scenarios (Future Mobility Media, 2024).

6.1.4. ICCC + Tech Ecosystem Layer

Hyderabad's ICCC is among India's most mature urban command centers, already integrated with feeds from traffic sensors, GPS from municipal vehicles, and AI-based dashboards. The Google-Telangana smart mobility partnership announced in 2023 further strengthens this ecosystem, enabling predictive routing and ETA analytics that can be paired with C-V2X platforms for real-time decision-making (The Hindu, 2025; Deccan Chronicle, 2025; Wake Up Telangana, 2025).

6.1.5. Key Enablers at a Glance

Table 6: Overview of Key Enablers for Implementing C-V2X in Hyderabad

Dimension	Status
5G Coverage	>95% RSRP (Airtel, Jio, BSNL)
Smart Traffic Junctions	400+ ATCS-enabled signals
ICCC Integration	Real-time traffic + emergency feeds
National Research Asset	TiHAN @ IIT-Hyderabad: C-V2X + AV simulation
Tech Collaboration	Google-Telangana Smart Mobility Lab (ICCC layer)

6.2. Integrating C-V2X into Hyderabad's Transport Ecosystem

Hyderabad's digital infrastructure presents a unique opportunity to integrate Cellular Vehicle-to-Everything (C-V2X) into its urban transport ecosystem - particularly to enhance emergency vehicle prioritization (EVP), improve road safety, and enable real-time signal optimization. This section outlines the technical architecture, operational workflows, and cybersecurity considerations for deploying end-to-end C-V2X systems in the city.

6.2.1. End-to-End Architecture

C-V2X enables direct and network-based communication between emergency vehicles, roadside infrastructure, and central traffic control systems. The architecture proposed for Hyderabad integrates:

Table 7: End-to-End Architecture of C-V2X in Hyderabad

Component	Function
OBUs (On-Board Units)	Installed in ambulances; transmit real-time location and ETA to infrastructure
RSUs (Roadside Units)	Installed at intersections; receive data from OBUs and coordinate with ATCS
ICCC Middleware	Processes incoming EVP requests, verifies ETA vs congestion, and preempts signals
MEC (Multi-access Edge Computing) Servers	Hosts low-latency signal optimization logic at the network edge
ICCC (GHMC/ HTRIMS)	Central control layer integrating RSU data and dispatch instructions
Dispatch Centers (EMRI)	Share route information with ICCC for signal prioritization

This setup enables real-time signal overrides as ambulances approach intersections, reducing manual dependency and improving consistency.

6.2.2. Signal Prioritization Logic

The system operates on a predictive logic stack that includes:

1. ETA Calculation: Real-time GPS data from OBUs combined with traffic flow data from RSUs
2. Congestion Heuristics: Dynamic evaluation of intersection load (SPaT/MAP messages)
3. Priority Determination: Only vehicles with emergency classification + ETA < 3 minutes at next junction are prioritized
4. Dynamic Signal Override: Command sent to adaptive signal controller 15-30 seconds before vehicle arrival

This ensures context-aware signal preemption, avoiding undue traffic disruption while maximizing emergency response benefits.

6.2.3. Backend Integration with ICCC

Hyderabad's ICCC, which already ingests feeds from traffic sensors, CCTV cameras, and municipal GPS vehicles, will act as the cloud-based command node. Key integration steps include:

1. APIs from EMRI's ambulance tracking system linked to ICCC dashboards
2. Interfacing RSUs with HTRIMS adaptive controllers for override signal execution
3. Redundant communication via both PC5 (direct short-range) and Uu (cellular 5G) channels
4. Audit trails for each override logged via ICCC for accountability and ML-based optimization

6.2.4. MEC and OTA (Over-the-Air) Updates

The system architecture leverages Multi-access Edge Computing (MEC) nodes hosted at telecom base stations to:

1. Host signal override models and routing algorithms locally
2. Minimize latency (~10-20 ms round trip)
3. Reduce ICCC cloud dependency for critical decisions

Firmware updates for RSUs and OBUs will be deployed using FOTA (Firmware Over-the-Air) protocols to ensure regular upgrades and security patching without downtime.

6.2.5. Cybersecurity and Privacy-by-Design

C-V2X systems handle mission-critical and personally identifiable information. Hyderabad's design must comply with:

1. DPDP Act (2023) principles of purpose limitation and data minimization (Digital Personal Data Protection Act, 2023)
2. ISO 26262 ASIL-B for functional safety in vehicular systems (ISO 26262, 2018)
3. TLS encryption of V2X messages (BTP and MAP/SPaT) (5GAA, 2021)
4. Tamper-resistant OBUs and RSUs to prevent spoofing of emergency priority requests (ETSI TS 103 097, 2020)
5. Role-based access control (RBAC) at ICCC for signal override commands (NIST SP 800-162, 2004)

6.3. Infrastructure and Investment Requirements

Successfully deploying C-V2X technology across Hyderabad requires a carefully phased infrastructure buildout, appropriate cost estimation, and sustainable financing models. This section outlines the physical components, estimated capital expenditure (CAPEX), and potential operating models for city-wide implementation.

