Expanding Connected Vehicle Data Framework (CVDF) Data Sources to Increase Applications and Use on Texas Roadways

TxDOT Project No. 0-7164

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THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

Technical Report Documentation Page

1. Report No. FHWA/TX-25/0-7164-1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Expanding Connected Vehicle Data Sources to Increase Applications and Use on Texas Roadways		5. Report Date Submitted: July 2024
		6. Performing Organization Code
7. Author(s) Anna McAuley, PhD; Andrea Gold; Kristie Chin, PhD		8. Performing Organization Report No. 0-7164
9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin 3925 W. Braker Lane, 4th Floor Austin, TX 78759		10. Work Unit No. (TRAIS) 11. Contract or Grant No. 0-7164
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Division 125 E. 11th Street Austin, TX 78701		13. Type of Report and Period Covered Technical Report August 2022 – August 2024 14. Sponsoring Agency Code
15. Supplementary Notes Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.		

16. Abstract

As connected freight and passenger vehicles become increasingly present on Texas roadways, the need for real-time, accurate, and cohesive data is growing. In some cases, this data is reliable and readily available to public agencies. In other cases, there are gaps in data availability or quality. A connected vehicle data framework (CVDF) enables the meaningful exchange of information between the Texas Department of Transportation (TxDOT), other public agencies, and third-party data providers who can be valuable assets in improving roadway safety, maintenance, and mobility. Project 0-7164 aims to leverage the existing CVDF developed through the Texas Connected Freight Corridors (TCFC) project to establish an understanding of data needs for connected vehicle (CV) applications and expand availability of that data from public agencies and third-party data providers.

17. Key Words	18. Distribution Statement
• Connected vehicle technologies, connected vehicle data, connected vehicles, data sharing, traveler information and communication systems, road weather information systems, digital infrastructure, real time information	No restrictions. This document is available to the public through the National Technical Information Service, Alexandria, Virginia 22312; www.ntis.gov.

19. Security Classif. (of report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	TBD [Total count excl. cover]	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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CTR Technical Report:	0-7164-1
Report Date:	Submitted: July 2024
Project:	0-7164
Project Title:	Expanding Connected Vehicle Data Framework (CVDF) Data Sources to Increase Applications and Use on Texas Roadways
Sponsoring Agency:	Texas Department of Transportation
Performing Agency:	Center for Transportation Research at The University of Texas at Austin

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

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Research Supervisor: Kristie Chin

Acknowledgments

The research team would like to express appreciation to the TxDOT Project Manager, Martin Dassi; the members of the TxDOT Project Monitoring Committee, Jianming Ma, Benjamin McCulloch, Charles Tapp, Matthew McCarty, and Steve Chiu; and research collaborators at Southwest Research Institute, Eric Thorn, Darin Parish, and Charles Hirsch.

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1 | INTRODUCTION

As connected freight and passenger vehicles become increasingly present on Texas roadways, the need for real-time, accurate, and cohesive data is growing. In some cases, this data is reliable and readily available to public agencies. In other cases, there are gaps in data availability or quality. A connected vehicle data framework (CVDF) enables the meaningful exchange of information between the Texas Department of Transportation (TxDOT), other public agencies, and third-party data providers who can be valuable assets in improving roadway safety, maintenance, and mobility. Project 0-7164 aims to leverage the existing CVDF developed through the Texas Connected Freight Corridors (TCFC) project to establish an understanding of data needs for connected vehicle (CV) applications and expand availability of that data from public agencies and third-party data providers. Major tasks include the following:

- Conduct interviews and outreach with public agencies to determine the current availability of data for CVDF applications.
- Identify, prioritize, and develop additional CVDF-supported applications and determine corresponding data needs.
- Analyze opportunities for partnerships with third-party data services to augment supported applications and data quality and availability.
- Streamline data sharing by establishing reporting, formatting, and use standards.
- Leverage existing CVDF to encourage effective, expanded use in the public and private sectors.

Project Overview

The University of Texas at Austin Center for Transportation Research (CTR), in partnership with Southwest Research Institute (SwRI), developed and tested a Road Weather Warning application that is integrated to the Connected Vehicle Data Framework (CVDF). The application uses data from Environmental Sensor Stations (ESSs) to disseminate alerts about adverse weather conditions to drivers.

Strengths

Lonestar Integration: Pulling from the CVDF feed simplifies data entry for TxDOT and Lonestar users, who are already familiar with the Lonestar event creation interface. There are also opportunities to scale the CVDF to other Lonestar users and integrations.

