FY 22 Strengthening Mobility and Revolutionizing Transportation (SMART) Safer, Smarter, Faster: Pairing Cloud-Based Vehicle Preemption and Advanced Intersection Analytics

Stage 1 Final Implementation Report

August 2023 to June 2025

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Part 1: Executive Summary

The *Safer, Smarter, Faster* project, funded by the FY22 SMART Grant, aims to enhance transportation safety, mobility, and reliability in southern Nevada by deploying cloud-based Transit Signal Priority (TSP) and Advanced Intersection Analytics (AIA) technologies.

Stage 1 of the project focused on proof-of-concept implementation in downtown Las Vegas and areas surrounding the Las Vegas Medical District, where the state's only Level I Trauma Center is located. The project area includes 35 census tracts, 31 of which are Historically Disadvantaged Communities (HDCs).

Project Goals and Objectives

The project seeks to:

- Improve bus on-time performance (OTP) and reduce delays.
- Enhance intersection safety and operational efficiency through real time detection and analysis of traffic conditions and potential hazards.
- Enable data-driven operations and performance monitoring.

Key Partners

- RTC-Freeway and Arterial System of Transportation (FAST): Lead agency and project manager
- City of Las Vegas Public Works: Infrastructure owner and deployment partner
- RTC Transit: TSP end-user and data provider
- Kimley-Horn: Cloud-based TSP technology vendor
- Derq USA: Intersection analytics vendor
- HDR and Parametrix: Evaluation and engineering support

Prototype Scope and Deliverables

- TSP deployed at 17 intersections on RTC Transit Route 206
- AIA installed at 20 intersections to monitor safety and traffic conditions.
- Integration with Trafficware's ATMS.now central traffic system software platform and transit AVL systems
- Cloud-based dashboards enabled real-time data access for multiple agencies.

Stage 1 Results

- Transit Performance: RTC Transit Route 206 saw a weekday OTP improvement of 3% to 6% during AM and PM peak periods, with average bus delay reduced by 7% to 13% and time savings up to 78 seconds per bus trip along the corridor.
- Analytics Accuracy: AIA systems achieved an accuracy of 92.2% for traffic detection and 97.6% precision in identifying red light running and near-miss events.

- System Validation: Of all TSP requests, 24% required no action as buses passed through without delay, while 76% required a controller response. In 100% of those cases, signal controllers responded successfully, most commonly by issuing REDUCE or EXTEND signal phase actions.
- Developed the agency's first TSP Business Rules document, a key institutional milestone that establishes a foundational framework for current and future TSP deployments. It enhances internal understanding, formalizes decision-making processes, and promotes consistent coordination among IT, signal operations, and transit stakeholders—supporting scalable and effective TSP implementation across the region.

Recommendations and Lessons Learned

- Advance stakeholder engagement and scope development to reduce procurement delays.
- Strengthen multi-vendor coordination and QA processes to address integration and data validation issues.
- Plan for local support capacity, especially for remote vendor systems, and enhance real-time system monitoring.
- Implement data governance protocols and staff training to ensure secure, effective use of analytics tools.
- AIA technologies require careful calibration and configuration based on local conditions including existing infrastructure such as camera type, resolution, and field of view, communication technologies, and intersection geometrics.

Stage 2 At-Scale Implementation Outlook

Building on Stage 1 findings and lessons learned, Stage 2 will:

- Expand cloud-based TSP to approximately 100 intersections and deploy cloud-based emergency vehicle preemption (EVP) at approximately 1,040 intersections.
- Extend AIA to 20 critical intersections, across all RTC partner agencies.
- Deliver over $176 million in benefits over 15 years, with a Benefit-Cost Ratio (BCR) of 3.07
- Improve transit reliability, emergency response, and system efficiency across the region.

Stage 1 has validated the feasibility and value of cloud-based traffic technology, positioning the region for impactful, equitable, and scalable transportation improvements in Stage 2. In addition, Stage 1 has also validated the value of the traffic and safety data that was collected by the AIA systems. The data collection, warehousing, and analytics from the AIA systems provided local planners and operators with new tools that enable them to improve the overall transportation systems' safety and efficiency.

Part 2: Introduction and Project Overview

Overview

Southern Nevada is a dynamic environment, which is primed for the convergence of transportation and technology. Las Vegas, located in southern Nevada, is home to over two million residents, and welcomes forty-three million visitors every year. The Las Vegas Medical District is home to the University Medical Center (UMC) hospital, the state's only Level I Trauma Center. UMC hospital is situated near downtown Las Vegas. The Regional Transportation Commission of Southern Nevada (RTC) FAST is leading the project effort in close participation with City of Las Vegas (CLV) Departments of Public Works and RTC Transit. RTC is the region's transit provider serving over 52 million passenger trips each year.

RTC's "Safer, Smarter, Faster" Smart Technology Traffic Signal Project implemented a cloud-based signal timing optimization system that supports Transit Signal Priority (TSP) and enhances intersection safety. This initiative will leverage advanced intersection analytics powered by artificial intelligence (AI) to enable smarter traffic management and proactive safety improvements.

Issues Addressed

Current challenges addressed with this project include:

1. **Fragmented Technology:** The Clark County metropolitan area includes six municipal agencies, each with its own traffic signal infrastructure and EVP technology. This fragmentation leads to increased emergency response times when fire departments respond across jurisdictional boundaries.
    a. Initially, a cloud-based EVP technology proof of concept was proposed. Throughout the course of the project, RTC coordinated with City of Las Vegas Fire and Rescue to obtain access to the Computer-Aided Dispatch/Automatic Vehicle Location (CAD/AVL) feed via an API. Through many conversations and in person meetings over the course of six months, RTC-FAST discovered Clark County Fire Department was the account holder for the CAD system that provides emergency vehicle dispatch for both unincorporated Clark County and City of Las Vegas. RTC-FAST immediately coordinated with Clark County Fire Department and Purchasing Department to gain permissions for accessing the 3rd party dispatch system. In December 2024, RTC-FAST was near finalizing a new agreement with the 3rd party dispatch system, when it became known a new API was being developed and no new account access was granted to the old API. RTC-FAST explored other options, such as accessing on-board modems for AVL data and 3rd party applications for dispatched state. However, in discussions with USDOT and limited time remaining in the project, deployment of cloud-based EVP was removed from the scope of work.
2. **Transit Signal Priority:** Previous TSP implementations on bus rapid transit routes faced challenges due to the need for line-of-sight. Obstructions often led to dropped calls. A cloud-based system using CAD/AVL data can prevent this issue and allow fine-tuning by the RTC-FAST signal operations team.
3. **Advanced Intersection Analytics:** Moving from a reactive to a proactive strategy, intersection video analytics can identify developing trends and alert transportation professionals earlier than waiting for historical crash data, often several months later. This technology provides data faster, saving staff time and enabling quicker, more effective safety and operational improvements.

Technologies Deployed

The Safer, Smarter, Faster project leverages a suite of innovative, cloud-based transportation technologies to modernize traffic signal operations, improve transit reliability, and enhance intersection safety in southern Nevada. The Stage 1 deployment focused on two primary technology components—cloud-based Transit Signal Priority (TSP) and Advanced Intersection Analytics (AIA)—both of which align with the SMART Grant deployment categories as described below:

1. **Smart Technology Traffic Signals:** At the heart of the deployment is a cloud-based signal optimization system designed to enhance the responsiveness and efficiency of traffic signals. The TSP component, deployed at 17 intersections along RTC Transit Route 206, uses real-time Computer-Aided Dispatch/Automatic Vehicle Location (CAD/AVL) data to enable virtual geofencing and dynamic signal priority for transit vehicles. This approach eliminates traditional hardware constraints (e.g., infrared line-of-sight systems) and enables scalable, data-driven signal control.
2. **Intelligent Sensor-Based Infrastructure:** The AIA component incorporates intelligent video analytics powered by central server computing and AI to capture vehicle counts, pedestrian movements, intersection safety events, such as red light running, speeding, and near-misses and signal performance metrics (SPMs). With an on-premise server deployed at the RTC-FAST's Traffic Management Center, the system processes video feeds from 20 intersections and delivers high-resolution, real-time data to support proactive traffic management and infrastructure planning.
3. **Systems Integration:** The technologies deployed are tightly integrated with existing regional traffic control and transit management systems. The TSP system interfaces with Trafficware's ATMS.now central traffic system and traffic signal controllers, while the AIA system streams data into cloud-hosted dashboards accessible to engineering, transit, and emergency response teams. This integration supports real-time operational decision-making and performance monitoring across multiple agencies.
4. **Connected Vehicles:** Although not using DSRC or cellular V2X for vehicle-to-infrastructure (V2I) communications at this stage, the system leverages connected data from transit fleets via CAD/AVL systems to issue priority requests. This represents a foundational step toward broader connected vehicle deployments that align with emerging V2X standards.
5. **Coordinated Automation:** By using automated decision rules within the TSP system, signal timing adjustments are made in real time without human intervention. These rules factor in bus lateness, and route performance, embodying the principles of coordinated automation at the infrastructure level.

