Solution Document

Secure AI-Powered Mobility & Crowd Safety for the FIFA World Cup 26

Philadelphia Regional Travel

2025 Transportation Technology Tournament (TTT)

UNIVERSITY of WASHINGTON

Team Member	Sruangsaeng Chaikasetsin	Ph.D. Student
	Mehrdad Nasri	
	Ollie Wiesner	
	Nutvara Jantarathaneewat	
	Shucheng Zhang	
	Justin Belk	Master's Degree Student
	Peter Yu	
Academic Advisor	Yinhai Wang, PhD, PE, Dist.M.ASCE, F. IEEE, F.ITE	Professor and Director, Smart Transportation Applications & Research at the University of Wahington, PacTrans, TTAP, and Chair for TRB AED50 AI and Advanced Computing Applications Committee
Agency Advisor	David L. Adams	Pennsylvania Department of Transportation
	Elizabeth Falcone	New Jersey Department of Transportation
Propose for	2025 Transportation Technology Tournament, National Operations Center of Excellence (NOCoE)	

Abstract
The FIFA World Cup 26 presents unprecedented transportation challenges across the Eastern Region, with millions of international visitors traveling between three major venues (Lincoln Financial Field, MetLife Stadium, and Gillette Stadium) connected by a 283-mile I-95 corridor, creating complex mobility demands including potential same-day multi-venue attendance and severe cross-state congestion. Our proposed solution, Secure AI-Powered Mobility & Crowd Safety or SafeMove, addresses these challenges through an innovative AI-powered mobility management system that employs a three-layer architecture combining real-time data fusion, predictive analytics, and multi-agency coordination, leveraging cooperative perception through vehicle-to-everything (V2X) communications and LiDAR/camera sensors to detect crowd movements and safety hazards while using federated AI models to predict demand patterns and optimize traffic operations. Key innovations include edge AI units at critical intersections that detect vulnerable road users and broadcast real-time safety alerts, advanced analytics that forecast congestion patterns enabling proactive traffic signal adjustments, unified regional dashboards creating shared situational awareness across multiple state DOTs and transit operators, and an ADA-compliant multilingual SafeMove app providing integrated multimodal trip planning with live transit schedules and safety alerts. The solution directly addresses Transportation Systems Management & Operations (TSMO) principles by maximizing existing infrastructure efficiency rather than requiring costly capital expansion, enhances public safety through proactive crowd monitoring integrated with FEMA's IPAWS system, and ensures equitable access for international visitors and people with disabilities. Beyond the World Cup, SafeMove establishes a reusable framework for large-scale event management with permanent infrastructure upgrades including advanced signal controllers, V2X communications, and inter-agency data sharing protocols, positioning the Northeast Corridor as a leader in cooperative ITS deployment while demonstrating how emerging technologies can transform special event transportation management and build lasting institutional partnerships for future challenges.

Table of Contents

1 DESCRIPTION OF PROBLEM

As one of eleven U.S. host cities for the FIFA World Cup 26, Philadelphia will host six matches at Lincoln Financial Field between June 14 and July 4, 2026. Lincoln Financial Field (capacity 67,594 [1]), home of the Eagles, will also host eight FIFA Club World Cup 2025 matches. These mega-events will draw hundreds of thousands of visitors into South Philadelphia, stressing transportation networks. The proposed ITS-based solution will be piloted in Philadelphia, leveraging existing infrastructure (e.g., Changeable Message Sign (CMS), highway advisory radio, transit), mobile communications, and two-way traveler alerts to manage event traffic and parking. This light concept of operation (ConOps) describes operational needs, system components, scenarios, and deployment, guided by ARC-IT architecture concepts and TSMO principles, to ensure safe and efficient travel for residents and visitors during these events.

1.1 Problem Statement

North America will open its doors to an international audience for one of the most viewed global events: the FIFA World Cup 26. From June 11th to July 19th, millions of visitors will travel to 16 different cities to watch 48 teams play 80 matches. The matches will be spread across the United States, Mexico, and Canada, which will decrease infrastructure stresses, but not eliminate them.