6.3.1. Core Infrastructure Components

Table 8: Core Infrastructure Components of C-V2X in Hyderabad

Component	Description
RSUs (Roadside Units)	V2X communication hardware installed at intersections. Interfaces with traffic signals and OBUs.
OBUs (On-Board Units)	Installed in ambulances. Transmit live data (GPS, ETA, vehicle status) to RSUs and backend systems.
MEC (Multi-access Edge Computing) Servers	Edge nodes hosted by telecom providers to run latency-sensitive applications (e.g., signal preemption logic).
AI Middleware	Software layer at ICCC to evaluate routing decisions, ETA estimation, and prioritization logic.
Firmware & OTA (Over-The-Air) Systems	Ensure secure, upgradable communication protocols between all components.

6.3.2. Cost Estimates

Table 9: Infrastructure Cost Breakdown for C-V2X Deployment in Hyderabad

Item	Unit Cost Estimate	Deployment Volume	Total Estimated Cost
RSUs	₹5.5 - 6 lakh per unit	~800 intersections	₹44 - 48 crore
OBUs for ambulances	₹30,000 - ₹50,000	~1,200 vehicles (EMRI fleet + city hospitals)	₹4 - 6 crore
AI Middleware & MEC	Lump sum (platform + infra)	5 - 10 edge zones + ICCC	₹5 - 7 crore
Training, red-teaming, audits	₹5 - 10 lakh per module	15 - 20 modules (covering training batches, test events, and audit rounds)	₹1.5 - 2 crore
Total Estimate	**-**	**-**	**₹54.5 - 63 crore**

Note: Costs reflect global benchmarks adapted to India's procurement trends (2024-25) (Towards Automotive, n.d.). May vary by exchange rates, vendor, and scale. Further, **the total investment remains under 1% of GHMC's 3-year smart mobility budget, making it a cost-effective, high-impact initiative**. For economic rationale and funding pathways, see Table 16.

6.3.3. CAPEX vs OPEX Considerations

Table 10: Brief Comparison of CAPEX vs. OPEX Models for Implementing C-V2X in Hyderabad

CAPEX Model	OPEX Model
Upfront investment from GHMC/state	Telecom or private partner hosts infrastructure and charges per use or subscription
One-time hardware + deployment cost	Cloud-based RSU/OBU data services charged monthly
Suitable for public grants, budgeted rollout	Suitable for hybrid PPPs and recurring revenue models

6.3.4. Public-Private Partnership (PPP) Potential

The system is well-suited to a PPP deployment model, especially for:

1. RSU and MEC infrastructure, hosted and maintained by telcos.
2. OBU installations, bundled with ambulance retrofitting contracts.
3. AI middleware, offered by Indian startups under an outcomes-based contract.

4. Alignment with Make in India for domestic hardware and firmware vendors.

6.4. Stakeholder Roles and Institutional Framework

Implementing C-V2X technology at city scale requires clear delineation of stakeholder responsibilities, robust inter-agency coordination, and policy support at both state and national levels. Hyderabad, with its active municipal institutions, emergency services, and research ecosystem, is well positioned to orchestrate a multi-stakeholder governance model for C-V2X-enabled emergency vehicle prioritization (EVP).

6.4.1. Key Stakeholders and Their Roles

Table 11: Roles of Key Stakeholders in Hyderabad's Governance of C-V2X-enabled Emergency Vehicle Prioritization

Stakeholder	Primary Roles and Responsibilities
GHMC (Greater Hyderabad Municipal Corporation)	Owns traffic infrastructure, junctions, and adaptive signal systems. Responsible for installing RSUs, coordinating with ICCC, and long-term maintenance.
Hyderabad Traffic Police	Operates signal control; defines Standard Operating Procedures (SOPs) for signal overrides and emergency preemption; ensures on-ground enforcement.
EMRI 108 & Telangana Health Department	Provides ambulance fleet and real-time dispatch data; enables OBU installation; integrates emergency medical response workflows with ICCC.
IIT-Hyderabad / TiHAN Foundation	Offers national R&D capacity, V2X stack testing, red-teaming for cybersecurity, and reinforcement learning (RL) signal scheduling models.
Telecom Operators (Airtel, Jio, BSNL)	Ensure robust 5G coverage; host MEC nodes; enable FOTA updates and secure V2X communication.
ICCC (Integrated Command & Control Centre)	Acts as the digital brain of the system, integrating feeds from dispatch centers, RSUs, and traffic networks for real-time decision-making.
MoHUA, MoRTH, MeitY (Government of India)	Provide policy support, spectrum clearance, and funding for V2X-enabled ITS infrastructure. Can designate Hyderabad as a national C-V2X lighthouse city.
ITS India Forum & OMI Foundation	Conveners and knowledge partners for C-V2X scale-up. Provide technical advisory, policy advocacy, global benchmarking, and capacity-building support. Lead stakeholder consultations, white papers, and evaluation frameworks.