Data Timeliness: The CVDF provides data to third-party users with relatively low latency. This is important for safety-critical CVDF applications.

Standardized and Secure: The CVDF incorporates and adheres to industry data standards. The CVDF also uses a Security Credential Management System (SCMS) to allow for secure and verified data exchange. The SwRI team can also track who is querying from the CVDF and how often.

Accessible: Queries to the CVDF are made through a RESTful interface, which is a web-based portal. This makes data requests more accessible to broader audiences. The CVDF also supports bulk downloads, which makes data downloads easier for the user.

Limitations

Lonestar Shortcomings: Because the CVDF pulls from Lonestar feeds, data is limited to what is available on the C2C feeds. Some public agencies are integrated with Lonestar, but in many cases, the CVDF would not have data about events on off-system roads. Additionally, event data is more readily available and reliable in urban areas; smaller districts do not always create events in Lonestar.

Unidirectional: Data exchange is currently unidirectional—third-party users can request data from the CVDF, but the CVDF cannot ingest any data from the third parties.

Manual Data Entry: Events in Lonestar are still largely created manually. In some cases, an event will be detected and auto-generated but still needs human verification to be finalized.

Request-and-Response Structure: Third-party users must query data through a request-and-response structure. This means that when the user queries, the data they only get the data that is currently available. There isn't a way for a user to request updates over a period of time.

Opportunities for Expansion

Develop Bidirectional Data Sharing: Ingesting supplemental data from CVs and third-party service providers will allow TxDOT to have more complete roadway data. For example, real-time data on vehicle speed and braking could be used to enhance queue or collision detection, and data on windshield wiper use could be used to develop road weather warnings.

Integrate External Agency Data into C2C Feed: While some public agencies use Lonestar data, there is a gap in event data for off-system roads. Non-TxDOT infrastructure owners and operators (IOOs) should share data on closures, incidents, etc. that occur on their network with the Lonestar feed so that road users receive warnings and notifications.

Leverage Existing TxDOT Data to Support Additional Applications: In addition to the road closures, incidents, and traveler messages that the CVDF currently supports, it is likely that TxDOT has other data that could be important to road users. For example, warnings about bridge heights, truck parking availability, or low water crossing status could be disseminated through the CVDF.

Partner with Additional Third-Party Providers: Currently, Drivewyze is the third-party service provider partnering with the TCFC team to disseminate CVDF information to road users through the Drivewyze smart device application. There may be other service providers that the research team could work with to increase coverage.

3 | CONDUCT STAKEHOLDER INTERVIEWS

Interviews and Discussion Questions

Based on feedback from the Project Management Committee, the project team identified stakeholders in both the public and private sectors that are involved in Connected Vehicle (CV) deployments or activities. These interviews were aimed at understanding current related efforts by TxDOT and peer agencies, identifying CV infrastructure needs and potential opportunities for the CVDF, prioritizing CV applications, and developing fleet, agency, and data partnerships. Table 1 below summarizes the stakeholders interviewed.

Table 1: Stakeholder Interview List

Sector	Agency and/or Department
Public	TxDOT – Data Management
	TxDOT – TPAS Project
	TxDOT – Houston District
	Florida DOT
	Minnesota DOT
	City of Austin
	North Central Texas Council of Governments
Private	Gatik
	Panasonic
	H-E-B
	CocaCola
	PepsiCo
	Crete
	Kodiak
	TuSimple

While each interview differed depending on the stakeholders' questions, experience, and related work, the research team used a number of guiding questions to frame the conversation.

Public Sector

- What applications is your agency supporting, and how are applications developed?
- What applications are high interest / high priority?
- What data sources is your agency using for CV deployments?
- What data availability and sharing capabilities does your agency have?
- How does information get from your agency to drivers?
- What corridors could be strategic for CV deployments?
- Are there potential partnership opportunities with your agency?

Private Sector

- What are the industry needs for CV applications?
- What applications are high interest / high priority?
- What data availability and sharing capabilities does your company have?
- What corridors could be strategic for CV deployments?
- Are there potential partnership opportunities with your company?

Key Findings

Applications

Leverage existing CV application deployments underway across the state, including along the I-45 corridor, Texas Triangle, and I-30.

Partnerships

Consider executing Data Sharing Agreements in major metropolitan areas to integrate data sources across agencies. Explore partnerships with transit providers that operate on interstates such as METRO, CapMetro, and Vonlane.