In the Eastern Region, matches will be hosted at three adjacent locations: Philadelphia, PA; Foxborough, MA (Boston area); and East Rutherford, NJ (NYC area), with East Rutherford hosting the finals. Fans will likely expect to spontaneously travel by ground between the three cities using a variety of modes. In addition, there will be several days of concurrent matches in both Philadelphia and East Rutherford, 94 miles apart, and fans may try to view matches in both cities on the same day. This concept of operation involves developing a plan that leverages all modes of travel and communicates options to fans for travel between these various sites. Additionally, it will manage local travel at individual stadiums to ensure safety and efficiency.

Coordination between agencies responsible for operations will be essential to ensure travel throughout the region can continue. Meeting this challenge will require strong regional coordination, including information sharing between agencies and travelers, which includes conveying information on incidents, possible travel routes, modes, and congestion. An element of Transportation Demand Management (TDM), such as messaging to promote telework and flexible work hours to residents, will also be an essential part of meeting these varied challenges.

1.2 Study Area

The matches will be held at Lincoln Financial Field (Philadelphia, PA), MetLife Stadium (East Rutherford, NJ), and Gillette Stadium (Foxborough, MA) (**Figure 1**). Limited parking will likely be reserved for teams, FIFA, and the media, while fans would likely not be able to park or need to pre-reserve spots. The stadiums may also have privately managed parking lots nearby.

MetLife Stadium is has a capacity of 82,500 and the stadium expects over 1 million people to visit throughout the World Cup. It is outside NYC and not accessible by foot. There are various transit options, including regular bus service and special train service, which will be enhanced

with additional service during the event. While it is still being finalized, there will likely be designated parking facilities outside of the FIFA perimeter, with shuttle options to the stadium.

Gillette Stadium has a capacity of 64,628 it is approximately 25 miles outside of Boston. The stadium has a designated drop-off and pick-up location and a permanent weekday commuter rail service with ten weekdays round trips.

Lincoln Financial Field is located within the City of Philadelphia, so it is likely to have many people walking to access the stadium during match times. The stadium is also connected to SEPTA Regional Rail lines – the Broad Street Line to/from NRG Station provides access to the stadium. SEPTA also provides a frequent bus network, which may bring people directly from where they are staying to and from matches, if they are made aware of it.

Figure 1: *Stadiums from the host cities of Philadelphia, Foxborough, and East Rutherford*

To connect stadiums, attendees have several multimodal options. Lincoln Financial Field is 94 miles from MetLife Stadium, which is 189 miles from Gillette Stadium. All three stadiums are connected along a stretch of I-95. In addition, these locations are connected by several Greyhound, Megabus, FLiXBUS, and AMTRAK travel options. The large number of transit agencies and transportation organizations throughout this corridor highlight the need for regional coordination. Demand for travel between cities can be better anticipated once the schedule is announced, and these agencies can provide appropriate options.

1.3 Study Area Challenges

The proximity of NY/NJ and Philadelphia supports multi-game participation. It's currently unclear whether scheduling could allow visitors to attend two games in the two cities in one day – but that should be planned for by transportation agencies just in case. Congestion will be an issue no matter the preparation, but traveler information and demand management strategies can be used to reduce the issue. This could include making people aware of shared modes to lower the number of single occupancy vehicles on the roadway, and/or telling those who do drive when an incident or other disruption has occurred. Because people will be traveling across state lines, coordination between agencies responsible for operations will be essential, and can be enhanced

through existing ITS strategies such as information sharing and real-time monitoring and evaluation, leading to coordinated demand management.

1.4 Stakeholders

Stakeholders will be diverse and include the agencies hosting the event, such as FIFA, the Philadelphia Convention & Visitors Bureau, as well as stadium operators. Additionally, the transportation agencies will need to maintain constant communication to ensure the event goes smoothly. These include: transit operators, such as the Southeastern PA Transportation Authority (SEPTA), NJ Transit, NYC Metropolitan Transportation Authority (MTA), and Massachusetts Bay Transportation Authority (MBTA) as well as state and local DOTs: PA Department of Transportation (PennDOT), NJ Department of Transportation (NJDOT), NY State Department of Transportation (NYSDOT), City of Philadelphia, Port Authority of NY and NJ, NYC DOT, City of New York, City of East Rutherford, City of Boston, and City of Foxborough. Also, the safety and incident first responders will need to utilize these tools to ensure effective and swift operation. Finally, and most importantly, the general public including locals and visitors attending matches and surrounding events, local residents not involved with the World Cup, and the traveling public will need to be informed of critical delays and safety incidents.