6.4.2. Inter-agency Workflow Snapshot

1. **Dispatch Event Initiation:** EMRI 108 flags an emergency call → ETA & routing data shared with ICCC via secure API.
2. **ICCC Orchestration:** ICCC forwards preemption request to RSUs and traffic police → verifies hospital proximity and congestion level.
3. **Signal Override Execution:** RSUs initiate green-light window based on ETA → ATCS controllers adjust phases → Traffic Police monitor override completion.
4. **Feedback Loop:** ICCC logs success metrics (delay reduction, signal compliance) → TiHAN/ICCC monitor data drift and model performance.

6.4.3. Suggested Institutional Mechanism

Table 12: Proposed Institional Mechanism for Implementing C-V2X-enabled Emergency Vehicle Prioritization in Hyderabad

Function	Proposed Mechanism
Governance	City-level C-V2X Coordination Cell under GHMC
Technical Evaluation	IIT-Hyderabad & TiHAN-led protocol and model audits
Vendor Onboarding	Tendered via Smart City SPV or State ITS Cell
Data Governance	ICCC/MeitY-approved Data Sharing and Protection SOPs
SOP Enforcement	Joint operating procedure by GHMC + Police + EMRI
Strategy & Capacity Building	ITS India Forum & OMI Foundation to lead training, knowledge transfer, and evaluation frameworks

Case for Formal MOU Framework:

A tripartite MoU among GHMC, Hyderabad Police, and EMRI 108 - enabled through state government facilitation - can institutionalize roles for pilot and scale phases. Parallel MoUs with IIT-H and telecom operators can codify technical, cybersecurity, and FOTA responsibilities.

Role of Ecosystem Enablers:

The successful deployment of C-V2X technologies also depends on robust ecosystem stewardship. Organizations such as the ITS India Forum and the OMI Foundation are instrumental in bridging the gap between government, industry, and academia. As leading conveners and research institutions, they provide the strategic frameworks, policy guidance, and knowledge sharing needed to scale EVP solutions across Indian cities. Their role includes cross-sector convening, global benchmarking, implementation support, and open knowledge dissemination. This report, jointly developed by these two bodies, represents a first step in anchoring Hyderabad as a national leader in C-V2X-driven emergency mobility.

6.5. Pilot Corridor Selection: Methodology and Rationale

Selecting the right pilot corridor is crucial to demonstrating the value of C-V2X technologies in improving emergency response outcomes. The chosen corridor in Hyderabad reflects a strategic intersection of high-impact variables - medical urgency, urban congestion, network readiness, and institutional feasibility.

6.5.1. Selected Pilot Corridor

1. Apollo Hospital (Jubilee Hills) ➔ AIG Hospitals (Gachibowli) ➔ Continental Hospitals (Financial District)
2. Total Length: Approx. 9.5 km
3. Estimated Peak-Hour Travel Time: 22-28 minutes
4. Expected Reduction with EVP & C-V2X: ≥25% (6-8 minutes)

Note: The projected 25% reduction in emergency vehicle travel time on the Apollo-AIG-Continental corridor is grounded in baseline traffic data, international benchmarks, and preliminary microsimulations[3]. Current peak-hour travel times range between 22-28 minutes, largely due to congestion and signal delays. With C-V2X-enabled EVP - leveraging adaptive traffic signals, green preemption, and low-latency OBU-RSU communication - travel time is expected to reduce by 6-8 minutes, improving patient outcomes and system efficiency. See Annexure 1 for details, including assumptions based on global benchmarks.

6.5.2. Corridor Highlights

Table 13: Highlights of the Selected Pilot Corridor for Implementing C-V2X-enabled EVP in Hyderabad

Attribute	Details
High Hospital Density	Three multi-specialty, tertiary-care hospitals within a ~10 km stretch
Emergency Call Volume	EMRI 108 records high demand from surrounding residential and IT clusters
Congested Arterial Roads	Jubilee Hills - Banjara Hills - Gachibowli corridor with sub-20 km/h peak speeds ➢ PS probe data from 2024 reveals peak-hour speeds averaging just 17 km/h between Jubilee Check-post and Gachibowli X-Road, highlighting the corridor's need for signal prioritization (Google Mobility Data, 2024).
Upgraded Signal Infra	Phase-IV adaptive traffic control system (ATCS) already deployed

[3] Based on global C-V2X pilots (e.g., Wuxi, Amsterdam), such systems have shown 25-47% reduction in emergency response time.

	➢ 70% of the 17 signalized junctions on this route have already been upgraded under GHMC's ATCS Phase-IV program, enabling rapid RSU deployment and ICCC integration (The Times of India, 2024).
5G Network Coverage	Airtel & Jio offer strong 5G RSRP and Qality of Service (QoS) along most of the corridor ➢ All three major telcos - Airtel, Jio, and BSNL - report >95% RSRP ≥ -95 dBm along this arterial corridor, making it ideal for low-latency, high-reliability V2X communication (nPerf, 2025).
ICCC Integration Feasibility	All junctions connected to GHMC's ICCC and pre-cleared for data integration

6.5.3. Selection Methodology

The corridor was selected based on a multi-criteria evaluation:

1. Medical Criticality
    a. Hospitals with ICU and trauma facilities
    b. Ambulance arrival time impact on mortality/morbidity outcomes
2. Traffic and Infrastructure Readiness
    a. High congestion indices (Google Maps, EMRI delay logs, GHMC signal data)
    b. Adaptive signal systems already in place (for smoother RSU integration)
3. Technological Enablers
    a. 5G availability (RSRP > -95 dBm along 95% of the corridor)
    b. ICCC signal override compatibility and data API readiness
4. Institutional Willingness
    a. Stakeholder alignment among GHMC, Hyderabad Traffic Police, EMRI 108, and hospital managements
    b. Support from Telangana's Emerging Technologies Wing, local urban mobility planning units (GHMC's planning division), etc.
5. Replicability Potential
    a. Corridor represents a microcosm of Hyderabad's broader urban layout
    b. Learnings can be scaled to similar arterial routes across the city and state

6.5.4. Rationale for Phased Implementation

Starting with a medically significant and infrastructure-ready corridor helps build proof of concept. This approach allows for:

1. Controlled A/B testing with and without EVP signal override
2. Evaluation of latency, accuracy, and traffic disruption metrics
3. Early citizen awareness and stakeholder confidence
4. Iterative model calibration using real-world telemetry and ETA data

6.6. Scalability and Roadmap for City-wide Rollout

Hyderabad's pilot C-V2X corridor serves as a foundational proof of concept. However, achieving transformational impact on emergency response, congestion reduction, and traffic efficiency requires a city-wide deployment strategy. This section, therefore, outlines the phased roadmap, institutional enablers, integration pathways, and replication models to scale C-V2X infrastructure across Hyderabad and beyond.

6.6.1. Vision 2027

100% signalized intersections in Hyderabad equipped with C-V2X-compatible EVP capabilities, ensuring <8-minute response times for 95% of critical emergency calls.

6.6.2. Phased Rollout Strategy

Table 14: Phased Implementation Strategy of C-V2X-enabled EVP in Telangana

Phase	Timeframe	Target Coverage	Key Focus Areas
Phase I	2025-26	Pilot corridor (Apollo - AIG - Continental) + 2 new corridors	Real-world testing, public awareness, feedback
Phase II	2026-27	All hospital catchments + 100 additional intersections	Multi-agency SOPs, OBU retrofitting, signal APIs
Phase III	2027 onwards	100% ATCS-covered junctions (GHMC-wide)	AI-based optimization, signal harmonization

6.6.3. Integration with Other Smart Mobility Initiatives

1. Hyderabad ICCC: Central control point for signal coordination, data analysis, and emergency alerts.
2. MoHFW-EMRI Integration: Direct API hooks into ambulance dispatch systems for real-time ETA-based routing.
3. Google/Telangana Signal Optimization Partnership: Can be extended to integrate C-V2X alerts and dynamic signal adjustments.
4. ATCS Phase-V Upgrades: Ensure new signal installations are RSU-ready and support MAP/SPaT messages.

6.6.4. Risk Mitigation and Interoperability Planning

Table 15: Risk Mitigation Strategy for Scaling C-V2X-enabled EVP in Telangana

Risk	Mitigation Strategy
Legacy signal controllers at key junctions	Retrofit kits or controller replacements under GHMC ATCS roadmap

OBU/RSU interoperability issues	Adopt DSRC+PC5 fallback layers; align with ISO/SAE standards
Data silos between agencies	Unified data model and shared SOPs under ICCC governance
Vendor lock-in and integration challenges	Open procurement frameworks with API compliance requirements

6.6.5. Replication Across Telangana Cities

Following successful deployment in Hyderabad, the model will be adapted to:

1. Warangal: Phase-II Smart City with strong medical institutions
2. Nizamabad: Active EMRI-108 network and ATCS coverage
3. Khammam and Karimnagar: Strong 5G network presence and civic digitalization projects

OMI Foundation and ITS India Forum can support pilot evaluations and readiness assessments in each city, helping Telangana become a national leader in emergency mobility.

6.7. CRISP-ML(Q) Implementation Framework

To deploy a data-driven and responsive C-V2X ecosystem at scale, the state must go beyond hardware installation and focus on robust machine learning pipelines, real-time decision-making, and quality assurance. The CRISP-ML(Q) (Cross-Industry Standard Process for Machine Learning with a Quality Layer) framework ensures transparency, scalability, and performance across each lifecycle stage of the C-V2X implementation.

6.7.1. Business Understanding

1. Goal: Ensure <8-minute response time for 95% of critical emergency calls across GHMC limits by 2027.
2. Value Proposition: Lives saved, public trust, congestion relief, and healthcare system efficiency.

6.7.2. Data Collection

1. Sources:
    a. EMRI 108 logs: Emergency call locations, timestamps, ETA, dispatch paths; Duration: 12 months.
    b. GHMC traffic sensors: Vehicle density, junction dwell times.
    c. 5G telco data: Signal strength, coverage, and Quality of Service (QoS).
    d. ICCC logs: Signal override events, public compliance.
    e. Onboard device data: OBU sensor feedback, speed telemetry.
2. Privacy Compliance: All personal identifiers removed; DPDP-compliant architecture.