Other Opportunities

Consider deploying a statewide secure network (as opposed to district-level networks) for ITS equipment operations.

Potential Applications

The project team identified potential CVDF expansion applications. Feasibility, data needs, and benefits are discussed for each of the seven applications below. Additionally, each application is given a feasibility ranking that represents the feasibility determined by the research team when considering technology maturity, resource intensity, data needs, goal alignment, and expected impacts. The research team evaluated each application based on three criteria:

- Resource Intensity – How difficult is it to develop the application? (1= High Intensity, 5= Low Intensity)
- User Adoption – Who are the users of the application? (1= Low Adoption Impact, 5= High Adoption Impact)
- Goal Alignment – What are the expected benefits? (1= Low Alignment, 5= High Alignment)

Road Weather Warning

Road Weather Warning (RWW), sometimes also called Spot Weather Impact Warning (SWIW) provides localized roadway condition and weather event information, such as fog, icy roads, heavy rainstorms, or flooding.

Criteria	Summary	Score
Resource Intensity	TxDOT maintains Environmental Sensor Stations (ESS) with weather data	**4**
User Adoption	Benefits all roadway users	**4**
Goal Alignment	Reduce weather-related crashes; Improve situational awareness	**4**

Low Clearance Warning

Low clearance warnings transmit information about bridge clearance heights to vehicles near the infrastructure. In some deployments, sensors can detect and measure the approaching vehicle's height and width, and alert the driver to exit if the vehicle is oversized. This application could be expanded to include other static roadway infrastructure information that may support AV operations, such as lane widths, frontage road geometry, and locations of entrance/exit ramps.

Criteria	Summary	Score
Resource Intensity	Oversized vehicles detected by Lonestar (LS) are already provided in the CVDF	**3**
User Adoption	Benefits commercial vehicles	**3**
Goal Alignment	Reduce crashes due to driver error; Reduce crash-related congestion	**3**

Responder-to-Vehicle Alerts

First Responder Alerts, sometimes also called Responder-to-Vehicle or R2V alerts, transmit information about law enforcement, public safety vehicles, and first responders to surrounding vehicles. The alerts notify vehicles of nearby first responders and can help reduce crashes or interference with emergency response. In some cases, the R2V alerts can also trigger a Federal Emergency Management Agency (FEMA) Wireless Emergency Alerts on cell phones in the area, similar to an Amber Alert.

Criteria	Summary	Score
Resource Intensity	Third-party platform integration; First responder vehicle schema generation;	**3**
User Adoption	Benefits all roadway users	**4**
Goal Alignment	Reduce crashes; Improve situational awareness, driver decision-making, and emergency response time	**4**

Truck Parking Availability

Several states have either independently, or in collaboration with one another, launched Truck Parking Information Management Systems (TPIMS). Such systems are designed to share real-time information to truck drivers about available parking in an effort to maximize utilization of existing truck parking capacity. TPIMS use differing kinds of technology. In general, these systems collect real-time parking availability information using sensors in the parking facilities. This data is then sent to a central information hub for processing and then converted into parking availability information. The processed information is then shared via different communication channels to drivers to inform them of parking availability.

Criteria	Summary	Score
Resource Intensity	Requires integration with truck parking data	**3**
User Adoption	Benefits commercial vehicles	**3**
Goal Alignment	Reduces roadside parking instances; Reduces emissions from idling	**4**

Pedestrian Crossing

Pedestrian detection systems can be implemented in vehicles, in the infrastructure, or using pedestrians' mobile devices to provide warnings to drivers, pedestrians, or both.

Criteria	Summary	Score
Resource Intensity	LS integration with signal controllers that support MAP and SPaT messages; Deployment of pedestrian detections sensors along crosswalks; API that includes MAP and SPaT data	**1**
User Adoption	Benefits all roadway users	**3**
Goal Alignment	Protect vulnerable road users on heavily trafficked corridors	**4**

Cloud-based Signal Preemption

Priority and preemption are used at intersections with traffic signals to modify signal patterns for buses, light rail, streetcars, trucks, emergency vehicles, or trains. The primary purpose is to reduce travel times, improve safety and accessibility, and clear a path so that the priority vehicle can arrive at its destination quicker.

Criteria	Summary	Score
Resource Intensity	Signal Controller upgrades; Added functionality for LS and the CVDF to support MAP, SSM and SRM; Extensive latency and privacy testing in the field	**1**
User Adoption	Benefits all roadway users	**3**
Goal Alignment	Improves first responder response times; Improves travel time and reliability	**4**

5 | DATA SHARING AND STANDARDS

This project team developed data formats, performance requirements, and security concerns for each of the potential applications to be supported by the CVDF.