2 DESCRIPTION OF SOLUTION

SafeMove is a secure, AI-powered, multilayer system for managing mobility and crowd safety across the World Cup region. The system integrates sensors, data fusion, advanced analytics, and communication platforms to serve both agencies and travelers. Key features include enhancing public safety and traveler efficiency through several key principles.

To improve public safety, SafeMove will integrate FEMA's Integrated Public Alert and Warning System (IPAWS) to communicate official, geofenced emergency alerts. These alerts will allow swift communication of emergency conditions in multiple languages to alert the crowd of specific evacuation instructions. Additionally, traffic safety will be enhanced by deploying sensing equipment to detect vulnerable road users (e.g. pedestrians, cyclists) who may be at risk. Through cooperative perception (e.g. shared vehicle and infrastructure sensors), vehicle-to-everything (V2X) sensors communicate encrypted messages to warn drivers of nearby crowds or hazards through in-vehicle warnings, which can greatly reduce crash risk in busy areas.

To improve traveler efficiency, SafeMove will integrate several features that enhance crowd management, traveler mobility, and accessibility. Real-time density analytics utilize camera and LiDAR feeds to estimate crowd sizes, which the system can use to geofence congested areas and suggest reroutes for vehicles and pedestrians. AI models can then ingest these feeds for pedestrian surge management to dynamically optimize traffic signal timing and crowd flows to prevent bottlenecks. Additionally, a user-friendly SafeMove App/Portal provides fans and residents with up-to-date multimodal trip planning (transit, driving, parking) and wayfinding in their preferred language. Edge AI at field locations detects incidents and disruptions immediately, feeding alerts into the system. Finally, all traveler information and alerts are provided in multiple languages and meet ADA standards for visual/auditory messages.

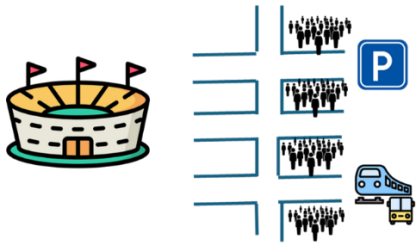

***Figure 2**: SafeMove: the solution for enhanced mobility and safety*

2.1 Proposed Solution for the Problem

SafeMove aims to ensure safe, efficient travel between event sites while maintaining overall network performance. Objectives include reducing travel times and congestion, minimizing pedestrian-vehicle conflicts, and improving emergency response times. The system aligns with ITS and Transportation Systems Management & Operations (TSMO) principles by maximizing the efficiency and safety of existing infrastructure. For example, it builds on current signal controllers, traffic cameras, and transit data feeds, augmenting them with advanced AI and communication capabilities. This solution is an integrated traveler information and alert system, combining pedestrian safety, enhanced traveler experience, and dynamic operations (**Figure 3**).