Project team and stakeholders

The Project Team is comprised of the Regional Transportation Commission of southern Nevada (RTC) staff. RTC-FAST is the grant recipient and will be the Project Manager for the project. The City of Las Vegas Departments of Public Works as well as RTC-Transit are project partners, end users or data support.

Table 1 lists roles and responsibilities of project stakeholders that are engaged in this project.

Table 1: Project Stakeholder List

Organization	Role	Responsibilities
RTC-FAST	▪ Project Manager ▪ Regional Traffic Management Operator	▪ Project Management ▪ Stakeholder engagement ▪ Solicit RFPs for (2) vendors and (1) engineering firm and manage their contracts ▪ Prepare quarterly and project reporting
City of Las Vegas Public Works	▪ Project Partner ▪ Owner of Stage 1 grant traffic signals	▪ Provide project support/coordination ▪ Review RFP submittals and participate as a stakeholder in vendor/engineering firm selection ▪ Participate in all project meetings ▪ Assist during field deployments ▪ Provide technical support ▪ Provide feedback on intersection analytics dashboard and performance metrics
City of Las Vegas Fire and Rescue	▪ Project End User	▪ Provide existing emergency response performance metrics ▪ Provide end user feedback of cloud-based EVP implementation
RTC-TRANSIT	▪ Project End User	▪ Provide existing transit performance metrics ▪ Provide end user feedback of cloud-based TSP implementation
RTC Information Technology	▪ Project Support	▪ Share CAD/AVL transit data for before and after scenarios to aid in project evaluation
TSP Vendor (Kimley-Horn)	▪ Provider of cloud-based technology	▪ Meeting requirements of RFP and Smart Grant
Intersection Analytics Vendor (Derq, USA)	▪ Provider of cloud-based technology	▪ Meeting requirements of RFP and Smart Grant
Engineering Firm (HDR and Parametrix)	▪ Engineering Support Services	▪ Engineering support for data collection and management ▪ Evaluation of before and after project performance measures ▪ Provide technical assistance during field deployments and evaluation performance period ▪ Assist in the development of the TSP performance parameters ▪ Support for Implementation Report ▪ Document the lessons learned

Stage 1 Deployment

The limits for Stage 1 pilot project encompass UMC hospital and downtown Las Vegas. The project area includes 35 census tracts, of which 31 are categorized as Historically Disadvantaged Communities (HDCs).

For Stage 1 proof-of concept, RTC worked with CLV to identify signalized locations with good quality video detection systems in place within the project limits. Intersection analytics were deployed at 20 intersections. TSP was implemented at 17 continuous intersections along RTC Transit Route 206 on Casino Center Boulevard from Bonneville Transit Center to Charleston Boulevard and from Casino Center Boulevard to Fremont Street. This route often experiences lower on-time performance (OTP) scores than many other routes in the region, while being the 3rd highest passenger route. Figure 1 provides an overview map of the project intersections.

Figure 1: Project Intersections

Stage 1 Project Activities Milestones

The Stage 1 proof-of-concept utilized two vendors, the first vendor, Kimley-Horn, delivered Transit Signal Priority (TSP) with Traction Priority. The second vendor, Derq USA, provided advanced intersection analytics. With this cloud-based approach, no new TSP or intersection analytics equipment or infrastructure was installed in the field. Both solutions utilized on-premise servers located at RTC-FAST's Traffic Management Center. A key component of this project was to limit the addition of in-field devices at the signalized intersections. A third vendor, HDR with Parametrix, supported data collection, management, and evaluation efforts.

The following is an overview of the key activities completed:

1. Prepared and advertised Requests for Proposals (RFPs) for technology vendors/contractors and consultant support services.
2. Evaluated proposals, awarded contracts, executed agreements, and issued Notices to Proceed for vendors and consultants.
3. Acquired an on-premises server and initiated testing and integration of the AI-based advanced intersection analytics technology at 20 intersections.
4. Received General Transit Feed Specification (GTFS) feed from Swiftly and integrated it into the Kimley-Horn Traction Priority dashboard.
5. Conducted stakeholder outreach.
6. Collected data on existing conditions.
7. Completed testing and validation of intersection analytics.
8. Completed testing and validation of the Traction Priority TSP module.
9. Developed Transit Signal Priority Business Rules document.
10. Submitted quarterly progress reports, the Data Management Plan, and the Performance & Evaluation Plan.
11. Prepared this final Implementation Report, updated DMP toolkit and submitted project data.

Figure 2 provides a roadmap of key project activities.

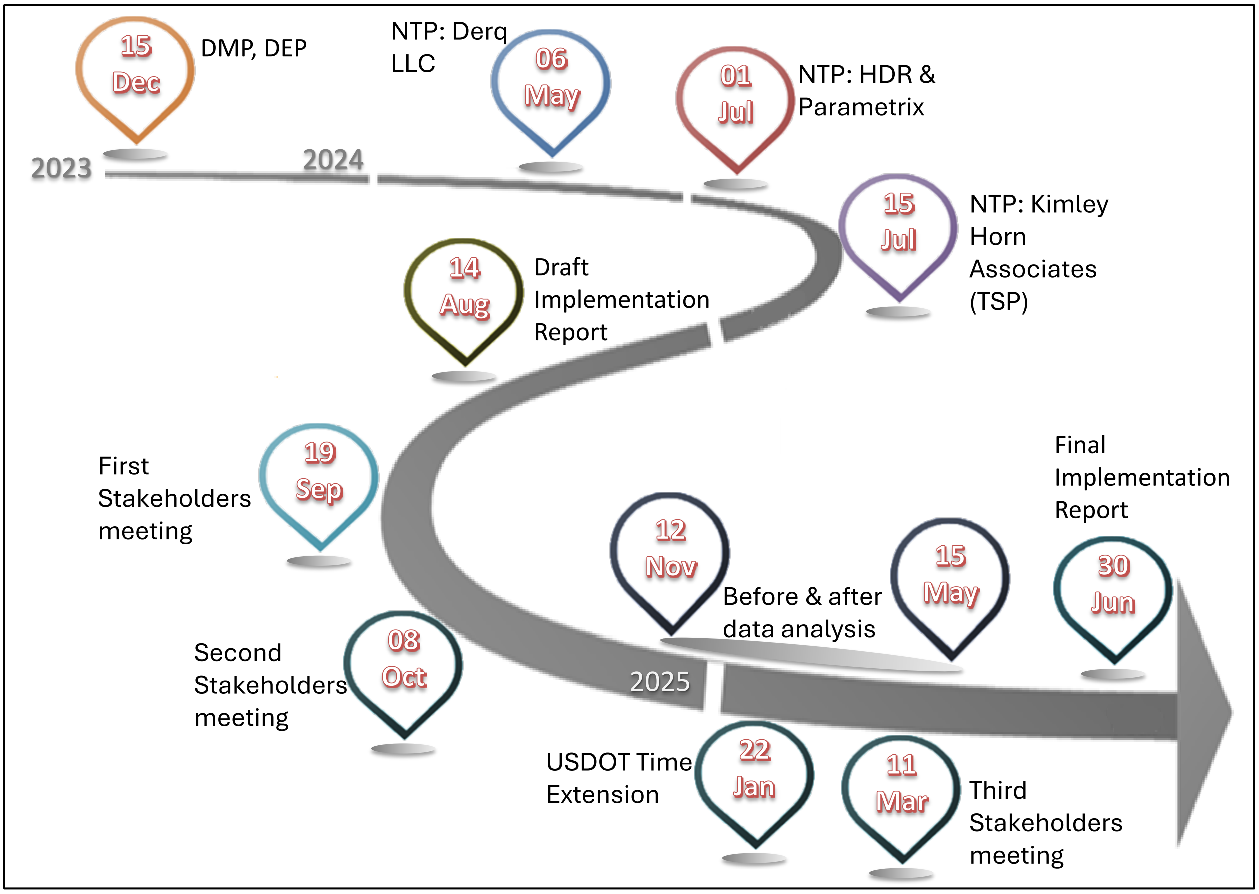

Figure 2: Project Key Activities Milestones

Stage 2 Deployment (At Scale Implementation)

Stage 2 Scope

The Stage 2 deployment will build on the successful proof-of-concept completed in Stage 1 by scaling cloud-based and AI technologies—Transit Signal Priority (TSP), Advanced Intersection Analytics (AIA), and Emergency Vehicle Preemption (EVP)—across a broader regional footprint. This phase will significantly expand coverage, data integration, and inter-agency coordination, delivering measurable benefits across southern Nevada's transportation ecosystem.