Identified Data Needs

The project team developed a list of data requirements for CV applications, summarized in Table 2.

Table 2: Identified Application Data Needs

Application	Data Needs
Low Clearance Warning	• Roadway geometry data including heights and the presence of tunnels, bridges, or overpasses. • Height restrictions for tunnels, bridges, overpasses • Height of vehicles
Pedestrian Crossing Detection	• MAP and SPaT data at signal • Alerts from a pedestrian detection system • Pedestrian localization data provided by a third party
Responder-to-Vehicle	• Emergency vehicle location and speed • Emergency vehicle arrival and departure time Incident location and description
Truck Parking Alerts	• Parking lot location • Number of space available • Current filled percentage • Restrictions such as height, length, and weight.
Cloud-based Signal Preemption	• MAP and SSM from signal • SRM provided by third party

Performance Guidelines and Security Considerations

Additionally, the project team developed a list of performance guidelines and security concerns for CV applications, summarized in Table 3.

Table 3: Performance Guidelines and Security Concerns

Application	Performance	Privacy and Security Concerns
Road Weather Warning	NTCIP 1204 standard; hourly	Verified vendors and data providers Conflict resolution plan Recommended driver action
Low Clearance Warning	SAE J2945/1 standard ; real-time	Anonymized BSM data Verified MAP data
Responder-to-Vehicle	Real-time, lane precision	Concern about real-time location information for first responders
Pedestrian Crossing	Real-time	Should not include PII Anonymized Bluetooth or mobile data
Truck Parking Alerts	Dependent on demand, time-of-day	Verified vendors and data providers

6 | APPLICATION DEVELOPMENT AND TESTING

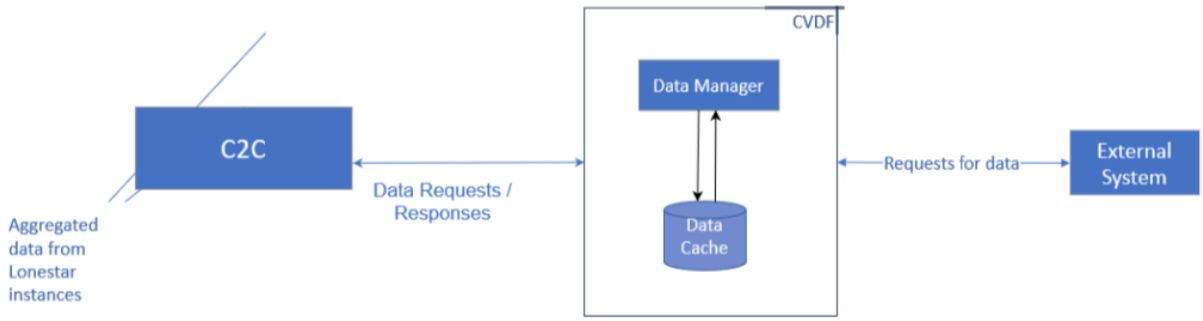


Figure 1: CVDF System Components

Application Development and Testing

Together with Southwest Research Institute, the project team developed the Road Weather Warning application to incorporate into the CVDF. This application leverages data from Environmental Sensor Stations to alert drivers of adverse weather conditions.

Environmental Sensor Stations

The Environmental Sensor Station (ESS) is an existing Lonestar subsystem that collects weather information from devices that contain a variety of weather sensors, such as thermometers, barometers, water sensors, etc. These ESS devices can be configured to send weather alerts based on threshold values. For example, an ESS device may send a flood alert if a weather sensor detects more than a configurable amount of water on a ground or road surface. These weather alerts are provided to the CVDF via C2C.

System Requirements and Testing

Logging and Caching. Logging and caching are important for the CVDF because it ensures that the CVDF contains all the relevant weather alert data that is made available by the Lonestar Environmental Sensor Subsystem (ESS) via C2C and that the data is available for publication as requested. A Road Weather Information System (RWIS) simulator was used to simulate weather data for testing. The application passed the test.

Publishing. Publication is important for the CVDF because it ensures that the CVDF makes data available via industry standard means such as the OpenAI/Swagger interface to which it conforms.

Filtering. Filtering is important for the CVDF because it ensures that the CVDF provides a means by which data consumers can request and receive only the data in which they are interested. Alerts can be filtered by district, roadway, polygon, or point.