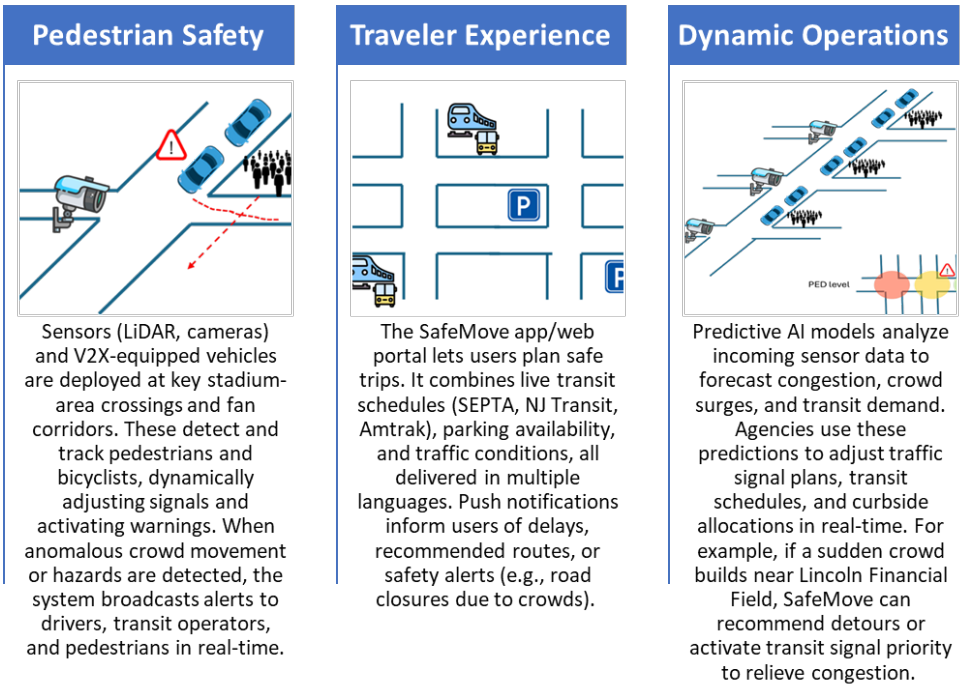

***Figure 3**: SafeMove Core Principles*

2.2 Integrated with the Existing Environment

SafeMove is designed to augment, not replace, existing systems by leveraging current traffic cameras, signal controllers, PA 511 travel advisory feeds, and transit control systems to enhance the technological capabilities of the existing infrastructure. Edge-AI units and cooperative perception nodes at select locations (e.g. busy areas, parking lots) will capture high-fidelity data.

To integrate the data, secure APIs and blockchain-anchored data sharing connect SafeMove to agency systems (e.g. PA 511, SEPTA/Amtrak databases, city traffic management centers). This ensures a seamless flow of information between agencies. Data privacy is maintained by using federated AI, agencies collaboratively train shared predictive models without exposing raw data.

To ensure the system is deployed appropriately, there will be several phases to ensure the project is rolled out smoothly. To start, the project will be focused on being configured appropriately during the FIFA Club World Cup 2025 in the Philadelphia region at Lincoln Financial Field and along the I-95 corridor, with the ability to expand to New Jersey and Massachusetts sites. Phase roll-out allows testing and legacy integration, ensuring SafeMove can operate alongside current traffic management center (TMC) and transit management systems. Using universal communication strategies, any level of deployment of the SafeMove system can help generate and inform Wireless Emergency Alerts and other PA 511 travel advisory feeds. Integration with IPAWS can allow any official agency (e.g. transportation, emergency management, or law enforcement) to send messages tailored to a specific system condition and the targeted audience. Links within the message can send users to the official FIFA event website, agency page, social media post, or PDF (evacuation/detour map) for further instructions and multi-language support.

2.3 Stakeholder Engagement

SafeMove serves diverse stakeholders (**Table 1**). For transportation agencies (PennDOT, NJDOT, etc.), it provides a real-time dashboard, AI-driven congestion alerts, and tools for coordinated response. City managers and event organizers gain predictive analytics for crowd control and resource deployment. Law enforcement and emergency services receive live camera feeds and alerts to target incident response. Fans and residents use the SafeMove app to plan trips and receive timely, multilingual alerts. Transit operators and rideshare services get dynamic routing and crowding information to optimize schedules and pick-up/drop-off operations.

***Table 1**: Tiered Stakeholder Engagement*

Tier 1	Transportation Agencies	Monitor real-time dashboards, receive AI-driven incident and congestion alerts, coordinate responses, and optimize service.
	City & Event Managers	Use predictive analytics and live data to manage crowds, deploy resources, and communicate with the public.
	Law Enforcement & Emergency Services	Access live feeds and alerts for rapid, targeted response to incidents or emergencies.
	Transit Operators & Rideshare	Receive dynamic routing, curb management, and crowding information to enhance service and safety.
	Vehicle Drivers	Drivers who receive timely warnings and notifications to prevent accidents. Ensuring their awareness and compliance with the new system is crucial for reducing the risk to the crowd.
Tier 2	Fans and Residents	Plan safe, efficient trips via the FAIR Transit+ app/web portal, receive real-time, multilingual alerts, and benefit from improved VRU safety and travel reliability.