The Stage 2 implementation will include:

- **TSP Expansion**: Approximately 100 additional signalized intersections—prioritized along major corridors with high ridership and poor on-time performance—will be equipped with cloud-based TSP. Candidate corridors include Charleston (17 miles), Boulder Highway (15 miles), and Maryland Parkway (7 miles).
- **EVP Integration**: Cloud-based EVP will be deployed at signalized intersections with fiber-optic communication capability in City of Las Vegas and Unincorporated Clark County (approximately 1,040 of 1,746 signals in southern Nevada), in collaboration with two fire and rescue departments. This effort will standardize emergency response technology across jurisdictional boundaries.

- **AIA Deployment**: AIA will be implemented at up to 20 critical intersections—identified by local agencies as high-crash areas, consistent citizen inquiries, or intersections with evolving traffic patterns—to enhance safety monitoring and operational efficiency.
- **Data integration, warehousing, and analytics**: data from the above three implementations will be integrated into an online data solution via API's that summarizes key performance and safety metrics providing valuable multimodal insights to the region's planners and operators.

Goals and Desired Outcomes

The overarching goal of Stage 2 is to leverage advanced data, cloud-based infrastructure, and AI analytics to improve transportation safety, mobility, and operational performance across the region. Specific goals and associated statutory outcomes include:

- **Reduce Congestion and Delays for Commerce and the Traveling Public *(I)***: Cloud-based TSP will reduce bus delays and smooth traffic flow, ease congestion along heavily traveled corridors and increase the efficiency of commerce and transit operations.
- **Improve Safety and Integration of Transportation Facilities for All Users *(II)***: AIA will enable real-time detection of red light running, speeding, and pedestrian-related violations, enhancing safety for drivers, bicyclists, and pedestrians alike.
- **Enhance Access to Jobs, Education, and Essential Services *(III)***: Improved transit reliability and travel time predictability will make public transportation a more viable and appealing option, especially for those relying on transit to reach employment centers, schools, and medical facilities.
- **Expand Access for Underserved Populations and Reduce Transportation Costs *(IV)***: With 31 of the 35 census tracts in the project area classified as Historically Disadvantaged Communities (HDCs), Stage 2 will expand access to transit service and safety in areas that have historically lacked investment.
- **Promote Medium- and Long-Term Economic Competitiveness *(V)***: More efficient transportation infrastructure supports regional economic development by reducing time lost to traffic delays and improving workforce mobility.
- **Improve Reliability of Transportation Systems *(VI)***: Cloud-based signal control and analytics enable consistent, predictable traffic operations and responsive system management. Improving fixed transit route on time performance improves public confidence in transit reliability.
- **Promote Connected and Integrated Transportation Systems *(VII)***: The deployment fosters data-driven connectivity between transit vehicles, traffic signals, and traffic operations centers, setting the stage for future connected vehicle and smart infrastructure integration.
- **Incentivize Public-Private Partnerships *(VIII)***: The project collaborates with private consultants and technology vendors (Kimley-Horn, Derq) and positions RTC to engage with telecommunications providers and AI analytics partners in future phases.
- **Improve Emergency Response *(XI)***: Implementing EVP will reduce delays for emergency responders, improving response times and public safety outcomes across municipal boundaries.

- **Improve Energy Efficiency and Reduce Pollution *(IX)***: Reduced idling times from TSP and EVP contribute to lower fuel consumption, supporting regional efficiency goals.
- **Increase System Resiliency *(X)***: By transitioning from hardware-dependent systems to scalable, cloud-based platforms, the project enhances the adaptability and maintainability of the transportation network.

Project Visibility

The project has received notable visibility through various channels since the initial award announcement, helping to highlight its progress and regional relevance:

- Derq USA issued a press release on July 9 announcing their award for the intersection analytics component of this Stage 1 opportunity.
- The advanced intersection analytics portion was presented at the Nevada Safety Summit on November 13, 2024.
- Derq was interviewed by USDOT on December 31, 2024, as part of an update to the AI for ITS Challenges and Potential Solutions, Insights, and Lessons Learned Report (2022).
- The FAST team provided regular project status updates at Operations Sub-Committee meetings, held bi-monthly (every even month) since August 2023.
- The project was highlighted in the State of Traffic System presentation to the RTC Board on March 13, 2025.
- The initial findings for AIA project component were presented on June 4, 2025, at TRB Standing Committee on Traffic Signal Systems (ACP25).

Part 3: Proof-of-Concept Evaluation Findings

The Stage 1 deployment of the "Safer, Smarter, Faster" project served as a proof-of-concept to validate the performance and feasibility of cloud-based Transit Signal Priority (TSP) and Advanced Intersection Analytics (AIA) systems. These technologies were tested to determine their potential for improving safety, efficiency, and operations across regional deployment. The findings discussed below are informed by the performance metrics identified in the Implementation Plan and reflect both the strengths and limitations of both deployments.

Performance Metrics and Data Collected

The proof-of-concept was evaluated using a set of performance metrics aligned with project goals.

Table 2 lists the project performance measures categorized by the SMART Grant Program Benefit Areas. It includes a qualitative description of the impacts of Stage 1 implementation and any available historical data to aid in informing this evaluation. Table 3 provides the performance measure targets that quantified with Stage 1 implementation.

Table 2: Qualitative Description by Program Benefit Area

Measure	Qualitative Description	Historical Data Available
Safety and Reliability	Capture speed, red light running and turning movement counts (AIA)	Turning movement counts and speed studies performed by each maintaining agency.
Resiliency	Increase on-time arrivals of transit service (TSP).	On Time Performance data for all routes, including Transit Route 206.
Integration	Reduce infrastructure installed on fleet vehicles and on traffic signals with cloud-based technology (TSP)	N/A

TSP – Transit Signal Priority AIA – Advanced Intersection Analytics

Table 3: Evaluation Performance Measures and Methodology

Evaluation Question	Performance Metric	Target
Improve bus service reliability	On-Time Performance (OTP) for Route 206	≥ 3% improvement
Reduce delays at intersections	Average bus delay and time saved during TSP events	Quantitative reduction
Validate TSP responsiveness	Signal controller response rate to TSP requests	Confirm successful operations
Verify AIA accuracy	Vehicle/VRU counts, SPMs, red light running detection	≥ 95% accuracy

VRU – Vulnerable Road Users SPMs– Signal Performance Metrics

While the original goal was to achieve 95% accuracy for AIA, the observed accuracy exceeding 90% is still considered effective in meeting stakeholder needs. This level of performance is sufficient to reliably identify trends and support actionable countermeasures that enhance safety and signalized intersection operational outcomes.

Evaluation Findings

Transit Signal Priority (TSP)

As part of the SMART Grant Stage 1 implementation, Transit Signal Priority (TSP) was deployed at 17 continuous intersections along RTC Transit Route 206. The demonstration corridor included segments on Casino Center Boulevard and Charleston Boulevard, where RTC Transit Route 206, despite being the third highest ridership route, frequently experiences low on-time performance (OTP). The proof-of-concept evaluation aimed to assess whether TSP could improve service reliability and reduce bus delays.

Data was collected during the pre-implementation period (December 1–31, 2024) and the post-implementation period (February 12–May 15, 2025). On-Time Performance (OTP) was evaluated at three key time points (F, G, and H) along RTC Transit Route 206. Among these, Time Point G (Charleston Boulevard at Maryland Parkway) served as the most representative location for assessing the effectiveness of TSP, as it benefits both eastbound and westbound buses.

Figure 3 illustrates the location of these three points along the demonstration corridor.