The Task 6 implementation of Weather Alerts has been deployed and tested on internal SwRI servers. To provide additional testing to actual third-party consumers, such as Drivewyze, the Task 6 implementation would need to be integrated with the Lonestar code base being exposed to third parties at https://cvdf.datasys.swri.org/cvdf/swagger/index.html. This integration could best be handled by the SwRI Lonestar team.

Takeaways

The application development and testing provided a strong proof of concept. Environmental Sensor Stations are currently deployed across the state and can support the Road Weather Warning application.

7 | RECOMMENDATIONS FOR EXPANSION

Growth Opportunities

The research team has identified several opportunities to supplement the growth and scaling of the CVDF.

Additional Applications. Through this effort, the research team developed the Road Weather Warning application. Stakeholder input and industry development indicate strong interest and maturity for a number of other CV applications. To support expanded use of the CVDF, TxDOT should consider additional applications that were identified as priorities.

New Data Partners. While Drivewyze is currently disseminating Work Zone Warning alerts through the CVDF, there is an opportunity to scale third-party integration. Other providers such as Google Maps and Waze could integrate with the CVDF to query and share information. Additionally, ELDs and other in-cab alert providers in the commercial vehicle sector such as Trimble and Geotab could directly integrate with the CVDF as Drivewyze has. New data partners such as HAAS Alert, Spoke, and Wejo may be able to support additional CV applications including Responder-to-Vehicle alerts and Vulnerable Road User detection.

Strategic Corridor Investment. Many of the mature CV applications greatly benefit commercial drivers and can lead to safer freight operations. Texas' roadways have heavy freight traffic, and these corridors provide an opportunity to improve freight operations through CV applications. Focusing on the Texas Triangle and freight routes in other parts of the state on I-10, I-20, and I-30 will help focus the geographic deployment of CV technology.

Strategic Recommendations

The research team has also identified several strategic recommendations:

Support the Texas Connected and Automated Transportation (CAT) Program. The CAT Program is a TxDOT initiative that works to integrate emerging transportation technologies, including AVs and CVs, into the state's transportation system. This program serves to uplift necessary policy and procedural decisions that will maximize the benefit these technologies bring. The CAT Plan specifically works to implement these technologies that can offer benefits to roadway safety, transportation reliability, economic vitality, response agility, and an accessible and comprehensive mobility system. The CVDF aligns with many of the primary goals for the CAT Program, including transportation reliability, economic vitality, and an overall improved mobility system. The CAT Program could serve as a formal body to secure and align necessary coordination that paves the foundational policies and procedural needs to sustain and amplify the impact of this project.

Consider Digital Infrastructure to Support CV Applications. For example, technology that enables smart work zones, such as connected barrels, cones, and arrow boards, allows for real-time information on work zone conditions that can be shared through the CVDF. Sensors and detection technology can improve information related to wrong-way driver incidents, truck parking availability, and overheight vehicles approaching a bridge. These infrastructure assets can enable additional CV applications with roadway information that can be shared through the CVDF.

VALUE OF RESEARCH

Table A-1 presents the summary of the value of research (VoR) estimation for Project 0-7164 based on the functional areas selected by the research team and TxDOT. The functional areas deemed relevant and noted in the project contract include both qualitative and economic components.

***Table A-1**: 0-7164 Value of Research Benefit Areas*

Benefit Area	Qualitative	Economic	Both	TxDOT	State	Both
Level of Knowledge	X			X		
Management and Policy	X			X		
Traffic and Congestion Reduction		X			X	
Safety		X				X
Intelligent Transportation Systems		X				X

Qualitative Benefits

Level of Knowledge, Management, and Policy

This research identified expansion opportunities for the Connected Vehicle Data Framework (CVDF) and developed a Road Weather Warning Application. The research identified data needs for other applications, high-priority corridors for deployment, and feasible opportunities for expansion. This research developed knowledge about stakeholder priorities, operations needs, CV application maturity, recommended data standards and performance, and strategic investment opportunities. This research improved knowledge for successful implementation and expansion of CV technology on Texas roadways.