3 SOLUTION ARCHITECTURE

To effectively manage the complex mobility and safety challenges of the FIFA World Cup 26, the SafeMove system is structured into a three-layer architecture: **Data Layer, Analysis Layer, and**

Interface Layer. This modular design ensures seamless integration with existing infrastructure while enabling scalable, intelligent operations across agencies and users.

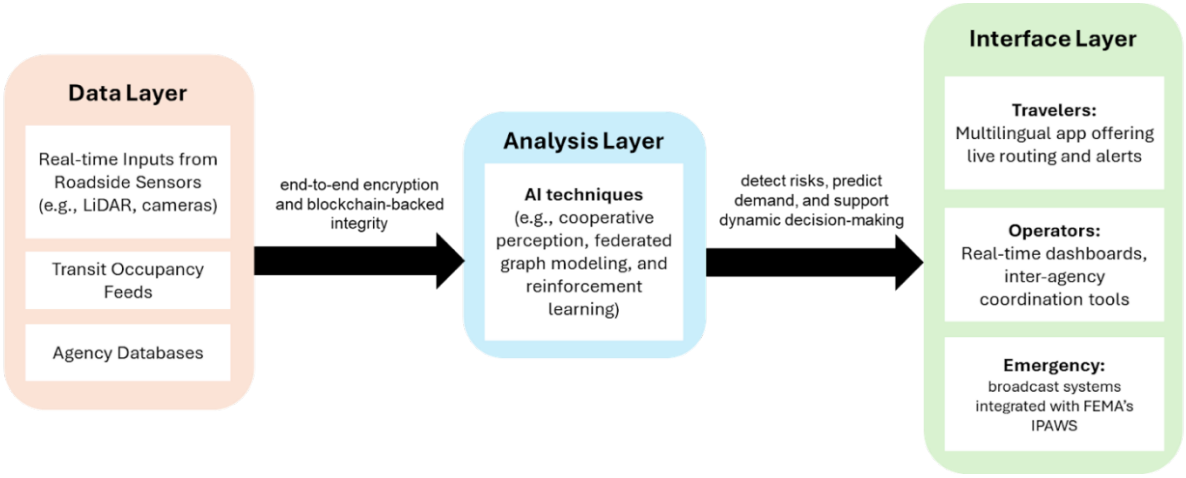

***Figure 4**: SafeMove system structured into a three-layer architecture*

The **Data Layer** aggregates real-time inputs from roadside sensors (e.g., LiDAR, cameras), transit occupancy feeds, and agency databases, ensuring secure, federated data storage with end-to-end encryption and blockchain-backed integrity. The **Analysis Layer** applies advanced AI techniques, including cooperative perception, federated graph modeling, and reinforcement learning, to detect risks, predict demand, and support dynamic decision-making. Finally, the **Interface Layer** bridges system intelligence with users: travelers interact via a multilingual app offering live routing and alerts, while operators access real-time dashboards, inter-agency coordination tools, and emergency broadcast systems integrated with FEMA's IPAWS. Together, these layers enable SafeMove to deliver real-time, adaptive, and secure transportation management during large-scale events.

3.1 High-level Function Architecture

Table 2 outlines the roles and responsibilities of each system component from field devices and cloud services to agency control centers and traveler interfaces, highlighting how these entities work together to detect, respond to, and communicate real-time events. Each component is assigned specific functional objectives, such as adjusting signal timing, issuing safety alerts, or relaying transit updates, all of which contribute to an integrated response strategy. At the core of this architecture is a distributed network of **edge devices** and **cloud-based analysis tools** that detect anomalies (e.g., crowd surges, incidents, or infrastructure failures) and trigger responsive actions through connected systems. Field equipment, including cameras, barrier gates, changeable message boards, and V2X units, interacts with traffic and transit management centers to adjust control logic in real time. Personal devices and vehicle onboard units receive immediate alerts to enhance situational awareness. This layered and interoperable design aims to maintain high levels of responsiveness, resilience, and coordination during large-scale events.