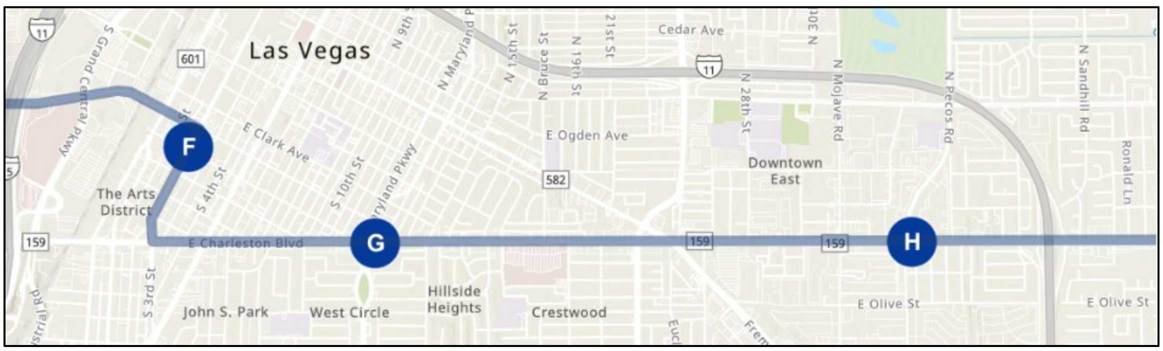

Figure 3: Time Point Locations Along RTC Transit Route 206: F, G, and H

On-Time Performance (OTP) Definitions

OTP refers to how well buses adhere to their scheduled arrival times. Two standard RTC Transit thresholds were used to assess performance:

- **5-Minute Window:** A bus is considered on time if it arrives no more than 5 minutes early or late.
- **2-Minute Window:** A more stringent metric on which buses must arrive within 2 minutes of the scheduled time to be considered on time.

OTP is calculated as the percentage of trips that fall within these windows over a specific period.

TSP Signal Controller Response Types

TSP system validation was categorized based on how signal controllers responded to bus requests:

- **REDUCE:** The controller shortened the green time of non-TSP phases to prioritize the bus.
- **EXTEND:** The controller extended the green time to allow the bus to pass through the intersection.
- **NONE:** No change was made to signal timing; the bus proceeded without assistance.
- **FREE:** The controller was operating in free mode without coordination.
- **LOCKOUT:** TSP was not granted due to system settings or constraints.

The evaluation showed consistent positive impacts from implementing Transit Signal Priority (TSP) across multiple metrics.

- **On-Time Performance (OTP):** RTC Transit Route 206 saw a notable **+3% to +6% improvement in OTP** during the AM and PM peak periods, particularly at Time Point G, a key transfer hub. Overall, weekday OTP improved by up to **+6%**, achieving the target.
- **Bus Delay Reduction:** Along Route 206, the Traction TSP system effectively reduced bus delays at 13 signalized intersections. On average, bus approach delays decreased by 7% (about 3 seconds per intersection) on weekends and 12% (about 6 seconds per intersection) on weekdays, resulting in total time savings of approximately 39 to 78 seconds per bus trip along the corridor.
- **Average Bus Time Saved:** TSP events typically yielded **25–30 seconds** of time savings **each time priority was granted**. In cases where an EXTEND signal response was triggered, buses avoided waiting through a full signal cycle (up to 180 seconds), resulting in up to **63 seconds of time saved**. Note that the 63 seconds represents the time saved in the signal cycle, not the actual time extension provided to the bus by the signal.
- System Validation: Of all TSP requests, 24% required no action as buses passed through without delay, while 76% required a controller response. In 100% of those cases, signal controllers responded successfully, most commonly by issuing REDUCE or EXTEND signal phase actions, indicating a high rate of successful TSP engagement.

Table 4 shows the cumulative results for time points F, G and H where TSP was deployed, and Table 5 shows the results for the representative location G representative of both directions EB and WB. Figure 4 shows the controller response for each TSP request.

Table 4: OTP RTC Transit Route 206

Results	Percent Change					
Route 206, Time Points F, G & H	All Trips		EB		WB	
	5 minute	2 minute	5 minute	2 minute	5 minute	2 minute
Weekdays	+1	+1	+3	+3	-1	+0
AM Peak 7a-11a	+3	+5	+3	+6	+3	+5
PM Peak 2p-6p	+3	+3	+3	+3	+2	+4
Weekends	-2	-4	+1	-2	-4	-6

Table 5: OTP For the Representative Point G

Results	Percent Change					
Time Point G Only	All Trips		EB		WB	
	5 minute	2 minute	5 minute	2 minute	5 minute	2 minute
Weekdays	+1	+0	+3	+1	-1	+0
AM Peak 7a-11a	+4	+5	+6	+4	+3	+6
PM Peak 2p-6p	+2	+3	+1	+1	+3	+5
Weekends	-3	-5	-1	-6	-5	-5

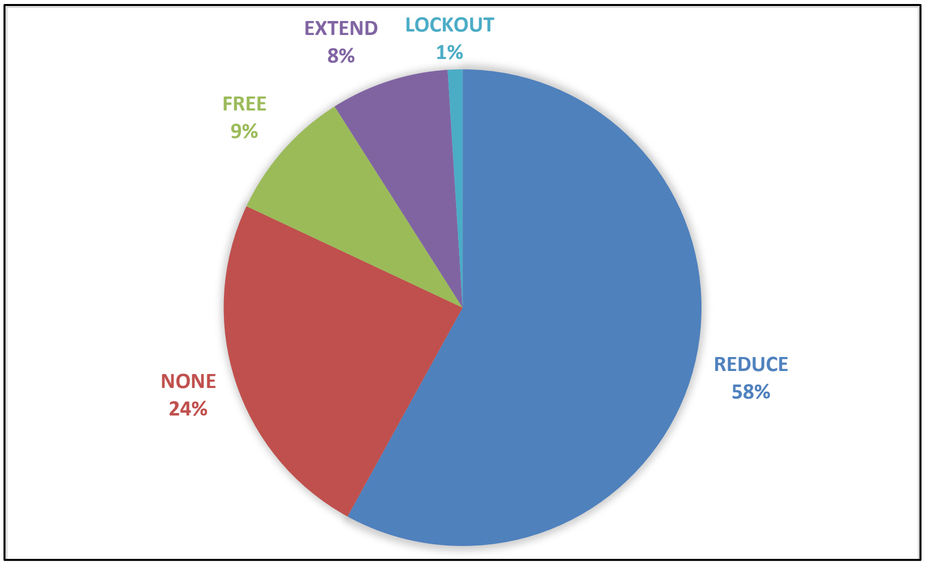

Figure 4: Signal Controller Response for TSP Requests During System Validation

Advanced Intersection Analytics

The Advanced Intersection Analytics system, powered by Derq's AI video analytics platform, utilized edge-based computing and cloud-hosted dashboards to process real-time traffic video feeds. Deployed across 20 intersections, the system captured vehicle counts, pedestrian activity, red light running, speeding, near misses, queue lengths, and arrivals on red.

The evaluation focused on measuring the accuracy, precision, and recall of the system's video analytics. Ground truth data was established through manual verification of recorded video footage, ensuring an objective comparison with the AI-detected events. The key performance metrics assessed include:

- **Traffic Insight Accuracy:** Correct identification of vehicle and VRU counts.
- **Safety Insight Precision & Recall:** Correct classification of near-miss events and violations.
- **Signal Performance Metrics (SPMs):** Accuracy of Arrival on Red, Queue Length Estimation, and Vehicle Delay.
- While the project's Implementation Plan set module accuracy thresholds at 90%, the original targeted 95% accuracy for AIA was not fully achieved. However, the observed accuracy exceeding 90% is still deemed effective for meeting stakeholder needs, as it reliably identifies trends and supports actionable countermeasures to improve safety and operations.

The quantitative performance evaluation showed high accuracy across most intersections, meeting or exceeding the 90% acceptance threshold for multiple key metrics.

Key highlights from this evaluation are summarized in Figure 5 on the following page and include the following:

- **Traffic Insight Accuracy:** Cumulative traffic count accuracy across all intersections was **92.2%**, with 98.00% for vehicles and 70.09% for VRUs.

  - AIA accuracy was validated against selected data collected during project deployment utilizing traditional data collection methods, such as independent field deployed cameras and sensors during AM and PM peak hours.
  - VRU counts have a lower accuracy rate compared to traditional data collection methods, as utilizing vehicle video detection feeds has a limited VRU field of view. The video detection feeds are focused on stop bar approaches. However, from the data and images captured throughout the project, RTC and other project partners were able to gain insights to VRU trends outside of traditional peak hours and travel pattern behaviors. RTC and project partners understand and accept the limitations in the field of view in order to achieve a project goal to utilize existing field devices for intersection analytics.