6.7.3. Data Preparation

1. Tasks:
    a. Anonymize EMRI and vehicle-level GPS traces.
    b. Harmonize time formats and align geospatial coordinates.
    c. Merge SPaT (Signal Phase and Timing) and MAP messages from RSUs.
    d. Filter incomplete or outlier events (e.g., cancelled calls or invalid GPS).
    e. Aggregate SPaT/MAP signals, traffic sensor readings, and OBU telemetry into 100 ms feature windows before model training.
2. Outcome: A clean, stitched dataset ready for model training.

6.7.4. Modeling

1. Techniques:
    a. ETA Prediction using XGBoost/ LightGBM.
    b. Reinforcement Learning-based Signal Scheduler for green-wave optimization.
    c. Priority Score Computation for each ambulance based on urgency and congestion.
2. Simulation Environment: TiHAN's V2X emulation platform for pre-deployment testing.

6.7.5. Evaluation

1. KPIs:
    a. Mean Absolute Error (MAE) of ETA predictions ≤ 15 seconds.
    b. Emergency vehicle clearance rate ≥ 90% at targeted junctions.
    c. Non-priority traffic disruption ≤ 5%.
2. Method: A/B testing at junction pairs with vs. without active EVP logic.

6.7.6. Deployment

1. Tooling:
    a. Helm charts for container orchestration.
    b. Deployed on MEC (Multi-access Edge Computing) nodes to reduce latency.
    c. Real-time override commands pushed via secure OTA (Over-the-Air) updates to RSUs.
2. Device Sync: OBUs regularly updated with new routing models and congestion maps.

6.7.7. System Monitoring, Drift Detection, and Cybersecurity Readiness

1. As India scales its C-V2X deployments, robust cybersecurity becomes critical. Recent advances in **machine learning-based intrusion detection** for V2X networks offer promising safeguards against spoofing and unauthorised signal priority requests. Techniques such as cryptographic protocol validation, anomaly detection using real-time datasets, and zero-trust architectures are recommended (Venkatasamy et al., 2024; NIST, 2024). India should also adopt **interoperability testing protocols** like those proposed by NIST TN 2315 to ensure OBU-RSU compatibility across vendors and geographies.

6.7.7. Monitoring & Maintenance

1. Health Checks:
    a. Real-time feature drift detection.
    b. Calculate PSI across model input features; retrain when PSI > 0.2 to maintain prediction accuracy.
    c. Alert if ambulance priority fails to register at any RSU.
2. Uptime Goals:
    a. Mean Time to Recovery (MTTR) < 5 minutes for signal override failures.
    b. 99.5% uptime SLA for signal-edge-cloud communication.

6.7.8. Quality Layer

1. Standards:
    a. ISO 26262 (ASIL-B) for functional safety in intelligent transport.
    b. DPDP 2023 compliance for personal data governance.
    c. End-to-end cybersecurity audits (NIST RBAC / ABAC, OWASP IoT Top 10).
2. Auditability:
    a. Automated logs of override events, manual interventions, and fallbacks.

6.8. Budget Snapshot and Economic Rationale

Scaling C-V2X infrastructure citywide across Hyderabad involves significant capital investment, but the social and economic returns - especially in terms of lives saved, congestion reduction, and system efficiency - make a compelling case for deployment. This chapter outlines the estimated costs, potential return on investment (RoI), and viable funding strategies.

6.8.1. Capital Expenditure (CAPEX) Estimate

Table 16: Economic Summary and Investment Snapshot for City-wide C-V2X

Component	Estimated Cost
RSUs (800 units)	₹44 - 48 crore
OBUs (1,200 units)	₹4 - 6 crore
Middleware, MEC, OTA stack	₹5 - 7 crore
Training, red-teaming, audits	₹1.5 - 2 crore
Total Estimated CAPEX	**₹54.5 - 63 crore**

Note: Costs reflect global benchmarks adapted to India's procurement trends (2024-25). May vary by exchange rates, vendor, and scale. For a detailed cost breakdown by deployment volume and hardware category, see Table 9.

6.8.2. Return on Investment (RoI)

1. Lives Saved
    a. Target: ~1,000 critical cases/year benefit from faster response
    b. DALY Value (ICMR/WHO): ₹1.5 crore/life saved
    c. Annual Societal Return: ₹1,500 crore+
2. Congestion & Fuel Savings
    a. Green-wave spillovers reduce delays for non-emergency vehicles
    b. Conservative estimate: ₹60-75 crore/year in time & fuel saved
3. Healthcare Outcome Improvements
    a. Reduced mortality & complications in trauma, stroke, cardiac cases
    b. Indirect benefit: ~₹200 crore/year across public and private hospitals
4. Public Trust and Reputation
    a. Civic trust in smart governance
    b. Use of indigenous, AI-based, scalable emergency tech

Note: Please see Annexure 2 for detailed assumptions and calculations.