***Table 2**: Function Architecture*

Physical Object	Functionality	Functional Description
Traffic Management Center	TMC Signal Control	Receives real-time intersection data (e.g., pedestrian volume, conflicts) from edge devices and adjusts traffic signal timing accordingly.
Transit Management Center	Transit Schedule	Adjusts transit schedules based on input from traffic operations personnel (e.g., increase, suspend, or reroute).
Transportation Information Center	Traffic Control Dissemination	Disseminates updated traffic signal plans and transit schedules. Pushes notifications to the SafeMove app/website. Advise on parking locations.
ITS Roadway Equipment	Edge Device	Uses computer vision and LiDAR to detect vehicles and vulnerable road users from panoramic video. Sends alerts to message boards, vehicle OBEs, and SafeMove app. Also, sends signal adjustment requests to the TMC.
	Changeable Message Board	Receives anomaly alerts from edge devices and displays messages for drivers.
ITS Communication Equipment	Communication System	Enables real-time data transmission between ITS components.
System Monitoring	System Monitoring	Collects status updates from ITS components. Sends alerts to traffic operations staff for issues like outages.
Vehicle	Vehicle OBE	Receives anomaly alerts from edge devices and communicates them directly to the driver.
Personal	SafeMove app/web	Displays real-time pedestrian, conflict, and parking info from edge devices to help users make informed travel decisions (e.g., avoid congestion, find parking).
	Traffic Operation Personal	Monitors system and SafeMove data. Sends transit schedule adjustment requests. Troubleshoots device issues (e.g., network failure), and can manually intervene.

3.2 High-level Physical Architecture

Figure 5 provides a detailed representation of the key physical components in SafeMove system and their interactions. Aligned with the ARC-IT framework, this architecture categorizes system elements into five main object types: **Center**, **Field**, **Vehicle**, **Personal**, and **Support**. It illustrates how physical objects such as traffic management centers, roadside units, on-board vehicle systems, and personal mobile devices interact through communication channels to support system functions like traffic control, incident response, and traveler information delivery.

Beyond traditional ITS deployments, the proposed architecture incorporates advanced components such as **edge AI units** to enable localized sensing, anomaly detection, and real-time actuation. The architecture also supports system monitoring, cybersecurity threat detection, and fail-safe mechanisms to maintain operational integrity. This physical architecture establishes the foundation for SafeMove's ability to deliver responsive, secure, and scalable mobility management during high-impact events like the World Cup.