- **Safety Metrics:** Safety event precision exceeded **97.5%**, including red light running, speeding and near-miss classifications.
- **Signal Performance Metrics (SPMs):** Metrics such as arrival on red, queue length, and vehicle delay were tracked. However, due to insufficient data collected to date, the Signal Performance Measures (SPM) component could not be validated.
  - The existing detection cameras at four project locations have software capable of measuring arrivals on red and queue lengths. This feature was activated during the SMART Grant project as a method to validate the AIA SPM measurements. Both systems reported widely varying performance metrics that often had conflicting outcomes. As a result of conflicting results and insufficient data collected, it is not recommended to rely on signal performance data from this system or to implement this component in Stage 2.
- **Limitations:** Minor challenges included limited nighttime visibility at some intersections and field of view obstructions that slightly reduced queue detection accuracy. Additionally, some sites occasionally experienced sensor failures due to communication drops between the traffic management center and intersection equipment. These were mostly site-specific and can be addressed in Stage 2 through improved calibration, and deployment of more resilient communications infrastructure to ensure consistent connectivity.

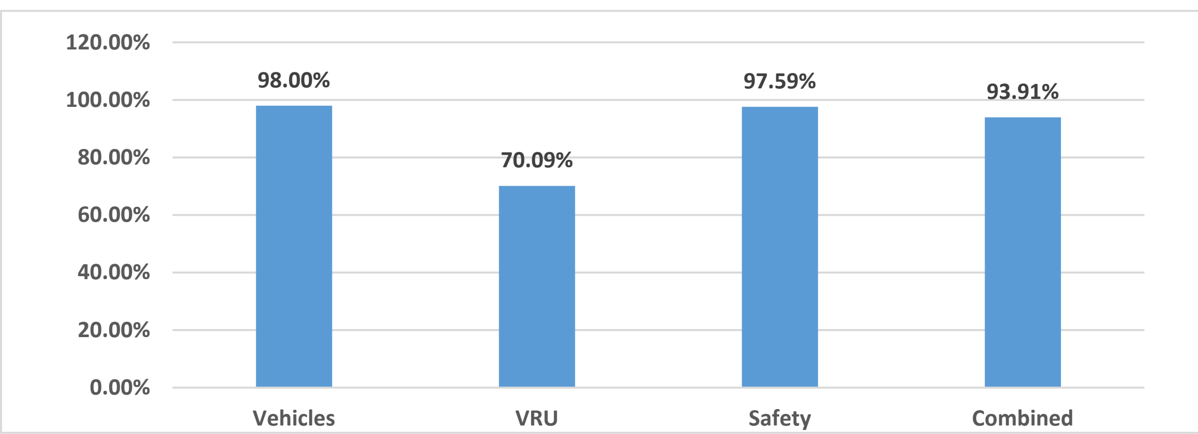

Figure 5: System Accuracy for Traffic and Safety Performance Measures

Safety Insights

The Advanced Intersection Analytics (AIA) system proved valuable in identifying and addressing critical safety issues at high-risk intersections. Through continuous video analytics and real-time data processing, AIA enabled the detection of high-precision safety violations, including frequent pedestrian near misses, red-light running and speeding incidents. These insights directly informed the implementation of a targeted countermeasure aimed at enhancing pedestrian and vehicular safety.

Leading Pedestrian Intervals (LPI)

Based on AIA-identified patterns of pedestrian safety violations, the City of Las Vegas deployed Leading Pedestrian Intervals (LPI) at three intersections along Charleston Blvd (Bruce Street, 4th Street, and 8th Street). These LPIs allow pedestrians to begin crossing before vehicles receive a green signal, improving their visibility and safety. Although the post-implementation data set was limited, the 8th Street site exhibited a notable reduction in pedestrian illegal crossings and violations by 9-17% and a 24% decrease in vehicle-vehicle near misses. During deployment of the LPI, Charleston Blvd and 4th St experienced an increase in safety events. Seeing this increase in all metrics, the project team further reviewed this specific location to determine what may have contributed to the increases. One condition that stood out, the City of Las Vegas hosts *First Friday* on the first Friday of each month. This event regularly draws in over 10,000 attendees each month to downtown Las Vegas. An influx of roadway users unfamiliar with the LPI could have an impact of the LPI deployment and other traffic signal timing strategies.
In Table 6, evaluation of safety metrics is shown for each of the LPI deployment locations.

Table 6: Evaluation of LPI Deployment

Intersection	Illegal Pedestrian Crossing Percent	Pedestrian Signal Violation Percent	Vehicle-Vehicle Near Miss Percent	Vehicle-VRU Near Miss Percent
Charleston at Bruce	-9.1	-2.4	+2.4	+8.8
Charleston at 8th	-16.7	-9.5	-23.9	-1.2
Charleston at 4th	+47.0	+31.0	+67.1	+213.3

While the evaluation period was limited for conclusive findings, the long-term benefits of LPI are well supported. According to the Federal Highway Administration (FHWA), LPI can reduce pedestrian-vehicle crashes at intersections by up to 60% over time when properly implemented and maintained (FHWA Proven Safety Countermeasures [1]).

Overall Impact of AIA on Safety Strategy

Though the results from the countermeasure implementations are constrained by limited before-and-after data periods and occasional sensor data gaps, AIA's contribution to safety improvement is clear.
By revealing real-time safety challenges and prioritizing high-risk intersections, AIA enabled data-driven decision-making that led to an actionable intervention. An integral part of this approach was the development of an online data integration and warehousing solution, which facilitated multimodal insights and ongoing evaluation across the corridor. These early efforts, when sustained and further evaluated over longer periods, are expected to yield measurable safety improvements across the corridor.

[1] FHWA-SA-21-032: Proven Safety Countermeasures, Leading Pedestrian Interval

Evaluation Against Original Project Goals

The Stage 1 implementation met or exceeded several of the project's original expectations as highlighted in Table 7.

Table 7: Evaluation of Stage 1 Outcomes Against Project Goals

Goal from Proposal	Evaluation Summary
Reduce traffic-related fatalities and injuries	AIA detected high-precision safety violations and informed the deployment of LPIs, a known countermeasure.
Reduce traffic congestion and improve travel-time reliability	TSP improved travel-time reliability by 4–6%, significantly reducing delay and improving transit performance.
Provide public access to real-time, multimodal information	The deployment of cloud-based TSP improved OTP by 4-6% in the AM and PM peak hours. Transit customers who regularly use mobile device applications such as Transit or RTC app, can gain real-time transit vehicle location
Improve access to jobs and essential services	Improved OTP along Route 206, serving underserved areas, enhanced transit reliability and reduced travel time, particularly benefiting home-to-work and other essential trips.

Statutory Outcomes Demonstrated During Stage 1

The Stage 1 deployment supports key national priorities, demonstrating the potential for broader regional or national benefits:

- **(I) Reduce Congestion and Delays:** Along RTC Transit Route 206, the Traction TSP system effectively reduced bus delays at 13 signalized intersections. On average, bus approach delays decreased by 7% (about 3 seconds per intersection) on weekends and 12% (about 6 seconds per intersection) on weekdays, resulting in total time savings of approximately 39 to 78 seconds per bus trip along the corridor.
- **(II) Improve Safety and Integration:** AIA enabled real-time detection of speeding and red-light running violations and pedestrian near-miss risk areas, directly supporting safety initiatives like Leading Pedestrian Intervals (LPI).
- **(III) Improve Access to Essential Services:** Enhancing transit reliability along RTC Transit Route 206 improved access to jobs and services, especially within Historically Disadvantaged Communities (31 of 35 census tracts in the pilot area).
- **(IV) Expand Access and Reduce Costs for Underserved Communities:** Improvements along RTC Transit Route 206 addressed mobility gaps in low-income and transit-dependent neighborhoods.
- **(V) Contribute to Economic Competitiveness:** More reliable transit and reduced signal delays support workforce mobility and commercial access in downtown Las Vegas and the Las Vegas Medical District.
- **(VI) Improve System Reliability:** Cloud-based TSP provided a centralized, maintainable, and remotely tunable system that responded consistently during the pilot. Reliable cloud-based technologies can begin to reduce the historic reliance on installing hardware-based field devices.

- **(VII) Promote Connectivity Across Modes:** The integration of AVL data, signal systems, and AI dashboards enabled a seamless flow of real-time information among transit, traffic signals, operations, and engineering teams.
- **(VIII) Incentivize Private Sector Partnerships:** Vendors Kimley-Horn and Derq provided cloud-based services, demonstrating strong public-private collaboration and scalable delivery models.
- **(X) Increase System Resiliency:** The transition from hardware-based to cloud-based technologies creates a more adaptable system with fewer failure points and easier remote troubleshooting.
- **(XI) Improve Emergency Response:** While EVP was not included in Stage 1, system integration groundwork was laid, and CAD/AVL data access challenges were identified and addressed in preparation for Stage 2.