6.8.3. Funding Options

Table 17: Strategic Funding Pathways for Scaling Emergency Mobility Infrastructure

Source	Desccription
GHMC Smart Mobility Budget	1% allocation suffices for citywide rollout
MoHUA Urban Innovation Challenge	For C-V2X as a replicable urban digital solution
Urban Mobility Programs of Multilateral Agencies	Hyderabad is a candidate city for urban resilience support from the World Bank, for instance
National Health Mission	To co-fund OBU deployment for EMRI 108 ambulances
PPP (Public-Private Partnership)	Vendors can co-invest in exchange for recurring analytics or O&M contracts
CSR & Philanthropy	For patient-centric digital health infrastructure

6.8.4. Payback Period

1. <4 years, assuming conservative monetization of congestion and healthcare gains alone.
2. Benefits accrue annually while infrastructure remains operational for 8-10 years.

6.8.5. Public-Private Partnership (PPP)

Beyond capital outlay, sustainable scaling will require **public-private partnership (PPP) models**. Telecom operators, hospital chains, and city-level SPVs can co-invest in RSUs, edge compute infrastructure, and maintenance contracts, supported by Viability Gap Funding (VGF) where appropriate. To justify public investment, health impact audits - estimating DALYs saved and emergency response acceleration - must be institutionalized through annual ROI scorecards.

6.9. Potential Benefits

Real-world pilots across Europe, China, and the United States demonstrate **25-47% reductions in emergency response times** when Emergency Vehicle Priority (EVP) is implemented via C-V2X systems. Signal simulation models tailored to Hyderabad's traffic flow suggest a **25-30% reduction in travel time** along major emergency corridors.

With **over 95% 5G coverage** and **Adaptive Traffic Control System (ATCS) readiness** at most junctions, Hyderabad is uniquely positioned to lead India's C-V2X adoption journey. A citywide EVP deployment under the proposed **C-V2X Strategy 2030** can generate the following benefits:

1. **Response Time Gains**: Up to **47% faster emergency response** in high-priority zones such as hospital corridors and accident hotspots.
2. **Health & Societal Impact**: An estimated **₹1,500 crore per year in lives-saved value**, based on reduced mortality and DALY gains in trauma, cardiac, and stroke care.
3. **Environmental Benefits**: **8-15% lower fuel usage** and **10-20% reduction in emissions** due to smoother traffic flows and signal synchronization.
4. **Congestion Relief**: Non-emergency traffic benefits from green-wave spillovers, improving average vehicle speeds and reducing idle times.
5. **Return on Investment (RoI)**: With a projected payback period of **under 4 years**, the initiative demonstrates strong economic and policy rationale.

These benefits - enabled by a connected ecosystem of vehicles, infrastructure, and cloud intelligence - position Hyderabad to become **India's first live testbed for national-scale C-V2X deployment**. A successful implementation will not only save lives and reduce congestion but also serve as a replicable blueprint for cities across India and the Global South.

7. Policy Recommendations for Telangana and India

To scale the benefits of Cellular Vehicle-to-Everything (C-V2X) technology and Emergency Vehicle Priority (EVP) across India, Telangana's leadership must be supported by a coherent set of national and state-level policy interventions. These recommendations are grounded in pilot learnings and international best practices.

7.1. C-V2X as a Public Health and Urban Resilience Strategy

India's C-V2X journey must move beyond viewing it as just a mobility upgrade. When deployed well, EVP and V2X technologies serve as:

1. **Public Health Enablers:** By reducing golden-hour loss in trauma and cardiac cases.
2. **Disaster Response Catalysts:** Enhancing route clearance for emergency vehicles during floods, earthquakes, or civic unrest.
3. **Climate Resilience Tools:** Optimizing signal timing and vehicle flows to cut idling and emissions.
4. **Digital Governance Accelerators:** Making ICCCs more than passive data centers - enabling real-time urban coordination.

7.2. State-Level Policy Recommendations (Telangana)

1. **Adopt a Statewide C-V2X Vision Plan**
    a. Publish a "C-V2X Telangana 2030" roadmap integrating emergency mobility, smart traffic management, and multimodal signal prioritization.
    b. Align this with the state's AI, 5G, and Smart Cities strategies.
2. **Fast-Track RSU Installation and Spectrum Clearance**
    a. Establish a single-window approval mechanism for installing RSUs on traffic infrastructure, with coordination between GHMC, Hyderabad Police, and Department of Telecommunications.
3. **Retrofitting Ambulance Fleets with OBUs**
    a. Use state transport and health department budgets to incentivize OBU adoption in both EMRI 108 and private hospital fleets.
    b. Integrate with emergency response SOPs.
4. **Launch Telangana Mobility Sandbox for V2X Startups**
    a. Facilitate real-world testing of Indian startups' OBUs, RSUs, and AI signal algorithms.
    b. Use testbeds like TiHAN (IIT-H) and live corridors like Jubilee Hills - Gachibowli.
5. **Mandate Signal Controller Interoperability**
    a. Update smart signal procurement standards to mandate support for V2X/EVP protocols, including SPaT/MAP broadcasting.

7.2. National Policy Recommendations (India)

To unlock the full potential of connected emergency mobility, India must adopt a whole-of-government approach that goes beyond individual pilots. The following **roadmap outlines priority interventions grouped into five national pillars**.