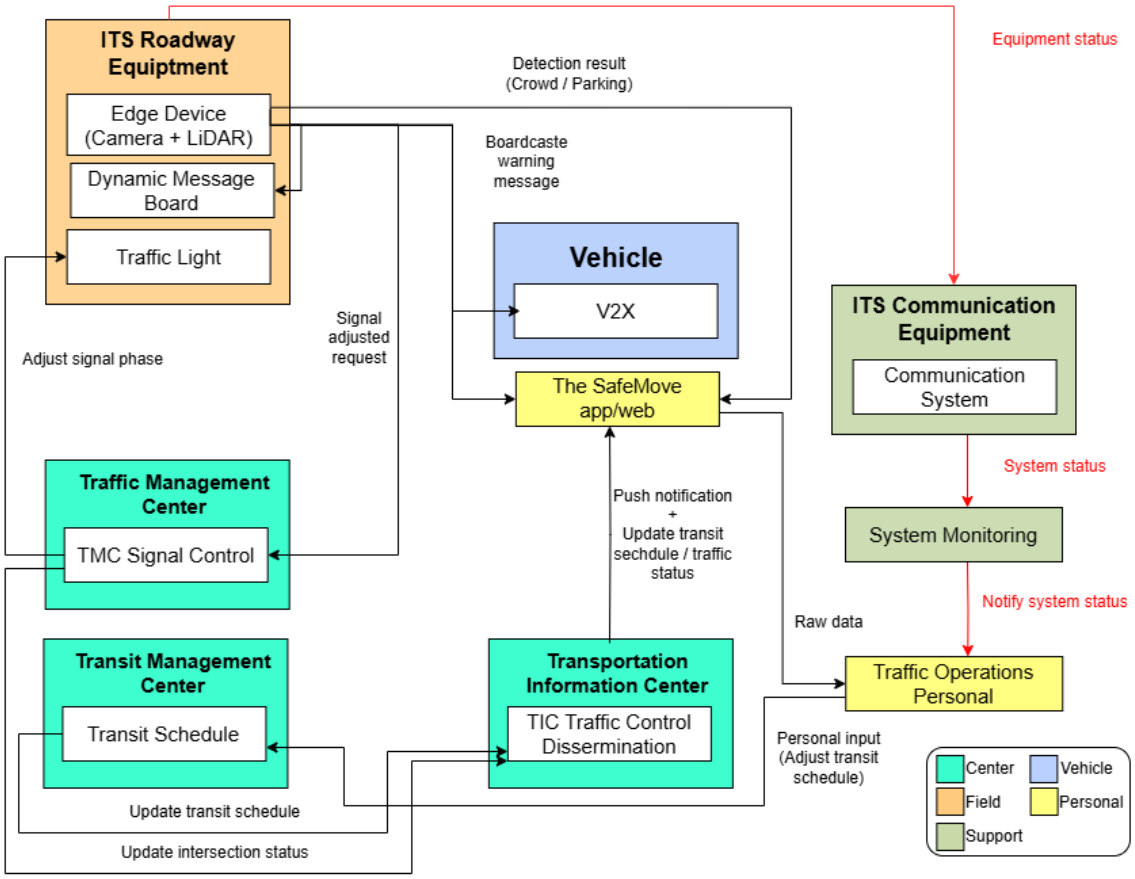

***Figure 5**: High-level Physical Architecture*

4 ANTICIPATED IMPACTS

The SafeMove solution is designed to address key transportation, safety, and mobility challenges identified for the FIFA World Cup 26 in the Eastern Region. By leveraging advanced AI, real-time analytics, and integrated communication platforms, this system will significantly enhance event coordination, transportation efficiency, public safety, and overall traveler experience.

4.1 Alignment with Goals & Objectives

The key goals of the SafeMove integrated system are to maintain safety, efficiency, equity and accessibility, as well as regional coordination. To maintain safety, cooperative perception and crowd analytics directly target collision hot-spots and bottlenecks, fulfilling the objective of minimizing VRU–vehicle conflicts and accelerating emergency response. System efficiency will be enhanced through predictive demand management and real-time multimodal guidance, which will optimize existing capacity rather than relying on costly capital expansion, meeting TSMO efficiency objectives. Ensuring equity and accessibility is of utmost importance. To do so, multilingual, ADA-compliant communication, and dynamic curb management enhance mobility for international visitors and people with disabilities. Finally, federated data governance and shared dashboards enable multi-jurisdictional partnerships for the tournament.

4.2 Benefits of the FIFA World Cup 26 Special Event

4.2.1 Public & Crowd Safety

Through proactive alerts and warnings, data-driven crowd oversight, and pedestrian-vehicle conflict mitigation, safety can be maintained throughout the event. This will enable stadium operators and public-safety agencies to broadcast multilingual, geo-targeted alerts that reach fans, motorists, and nearby residents instantaneously, guiding orderly evacuations and reducing panic during emergencies. Real-time density analytics from cameras and LiDAR help operators recognize emerging bottlenecks and redirect flows before dangerous crowding develops, lowering the likelihood of crowd crush incidents near stadium gates and transit hubs. Finally, cooperative perception between roadside sensors and connected vehicles warns drivers of VRUs in shared ROW, adding an additional defensive layer around busy crossings and drop-off points.

4.2.2 Traffic Operations & Traveler Mobility

Traffic operations and traveler mobility are crucial to ensure all fans make it to and from the stadium in a timely manner. Predictive congestion management, integrated trip planning, and targeted messaging enable services to be maintained. AI models continuously forecast road and transit demand, allowing TMCs to implement responsive signal plans, dynamic lane controls, or transit priority treatments to smooth traffic peaks. A single app and web portal give visitors curated multimodal options, rail, bus, shared mobility, supported by real-time data. This empowers fans who are unfamiliar with the region to make informed choices. Finally, coordinated outreach to local commuters encourages teleworking, off-peak deliveries, or alternative routes, reducing everyday traffic that would otherwise mix with event surges.

4.2.3 Inter-Agency Coordination

Creating a unified situational picture and a streamlined incident response will ensure efficient communication. A shared dashboard aggregates feeds from PennDOT, NJDOT, MBTA, transit operators, and municipal emergency centers, enabling quicker decisions across state lines—critical when fans travel between stadiums on the same day. Common operating protocols, supported by secure data-sharing APIs, shorten the information loop between first responders, traffic engineers, and transit dispatchers, which ensures information is issued from a sole source.