Conclusion

The Stage 1 proof-of-concept successfully validated the functionality, scalability, and impact potential of cloud-based TSP and AIA technologies. The evaluation confirms that these innovations can deliver measurable improvements in transit reliability, safety, and system integration, particularly in underserved areas. With refinements to data sharing and local support capacity, the project is well-positioned for Stage 2 deployment and regional expansion.

Part 4: Anticipated Costs and Benefits of At-Scale Implementation

Anticipated Impacts by Key Goal Area

Based on findings from Part 3 and performance results from Stage 1, the following qualitative assessments outline expected impacts from full-scale deployment across the statutory SMART Grant goals as highlighted in Table 8.

Table 8: Projected Impacts of At-Scale Implementation by SMART Statutory Goal

SMART Statutory Goal	Expected Impact of At-Scale Implementation
(I) Reduce congestion and delays for commerce and the traveling public	TSP expansion across key transit corridors is expected to reduce travel times for buses by 7–15%, easing general traffic congestion. EVP will minimize delays for emergency responders and decrease signal transition times.
(II) Improve safety and integration of systems for all users	AIA provides real-time safety event detection (e.g., red light running, near misses). Data-driven insights support the installation of safety countermeasures such as LPIs and refined signal timing plans for vulnerable road users (VRUs).
(III) Improve access to jobs, education, and essential services	Improved transit reliability across priority corridors serving Historically Disadvantaged Communities (HDCs) enhances access to healthcare, employment, and education.
(IV) Expand access for underserved populations and reduce transportation costs	Stage 2 will focus on corridors in areas with low car ownership and high transit dependence, reducing total travel times and improving transit accessibility and affordability.
(V) Contribute to economic competitiveness	Reduced travel delays and improved emergency response times enhance regional mobility and business productivity. TSP reduces lost time for the workforce, supporting economic resilience.
(VI) Improve system reliability	Cloud-based architecture with remote diagnostics and tuning reduces downtime and variability in system performance.
(VII) Promote connectivity among users and infrastructure	CAD/AVL data, smart traffic signals, and AI analytics dashboards will enable data exchange among connected vehicles, intersections, and public safety systems.
(VIII) Incentivize private sector investment	Ongoing partnerships with AIA and cloud-based TSP/EVP providers demonstrate effective vendor engagement.
(IX) Improve energy efficiency or reduce pollution	Reduced idling from TSP and EVP is projected to lower emissions and fuel consumption, aligning with efficiency goals.
(X) Increase resiliency of the transportation system	The shift from hardware-heavy to cloud-based platforms ensures scalability, easier maintenance, and adaptation to future operational changes.
(XI) Improve emergency response	At-scale EVP will reduce average response time and improve consistency in emergency vehicle passage through signalized intersections across jurisdictions.

Anticipated Costs of At-Scale Implementation

The total estimated cost for full-scale deployment (Stage 2) is derived from vendor quotes, operational planning, and the proof-of-concept pilot as shown in Table 9.

Table 9: At-Scale Implementation Costs (Stage 2)

Cost Element	Estimated Value
Infrastructure Investments (signals, edge devices, cloud systems)	$19,480,000
Annual Operations & Maintenance (O&M)	$5,500,000/year (28.2% of capex assumed for tech updates and replacement) [a]
15-Year Discounted Total Cost (including O&M)	$57,364,131

[a] Assumes a 15-year analysis period; higher annual O&M accounts for technical updates and equipment replacement.

Cost-Benefit Comparison

A Benefit-Cost Analysis (BCA) conducted for Stage 2 projects a Benefit-to-Cost Ratio (BCR) of 3.07, indicating that benefits far exceed anticipated costs, over 15 years (the use of 15 years period for the analysis is justified in the appendix), shown in Table 10.

Table 10: Summary of Costs and Benefits

BCA Summary	Value
Total Discounted Benefits	$176,312,617
Total Discounted Costs	$57,364,131
Net Benefits	$118,948,486

Major monetized benefits include:

- ~$19.6M annually in reduced emergency response fatalities (using VSL methodology)
- ~$4.1M annually in time savings for transit riders

Non-monetized benefits include:

- **Environmental Impact:** Reduction in vehicle emissions and fuel consumption due to decreased idling times. This benefit was not ignored but was not estimated for this analysis.
- **Economic Gains:** Long-term benefits include cost savings from reduced travel times, lower vehicle operating costs, and increased productivity. This benefit was not ignored but was not estimated for this analysis.
- **Safety benefits from implementing LPI:** LPI installations were informed by observations made possible by Advanced Intersection Analytics. LPI is a proven FHWS safety countermeasure (13% reduction in pedestrian-vehicle crashes at intersections).

Preliminary Baseline Data for Evaluation

The following baseline data was collected during Stage 1 to support Stage 2 evaluation, shown in Table 11.

Table 11: Stage 1 Baseline Data for Evaluating At-Scale Implementation

Metric Area	Baseline Level (Pre-Stage 1)
Transit OTP (Route 206)	63–67 percent weekday OTP before TSP deployment
Average Bus Delay (TSP intersections)	~59 seconds per intersection
Red Light Violation Rate (percent of Vehicles)	Red light running occurs at a rate of 7-10 percent of all vehicle traffic entering an intersection.
Safety Violations (AIA)	Red light running observed at ~2–5 violations/day at select intersections
AIA System Accuracy	Vehicle counts: 92.2 percent, Safety precision: 97.6 percent

Part 5: Challenges & Lessons Learned

Stage 1 implementation revealed several critical lessons to improve readiness and execution in Stage 2. The project successfully piloted cloud-based technologies but also encountered institutional and technical hurdles. New insights included:

- **Scope of Work Timing:** Future projects should have draft scopes of work nearly finalized for RFPs as soon as award notification is anticipated to avoid procurement delays.
- **Multi-Vendor Coordination:** Integrating transit signal priority (TSP) and traffic management technologies from multiple vendors (e.g., Swiftly, Traction, Trafficware controllers, and ATMS.now) required strong interagency coordination. Occasional data feed misalignments led to TSP validation delays, highlighting the importance of early integration testing and clear data interface standards for future phases.
- **Quality Assurance:** Continuous QA was essential to identify issues such as signal communication delays and geo-fence misalignment.
- **Late Stakeholder Identification:** It was discovered mid-project that 3rd party emergency dispatch services were contracted with Clark County Fire Department, not the City of Las Vegas Fire & Rescue, requiring new stakeholder engagement and delaying access to critical CAD/AVL data. While working closely with 3rd party vendor, their own product development of a new API prevented access to the existing API for new customers.
- **Remote Vendor Limitations:** A few limitations stemmed from the AIA system's event detection and classification capabilities. Many questions arose during the pilot regarding how specific events were categorized, highlighting the need for more in-depth training and clearer documentation. Future phases should include comprehensive training on the AIA system's functionality and enhance transparency around its analytical processes.
- **Identifying and Deployment of Countermeasures:** While AIA can deliver traffic and safety insights much earlier and on a greater scale than traditional data collection and analysis methods, engineering staff need to review the insights prior to selecting and deploying countermeasures. The deployment of LPI at 4 differing intersections, in terms of geometrics and operations, resulting in varying outcomes highlighted the need for selection of context sensitive solutions and continuous monitoring post deployment.

To improve future planning and execution for Stage 2, Table 12 summarizes the challenges and corresponding lessons learned.

Table 12: Challenges and Lessons Learned

Challenge	Lesson Learned
Preparing scope of work requirements for RFP solicitation after USDOT agreement executed	Begin drafting scope of work requirements as soon as the notice of award is anticipated to ensure readiness for timely advertisement and contract execution.
Multi-Vendor Coordination	Ensure strong interagency communication and early data alignment when integrating TSP and traffic management systems from multiple vendors (e.g., Swiftly, Traction, Trafficware controllers, and ATMS.now) to avoid TSP validation delays and ensure seamless system interoperability
Quality Assurance	Continuous QA is essential to identify issues such as signal communication delays.
Late Stakeholder Identification	Ensure early and comprehensive stakeholder identification and analysis during project development, including mapping roles, systems, and jurisdictions, to avoid mid-project surprises.
Ongoing effort to establish CAD/AVL data-sharing agreement	Allocate time in project schedules for formal agreements with external entities, or 3rd party vendors. Initiate discussions as early as possible.
Intersection analytics system lacked system failure alerts	Develop and implement real-time monitoring and alert features to flag system disruptions and data irregularities early.
Equipment issues misrepresented red-light running data trends	Implement validation checks to differentiate between true traffic behavior changes and equipment-related anomalies.
Reliance on local agency/vendor support while Vendor team is remote	Consider local staffing or support agreements to reduce downtime in troubleshooting and improve response times.
Limited understanding of how the AIA system categorizes events	Include comprehensive training on the AIA system's functionality to enhance transparency around its analytical processes.