1. **National Leadership and Institutional Frameworks**
    a. **Establish a National EVP Task Force:** Constitute a joint task force led by MoHUA, MoRTH, and MeitY to define national standards for OBUs, RSUs, and interoperable signal controllers, and to publish rollout timelines, certification protocols, and evaluation templates.
    b. **Develop a City Readiness Framework for V2X:** Introduce a phased certification system for cities (e.g., EVP-Ready, C-V2X Pilot-Capable, Full Interoperability Compliant) to guide central/state funding and program prioritization.
    c. **India Urban V2X Sandbox:** A national sandbox under **MeitY, MoHUA, and MoRTH** can allow cities, telcos, OEMs, and startups to test interoperable C-V2X deployments with real-time APIs, open data models, and privacy-preserving frameworks. Hyderabad, Pune, Bhopal, etc. could serve as founding nodes.
    d. **Institutionalize Health Impact Audits:** Mandate annual evaluations by health and transport departments to measure DALYs saved, golden-hour response improvements, and congestion reduction across deployed corridors.
2. **Infrastructure and Technology Modernization**
    a. **Modernize Traffic Signal Infrastructure:** Retrofit at least 100 Tier-2 and Tier-3 cities with RSU-compatible adaptive traffic signal controllers by 2028, using MoRTH urban transport funds, and other funding sources.
    b. **Standardize ICCC Middleware for EVP:** Fund software upgrades to enable Integrated Command and Control Centres (ICCCs) to process real-time C-V2X messages and activate green-wave logic.
    c. **Create a National C-V2X Protocol Stack:** Develop an open, secure C-V2X protocol through CDAC, NIC, and BIS, with accompanying certification labs for hardware/software quality assurance.
    d. **Mandate Public OBU Standards:** Standardize open OBUs for ambulances, fire brigades, and police fleets to ensure interoperability across states and vendors.
3. **Fleet and Corridor Readiness**
    a. **Mandate OBU Installation in Emergency Fleets:** Require all EMRI-108 ambulances, and others to be equipped with OBUs by 2027 to enable signal pre-emption and routing visibility.
    b. Extend **OBU mandates** to include **fire brigades, disaster relief fleets, and police vans** for universal emergency signal clearance.
    c. **Expand to High-Need Corridors:** Roll out EVP and C-V2X systems across high-risk rural zones, industrial corridors, NHs, and tribal belts, where delays in emergency response are most fatal.

   d. **Move Beyond R&D to Real-World Corridors:** Prioritize urgent deployments in trauma care zones, metro-affected areas, and high-congestion industrial districts to demonstrate real-world impact.

4. **Financing and Innovation Ecosystem**
   a. **Launch a Pilot-to-Scale Cities Program:** Provide capital and technical assistance to cities like Pune, Lucknow, and Coimbatore, etc. with proven ICCC pilots but limited scale-up budgets. Include outcomes-based PPP frameworks involving SPVs, traffic police, and private partners.
   b. **Introduce Make-in-India Incentives for V2X Hardware:** Expand PLI-style incentives for OBUs, RSUs, MEC devices, and edge-compute chips aligned with the IndiaAI and India Semiconductor Mission.
   c. **Tie C-V2X Rollout to Health and Safety Missions:** Align C-V2X investments with the National Health Mission, NHA's emergency care plans, and MoRTH's road safety programs to access cross-sectoral funding.
5. **Data, Governance, and Public Engagement**
   a. **Establish a National Mobility Data Exchange:** Use platforms like IUDX to enable secure, anonymized exchange of real-time emergency telemetry, signal timing, and congestion maps to guide evidence-based mobility decisions.
   b. **Run Public Sensitization Campaigns:** Launch national and city-level campaigns to promote ambulance right-of-way, lane discipline, and citizen understanding of EVP and green-wave logic.
   c. **Encourage Data-Driven Planning at the City Level:** Ensure cities use C-V2X and ICCC data for congestion heatmaps, predictive dispatch planning, and intersection prioritization.

8. Conclusion: A New Chapter in Emergency Mobility Leadership

Hyderabad has the infrastructure, institutional capacity, and innovation ecosystem to become the **national torchbearer** for C-V2X deployment in India. With over **95% 5G coverage**, **a growing network of smart signals**, and **TiHAN's cutting-edge autonomous mobility testbed**, the city is well-positioned to operationalize life-saving use cases like **emergency vehicle prioritization**, **collision avoidance**, and **real-time signal optimization**.

However, realizing the full potential of C-V2X requires **coordinated action at multiple levels of government**:

- ➢ At the **city and state level**, Greater Hyderabad Municipal Corporation (GHMC), Hyderabad Police, and Telangana's Emerging Technologies Wing must co-own a shared vision for safe and smart mobility. Public Health, Transport, and Urban Development Departments need to align investments to retrofit ambulance fleets, build RSU networks, and enable ICCC integration.
- ➢ At the **national level**, Ministries such as MoHUA, MeitY, MoRTH, DoT, and MoHFW must converge through a **National C-V2X Mission**. A whole-of-government strategy is essential to drive standardization, fund infrastructure upgrades, and create procurement and certification pathways for indigenous V2X solutions.

C-V2X is not just a technological upgrade - it is a **moral imperative**. In a country where thousands of lives are lost each year due to delayed emergency response, traffic mismanagement, and fragmented urban systems, **digital infrastructure can become life infrastructure**.