4.2.4 Cybersecurity & System Resilience

Continuous threat monitoring and redundant communication paths help maintain resiliency. Edge-AI agents flag suspicious network activity or sensor tampering early, preserving the integrity of traveler-information services at a time when high-profile hacking attempts are more likely. Blockchain-anchored data records and federated storage guard against single points of failure, allowing agencies to maintain public messaging even if one subsystem is compromised.

4.2.5 Accessibility and User Experience

Interfaces streamline all alerts, maps, and wayfinding cues to ADA standards and offer language choices reflecting the tournament's international audience, enhancing inclusivity for visitors and residents alike. Dynamic allocation of loading and pick-up zones balances rideshare, paratransit, and charter bus needs, supporting equitable access for people with mobility impairments.

4.2.6 Long-Term Economic & Institutional Benefits

Hardware and software installed for the World Cup—advanced signal controllers, V2X radios, high-resolution sensors—remain in place, bolstering ongoing Vision Zero and TSMO initiatives. The cross-agency agreements and data standards forged for SafeMove create a ready template for managing future large-scale events and unplanned emergencies throughout the NE Corridor.

4.2.7 Benefits to Special-Event Stakeholders

***Table 3**: Benefits to Special Event Stakeholders*

Stakeholder	Near-term Impact (World Cup)	Long-Term Impact (post World Cup)
Transportation agencies (State and City DOTs)	Unified dashboard, shared situational awareness, AI driven signal plan and detour recommendations	Permanent interjurisdictional data exchange and joint TSMO playbook
Transit operators (SEPTA, NJ Transit, MTA, MBTA, Amtrak)	Demand forecasts feed dynamic scheduling, vehicle crowding alerts, and coordinated wayfinding	Ongoing load balancing and integrated first/last mile information services
Law enforcement & emergency services	Live video and anomaly alerts for faster, better targeted response	Expanded use of cooperative perception for incident and evacuation management
Fans & visitors	Seamless, multilingual trip planning, shorter wait times, safer crossings	Blueprint for future largescale events and tourism promotion
Local residents & commuters	Fewer unexpected delays via proactive TDM messaging; prioritized emergency routes	Lasting reduction in peak hour congestion and improved pedestrian safety corridors
Shared mobility (micromobility)	Realtime curb availability and crowd direction data to optimize pickup/drop-off	Data driven curb management policy and equitable access enforcement

5 SUMMARY

SafeMove addresses the unprecedented transportation and safety challenges of the FIFA World Cup 26 by implementing a secure, AI-powered system that integrates advanced sensing, predictive analytics, and multilingual communication platforms across the Philadelphia-New York-Boston corridor. The solution augments existing infrastructure with cooperative perception technology, edge AI deployment, and real-time crowd analytics to enhance pedestrian safety, optimize traffic flow, and enable coordinated emergency response across state lines. Through its three-layer architecture and integration with FEMA's IPAWS system, SafeMove provides transportation agencies with unified situational awareness and AI-driven recommendations while offering travelers intuitive, multilingual trip planning through a comprehensive app and web portal. Beyond addressing immediate World Cup demands, the system establishes a lasting foundation for regional cooperation, with permanent infrastructure upgrades, inter-agency data sharing protocols, and coordinated response frameworks that will benefit ongoing transportation management, Vision Zero initiatives, and future large-scale events. The modular, scalable design ensures cybersecurity through blockchain-anchored data integrity and federated learning approaches while maintaining ADA compliance and multilingual accessibility, ultimately transforming the Northeast Corridor into a model for intelligent transportation systems that serve diverse communities with the highest safety and efficiency standards.

6 REFERENCES

[1] Lincoln Financial Field. (n.d.). Stadium facts. Retrieved May 29, 2025, from https://www.lincolnfinancialfield.com/stadium-facts/

[2] Arc-IT Team. (2024). Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) version 9.3. www.arc-it.net

[3] Intersection safety challenge | its joint program office. (2024). Retrieved May 30, 2025, from https://its.dot.gov/research-areas/Intersection-Safety-Challenge/