Part 6: Deployment Readiness

RTC identified several critical institutional, technical, labor, and data governance components that must be addressed to ensure a successful Stage 2 deployment. These include:

1. Institutional Implications:
    a. Early identification and engagement of all stakeholders, including emergency services and municipal traffic agencies.
        i. RTC-FAST has initiated conversations with Clark County, City of Henderson and City of North Las Vegas traffic engineering and fire departments for early identification of high risk signalized intersection ideal for AIA deployment and any cloud-based EVP pilot project findings.
    b. Advance preparation of RFP scopes of work prior to Stage 2 grant award notification.
    c. Expand TSP Business Rules for multiple route hierarchy.
        i. RTC-FAST and RTC-Transit have discussed At-Scale deployment, which includes the expansion of Transit Route 206 – Charleston (east-west route) and Transit Route 109 – Maryland (north-south route).
2. Technical Implications:
    a. Ensure fiber communications are in place at all intersections identified for Emergency Vehicle Preemption (EVP).
    b. Plan for potential replacement or upgrades of video detection systems in out-years (Years 3–4).
    c. Expand alert protocols for video loss, latency issues, or abnormal traffic trends.
3. Labor Considerations:
    a. RTC will assess the labor implications of the three proposed technology deployments and develop training and reskilling strategies as part of Stage 2.
    b. Provide hands-on training for local staff, especially in using vendor analysis tools such as Vendor's dashboard and analytics.
    c. Support small, women-owned, and minority-owned businesses through training and re-skilling aligned with new system deployments.
    d. Build local support capacity to reduce reliance on remote vendor troubleshooting.
4. Data Governance and Privacy:
    a. RTC will develop a comprehensive data management policy addressing storage, access controls, retention durations, and procedures specific to AI-driven analytics.
    b. Develop and enforce a data management policy to define storage durations, access control, and PII safeguards.
    c. No license plate or personally identifiable information will be collected by the system.

Part 7: Wrap-Up

Project Successes Achieved in Stage 1

The Stage 1 implementation successfully demonstrated the effectiveness of cloud-based Transit Signal Priority (TSP) and Advanced Intersection Analytics (AIA) technologies in a high-demand corridor. TSP, deployed at 17 intersections along RTC Transit Route 206, improved weekday on-time performance by up to 13% during peak hours and reduced intersection delay by 12%. Bus travel time savings averaged 24–27 seconds per TSP event, with EXTEND signal phase actions achieving up to 63 seconds of saved time.

The Advanced Intersection Analytics (AIA) technology, deployed at 20 intersections, has proven that it capable of providing important traffic operations and safety measures and insights. These insights can improve operations and safety and are useful in managing and optimizing the roadway system for all modes of travel and provide a basis for prioritizing investment decisions. The collected measures and safety insights perform well with accuracy above 90% when the video feeds is reliable and consistent. Even though the AIA for the Stage 1 SMART demonstration using existing detection feeds that were not meant to be used for AIA use case, the AIA still provided good results that RTCSN can build on and enhance in Stage 2 to provide excellent mobility and safety measure and insights. The AIA technology has proven viable and reliable for large-scale implementation.

In addition to these performance-based outcomes, the project achieved several strategic and institutional milestones. Most notably, the development of the RTCs first TSP Business Rules document marked a significant advancement in internal policy and operations. While not directly measurable in traditional metrics, this document establishes a foundational framework for ongoing and future TSP deployments. It strengthens internal understanding, formalizes decision-making processes, and enables consistent coordination between key stakeholders such as IT, signal operations, and the transit department. This institutional asset will continue to support effective and scalable implementation of TSP strategies across the region.

Expected Benefits of Full-Scale Implementation

The forthcoming Stage 2 deployment will scale these proven technologies region-wide, with the integration of EVP and broader TSP coverage. The expected benefits include:

- Improved Emergency Response Times: EVP will reduce delays for emergency responders, improving safety outcomes and reducing fatalities, with monetized benefits estimated at nearly $20 million annually.
- Increased Transit Reliability and Efficiency: Scaling TSP is projected to enhance service across the region’s most delay-prone routes, producing over $4 million in annual economic time savings for transit users.
- Enhanced Data for Safety and Operations: Expanded AIA deployment will improve the accuracy and timeliness of traffic performance metrics, accurate traffic counts and traffic safety insights enabling responsive engineering and traffic operation strategies.
- High Return on Investment: A Benefit-to-Cost Ratio of 3.07 reinforces the strong financial justification for full-scale deployment, with $176 million in total projected benefits over 15 years.

Next Steps and Additional Evaluations

RTC will initiate Stage 2 by refining RFP scopes and engaging new and existing stakeholders, including two fire and rescue agencies for EVP integration. Evaluation efforts will continue through enhanced before-and-after studies, expanded data sharing agreements, and the development of real-time alert systems for analytics anomalies. Additional focus will be placed on training local staff and building regional technical capacity to support sustained operations and maintenance. A comprehensive data privacy policy will also be finalized to ensure secure handling of AI-derived insights.

RTC is investing in over $6.5 million to upgrade the central traffic system, which includes new traffic signal controllers, firmware and central traffic system software. This investment will allow more robust and streamlined TSP and EVP deployment during SMART Grant Stage 2 at-scale implementation.

Appendix: Anticipated Costs and Benefits of At-Scale Implementation

Performance measures were developed from the project's goals and objectives. The following performance measures can be quantified to develop the benefits of at-scale implementation:

1. Reduce emergency response times to incidents and/or transporting patients by 5 percent.
2. Increase the on-time performance of bus transit by 3 percent.

Data from stage 1 deployment and the proposed technology systems for stage 2 will be used to quantify these specific metrics and estimate the anticipated costs and benefits of at-scale implementation. Assumptions and references are included since current data is not available yet from stage 1 implementation.

Approach and Assumptions

Benefits from EVP

Reducing emergency response time is expected to decrease the number of related fatalities. The statistical value of life is then used to monetize this benefit.

Recent studies suggest that reducing emergency response times can significantly decrease fatalities. One study indicates that reducing response time by just one minute could lead to a 17% reduction in mortality rates in emergency situations like cardiac arrest and trauma[2]. The study indicates that if it was possible to decrease the median emergency response time by 1 min, 0.00035 lives could be saved for every turn-out on average.

These findings highlight the critical impact of response times on survival rates, supporting the deployment of cloud-based EVP to enhance emergency response efficiency.

The U.S. Department of Transportation (USDOT) provides guidance on the Value of Statistical Life (VSL) [3]. This document provides guidelines for estimating the value of reducing fatalities and injuries. Based on the methodology adopted in the guidance, an estimated value of $13.2 million will be used to represent the VSL for the analysis base year of 2025.

To estimate the value per year for the deployment for emergency response time improvements, we can use the following equation:

Estimated Value per Year per project deployment $=(\Delta T/T)\times N\times V\times F$

Where:

- ΔT is the reduction in response time (assume 1 minute).
- T is the original average emergency response time to incidents and/or transporting patients (in minutes) before improvements ($\Delta T/T=5\%$).
- N is the number of runs for medical emergencies per year.

[2] https://link.springer.com/article/10.1007/s10694-016-0592-4

[3] https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis

- V is the average value of life saved per emergency response ($13.2 million).
- F is the fatality reduction factor, based on studies such as the one indicating 0.00035 lives could be saved for every 1-minute saving in response time on average.

In Las Vegas, emergency response vehicles handle a substantial number of calls annually. The Las Vegas Fire & Rescue Department responds to approximately 100,000 to 120,000 calls per year for medical and crash-related emergencies specifically. Around 70-80% of these annual calls are for medical emergencies and traffic accidents. In 2020, there were 84,694 emergency medical responses by the Las Vegas Fire & Rescue Department. Therefore, it is estimated that about 85,000 emergency medical responses would be made annually within the deployment area of Emergency Vehicle Preemption (EVP), covering 1,040 of the 1,299 signalized intersections within the City of Las Vegas.

Applying the above equation and assumptions results in a project benefit of $19,635,000 per year due to the Stage 2 deployment of EVP.

This calculation provides a rough estimate of the economic value per year per deployment area due to reduced emergency response times.

Benefits from TSP

Transit signal preemption is expected to improve on-time performance of transit services within the deployment area. An increase in the on-time performance of transit will result in shorter travel times for passengers, leading to time savings. The value of time is then used to monetize this benefit.

The U.S. Department of Transportation (USDOT) provides guidance on the value of travel time savings, which is used in transportation project evaluations[4]. For 2025, the average value of time for personal travel is about $18.80 per hour per person for all travel purposes, including commuting, business, and personal travel. Given the similarities in urban transit environments across major U.S. cities, this average serves as a reasonable estimate for Las Vegas residents.