Economic Benefits

Safety, Traffic and Congestion Reduction, and Intelligent Transportation Systems

Alerting drivers of adverse weather conditions will improve driver awareness, reduce weather-related crashes, and reduce weather-related congestion. Annual crashes related to weather were queried from the C.R.I.S. database for 2023, summarized in Table A-2. Annual costs were calculated based on severities and according to Table A-3. The crash reduction factor associated with weather alerts is 18%.[i]

***Table A-2:** Weather-related Crashes, 2023*

Weather Condition	Crash Severity				
	Fatal	Severe	Minor	Possible	Non
Fog	34	71	293	231	1241
Rain	219	850	4968	5924	29190
Wind	0	7	22	22	142
Hail	11	34	176	163	1068
Total	**264**	**962**	**5459**	**6340**	**31641**

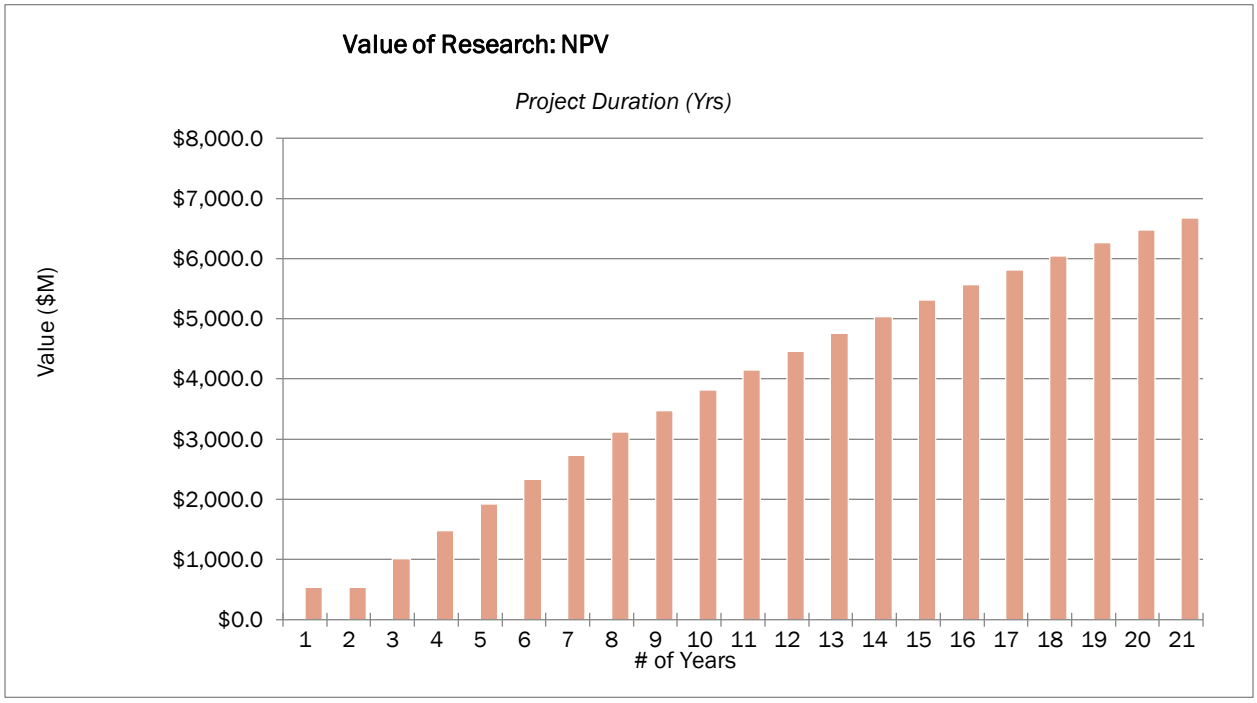
Table A-3: Average Economic Cost by Injury Severity or Crash

Crash Severity	Cost
Death (K)	$1,778,000
Disabling (A)	$155,000
Evident (B)	$40,000
Possible (C)	$24,000
Not Injured (N)	$6,700

Additionally, 15% of congestion is weather-related. In 2022, Texas roadways experienced $30,942,264 in delays.[ii] The project teams assumed 15% of this was weather-related, and weather alerts could alleviate 18% of the weather-related congestion. [iii]

Net Present Value Results

Net present value with a 5% discount rate over a payback period of 20 years was found to be $4,146,650,917. The cost-benefit ratio was calculated to be 11,848:1. Annual expected value was calculated to be $560,449,861.



[i] https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa09028/resources/CRF%20Desktop%20Reference.pdf
[ii] https://static.tti.tamu.edu/tti.tamu.edu/documents/TTI-2023-3.pdf
[iii] https://ops.fhwa.dot.gov/program_areas/reduce-non-cong.htm#:~:text=The%20three%20main%20causes%20of,(15%20percent%20of%20congestion).