A successful Hyderabad deployment can serve as a **template for Indian cities**, demonstrating how advanced mobility technology, when adapted for Indian constraints and governance models, can deliver **inclusive, secure, and high-impact public outcomes**.

From this point forward, the roadmap is clear. What is needed is **political will**, **policy clarity**, and **public-private coordination** to take C-V2X from pilot to platform, from corridor to city, and ultimately, from India's cities to the world.

Annexure 1: Justification for ≥25% Emergency Response Time Reduction

This section supports the estimated 25% travel time savings (~6-8 minutes) projected for Hyderabad's pilot corridor between Apollo Hospital (Jubilee Hills) and Continental Hospitals (Financial District). The assumption draws from international deployments of C-V2X and Emergency Vehicle Priority (EVP) systems, peer-reviewed evaluations, and technology performance benchmarks.

1.1. Summary of Time Reduction Estimate

Corridor Details	Value
Pilot Corridor Length	~9.5 km
Baseline Peak-Hour Travel Time	22-28 minutes (GPS probe data)
Projected Time with C-V2X + EVP	16-20 minutes
Expected Time Reduction	≥25% (6-8 minutes)
Key Interventions Enabling Reduction	Real-time signal preemption, low-latency communication, predictive routing

1.2. Supporting References and Global Benchmarks

Source	Evidence Summary
5GAA (2020)	Demonstrates 20-40% time savings via proactive signal preemption and V2I coordination in urban settings
USDOT (2024)	Reports real-world deployments where average EMS response time reduced by 25-30% with V2X
ITS America (2024)	Highlights deployments in Michigan and Florida with >6 minutes saved on congested arterials using RSUs and OBUs

1.3. Notes for Policymakers and Engineers

Time savings are amplified on corridors with:

1. multiple upgraded ATCS intersections
2. high emergency call volume
3. consistent 5G coverage and ICCC integration

Hyderabad's pilot corridor aligns with these prerequisites, justifying the ≥25% time-saving projection. Real-world measurement and A/B testing post-implementation are recommended to validate and refine performance metrics.

Annexure 2: Return on Investment (RoI) - Assumptions and Calculations

2.2. Lives Saved

- Assumption: Approximately 1,000 critical emergency cases annually could benefit from EVP-enabled response.
- Valuation Metric: Disability-Adjusted Life Year (DALY) Value for India = ₹1.5 crore/life (Indian State-Level Disease Burden Initiative, n.d.; WHO, n.d.).
- Annual Estimated Return:

$$1,000\ lives/year \times ₹1.5\ crore/life\ =\ ₹1,500\ crore/year$$

2.2. Congestion & Fuel Savings

- Real-world pilots suggest 8-15% fuel savings and up to 20% emissions reduction through signal synchronization and green-wave spillovers, thereby offering significant secondary benefits for urban climate targets (NITI Aayog, 2023; 5GAA, 2022).
- Assumption: Green-wave spillover effects reduce idling and delays for non-emergency vehicles (Rocky Mountain Institute, 2017; Petroleum Planning & Analysis Cell, 2021).
- Population Affected: 5% of daily commuters in GHMC (out of ~4 million).
- Time Savings: 4 minutes/day average across 250 working days/year.
- Valuation:

$$Time\ Value\ +\ Fuel\ Saving \approx ₹60\text{–}75\ crore/year$$

2.3. Healthcare Outcome Improvements

- Assumption: Faster ambulance arrival improves trauma/stroke/cardiac survival (Ministry of Health & Family Welfare, 2022).
- Benefit Calculation: Avoided complications, reduced ICU stay, faster recovery.
- Annual Indirect Savings:

$$₹200\ crore/year\ (aggregate\ savings\ across\ hospitals)$$

2.4. Public Trust and Reputation

- Qualitative Value: Increased civic satisfaction and faith in AI-led urban services (World Bank, 2022).
- Institutional Benefit: Readiness for World Bank or MoHUA smart mobility funding.

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About ITS India Forum

The **ITS India Forum** is a leading not-for-profit think tank dedicated to advancing Intelligent Transportation Systems (ITS) in India. ITS India Forum promotes safety, affordability, and inclusivity in transportation in alignment with the Viksit Bharat Vision 2047. The Forum serves as a collaborative platform for industry professionals, government agencies, and academic institutions working together to shape the future of transportation in the country.

About OMI Foundation Trust

OMI Foundation Trust is a new-age policy research and social innovation think tank operating at the intersection of mobility innovation, governance, and public good. Mobility is a cornerstone of inclusive growth providing the necessary medium and opportunities for every citizen to unlock their true potential. OMI Foundation endeavours to play a small but impactful role in ushering meaningful change as cities move towards sustainable, resilient, and equitable mobility systems, which meet the needs of not just today or tomorrow, but the day after.

OMI Foundation houses four interconnected centres that conduct cutting-edge evidence-based policy research on all things mobility:

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Suggested Citation

ITS India Forum and OMI Foundation. (2025, November). *Priority By Design: Advancing Emergency Mobility with Cellular Vehicle-to-Everything (C-V2X) in Telangana and India.* Futures Report.

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