To estimate the value per year per location for ridership travel time savings, you can use the following equation:

Estimated Value per Year per deployment area=$\Delta T \times P \times V \times D$

Where:

- ΔT is the reduction in transit travel time per trip (minutes).
- P is the number of bus passenger trips per year.
- V is the average value of time per passenger per hour ($18.80).
- D is the conversion factor to express the time saved in hours (since ΔT is in minutes, D=1/60).

[4] Benefit-Cost Analysis Guidance for Discretionary Grant Programs. https://www.transportation.gov/sites/dot.gov/files/2022-03/Benefit%20Cost%20Analysis%20Guidance%202022%20Update%20%28Final%29.pdf

According to RTC, the total bus ridership in 2023 across 39 routes was 49,590,971 trips. The Stage 2 deployment plans to implement Transit Signal Priority (TSP) on five major transit corridors that experience the highest delays for transit vehicles at signalized intersections. This deployment is estimated to involve about 100 signalized intersections, covering approximately 7 miles of bus routes. As a result, this will impact approximately 15% of the ridership, equating to around 7,440,000 bus passenger trips per year.

The time savings per bus trip due to the implementation of Transit Signal Priority (TSP) can vary based on several factors, including the type of TSP system, the level of traffic congestion, and the specific corridor or route where TSP is implemented. However, based on various studies and implementations, a modest estimate of time savings can be assumed to be 1 minute per bus passenger trip:

1. **General Estimates[5]:** Studies have shown that TSP can save buses approximately 5-15% of their total travel time. For typical urban bus routes, this often translates to savings of 1-3 minutes per trip, depending on the length and conditions of the route.
2. **Stage 1 results:** Overall weekday delay decreased by 12%, with a peak reduction of 16% during AM peak hours. The average time saved per intersection along Route 206 was approximately 7 seconds, totaling a savings of 105 seconds (1.75 minutes) over the entire route.
3. **Other Specific Examples:**
   - **Los Angeles Metro:** Implementations of TSP have resulted in average time savings of about 1.5 to 3 minutes per bus trip.
   - **Seattle:** In Seattle, TSP implementations have shown time savings of around 1-2.5 minutes per bus trip during peak hours.
   - **San Francisco:** The San Francisco Municipal Transportation Agency (SFMTA) reported savings of approximately 1.5 minutes per trip on routes where TSP was deployed.
   - Based on the above a value of 1.75 minutes per trip will be assumed.

Applying the above equation and assumptions results in a project benefit of $4,079,600 per year due to the phase 2 deployment of TSP.

This calculation provides an estimate of the economic value per year per deployment area due to reduced transit travel times.

Benefit / Cost Analysis

This section outlines the projected costs and benefits associated with deploying smart intersections in a city over the next 15 years. This analysis includes calculations of net present value (NPV) and sensitivity analysis to assess the impact of potential variations in costs and benefits.

5 https://www.itskrs.its.dot.gov/2009-b00613

Projected Costs

The total project costs include initial installation, annual maintenance, and operational costs. These costs are projected over a 15-year period, considering inflation and technological upgrades.

Stage 2 At-Scale Implementation Costs:

- $ 1,500,000 for Intersection Analytics at 20 traffic signals
- $12,480,000 for TSP/EVP, (This estimate assumes an installation cost of $12,000 per intersection for 1,040 intersections for EVP, which also includes TSP installation at 100 intersections).
- $ 5,500,000 per year for Operation and Maintenance, (includes annual subscription (SaaS)TSP/EVP service cost and upgrades/replacements).
- Total At-Scale Cost $19,480,000 (Stage 2).

Project Costs (Undiscounted – 2025 $)

Year	Capital Costs	O&M Costs	Total Costs
2025	—	—	—
2026	—	—	—
2027	$ 10,000,000	—	$ 10,000,000
2028	$ 9,480,000	—	$ 9,480,000
2029	—	$ 5,500,000	$ 5,500,000
2030	—	$ 5,500,000	$ 5,500,000
2031	—	$ 5,500,000	$ 5,500,000
2032	—	$ 5,500,000	$ 5,500,000
2033	—	$ 5,500,000	$ 5,500,000
2034	—	$ 5,500,000	$ 5,500,000
2035	—	$ 5,500,000	$ 5,500,000
2036	—	$ 5,500,000	$ 5,500,000
2037	—	$ 5,500,000	$ 5,500,000
2038	—	$ 5,500,000	$ 5,500,000
2039	—	$ 5,500,000	$ 5,500,000
2040	—	$ 5,500,000	$ 5,500,000
2041	—	$ 5,500,000	$ 5,500,000
2042	—	$ 5,500,000	$ 5,500,000
2043	—	$ 5,500,000	$ 5,500,000

Projected Benefits

The benefits from the smart intersections include reductions in emergency response times, improvements in transit on-time performance, and potential reductions in traffic-related fatalities. The following table projects these benefits over the next 15 years.

2025 $ (Undiscounted)

Year	Costs	Benefits		
	Total Costs	Travel Time Savings	Safety	Total Benefits
2025	—	—	—	—
2026	—	—	—	—
2027	$10,000,000	—	—	—
2028	$9,480,000	—	—	—
2029	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2030	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2031	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2032	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2033	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2034	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2035	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2036	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2037	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2038	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2039	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2040	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2041	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2042	$5,500,000	$4,079,600	$19,635,000	$23,714,600
2043	$5,500,000	$4,079,600	$19,635,000	$23,714,600
Total	$101,980,000	$61,194,000	$294,525,000	$355,719,000

Net Present Value (NPV) Calculation

The Net Present Value (NPV) is calculated to determine the project's financial viability. NPV considers the time value of money by discounting future cash flows to present value using a specified discount rate. A positive NPV indicates that the projected benefits exceed the costs, justifying the investment.

Formula:

$$\text{NPV} = \sum_{t=1}^{n} \frac{\text{Benefits}_t - \text{Costs}_t}{(1+r)^t}$$

Where:

- *t* is the year (from 1 to n).
- Benefits is the total benefits in year t.
- Costs_t is the total costs in year t.
- r is the discount rate (7%).
- n is the total number of years (15 years in this analysis).

2025 $ (Discounted)

Year	Costs	Benefits			NPV
	Total Costs	Travel Time Savings	Safety	Total Benefits	
2025	—	—	—	—	—
2026	—	—	—	—	—
2027	$8,734,387	—	—	—	$(8,734,387)
2028	$7,738,504	—	—	—	$(7,738,504)
2029	$4,195,924	$3,112,307	$14,979,447	$18,091,755	$13,895,831
2030	$3,921,424	$2,908,698	$13,999,484	$16,908,182	$12,986,758
2031	$3,664,882	$2,718,410	$13,083,630	$15,802,039	$12,137,157
2032	$3,425,124	$2,540,570	$12,227,691	$14,768,261	$11,343,137
2033	$3,201,050	$2,374,364	$11,427,749	$13,802,113	$10,601,063
2034	$2,991,636	$2,219,032	$10,680,139	$12,899,171	$9,907,536
2035	$2,795,921	$2,073,862	$9,981,438	$12,055,300	$9,259,379
2036	$2,613,010	$1,938,189	$9,328,447	$11,266,636	$8,653,625
2037	$2,442,066	$1,811,391	$8,718,175	$10,529,566	$8,087,500
2038	$2,282,304	$1,692,889	$8,147,827	$9,840,716	$7,558,411
2039	$2,132,995	$1,582,139	$7,614,792	$9,196,931	$7,063,936
2040	$1,993,453	$1,478,635	$7,116,628	$8,595,262	$6,601,809
2041	$1,863,040	$1,381,902	$6,651,054	$8,032,955	$6,169,915
2042	$1,741,159	$1,291,497	$6,215,938	$7,507,435	$5,766,276
2043	$1,627,252	$1,207,006	$5,809,288	$7,016,294	$5,389,043
Total	$57,364,131	$30,330,891	$145,981,726	$176,312,617	$118,948,486

Discount Rate =	7%
Total Discounted Costs	$57,364,131
Total Discounted Benefits	$176,312,617
NPV	$118,948,486
BCR	3.07

Sensitivity Analysis

A sensitivity analysis examines how the uncertainty in the input variables (costs and benefits) impacts the NPV. This analysis considers scenarios where project costs and benefits vary by ±20%. The results provide insight into the project's robustness against potential fluctuations, with the resulting Benefit-Cost Ratio (BCR) ranging from 2.05 to 4.61.