Concept of Operations

for Pedestrian Hit & Run Collisions in Nashville, TN

Pioneer Safety Solutions

2023 Transportation Technology Tournament

May 2023

Table of Contents

List of Figures

List of Tables

Problem Description

The city of Nashville, TN has an average of 14.5 deaths per 100,000 people, ranking 24th nationally in traffic deaths in comparison to identified peer cities, with 17% of all traffic deaths or serious injuries occurring in pedestrians.[1] This problem focuses on reducing the number of hit-and-run incidents occurring in Nashville through the use of technology and education.

Hit-and-runs are described as any incident in which someone driving a vehicle hits a person, object, or another vehicle and leaves the scene. According to the Nashville Vision Zero (NVZ) Action Plan, pedestrians make up 35% of hit-and-run collisions where someone is killed or severely injured.[2] Furthermore, data has shown that areas considered to be more vulnerable, as according to a methodology adapted from the Greater Nashville Regional Council, including low-income areas and communities of color, are overrepresented in traffic deaths and severe injuries – more than 30% of collisions for all modes occur in areas with the highest concentration of poverty, renters, and housing-cost burdened households.[3] The NVZ Action Plan has identified both the High-Injury Network as well as the High Injury Intersections, the former of which we have chosen to focus on as it identifies the most dangerous roads in Nashville. The top project sites listed under the High-Injury Network list include Nolensville Pike, for which a case study already exists, and Charlotte Avenue between 22nd Avenue N and 13th Avenue N, which is the site we are electing to model the implementation of our hit-and-run mitigation solution.

Site Description

The section of Charlotte Avenue between 13th and 22nd Avenues is a five-lane road along a strip of Tennessee State Route 24, just under a mile in length, with two lanes traveling in either direction and one turning lane in the middle for drivers to turn into retail stores located on either side of the roadway. On either side of the road there is, at times, a narrow bike lane located alongside the sidewalk, and along other sections bikes are meant to occupy a shared-use lane. While other locations in the High-Injury Network have missing pedestrian and bicyclist infrastructure, the entirety of this section of Charlotte Avenue has sidewalks on either side of the roadway as well as some bike lane signage. Furthermore, while this section of Charlotte Avenue is 0.8 miles according to Google Maps software, there are six traffic signals and only five intersections with pedestrian crosswalks spanning Charlotte Avenue, located at McMillin Street, 17th Avenue N, 18th Avenue N, 20th Avenue N, and 22nd Avenue N. There is only one location along Charlotte Ave between 13th and 22nd Ave with posted speed limit signs of 40 MPH, found on either side of the road at the intersection of Charlotte Avenue and 21st Avenue N. The locations of existing traffic signals and the speed limit sign along the corridor are shown in Figure 1. Figure 2 shows the one location of the speed limit signs located on either side of Charlotte Avenue.

[1] Nashville Vision Zero Action Plan 2022-2026 p.11
[2] Nashville Vision Zero Action Plan 2022-2026 p.14
[3] Nashville Vision Zero Action Plan 2022-2026 p.15

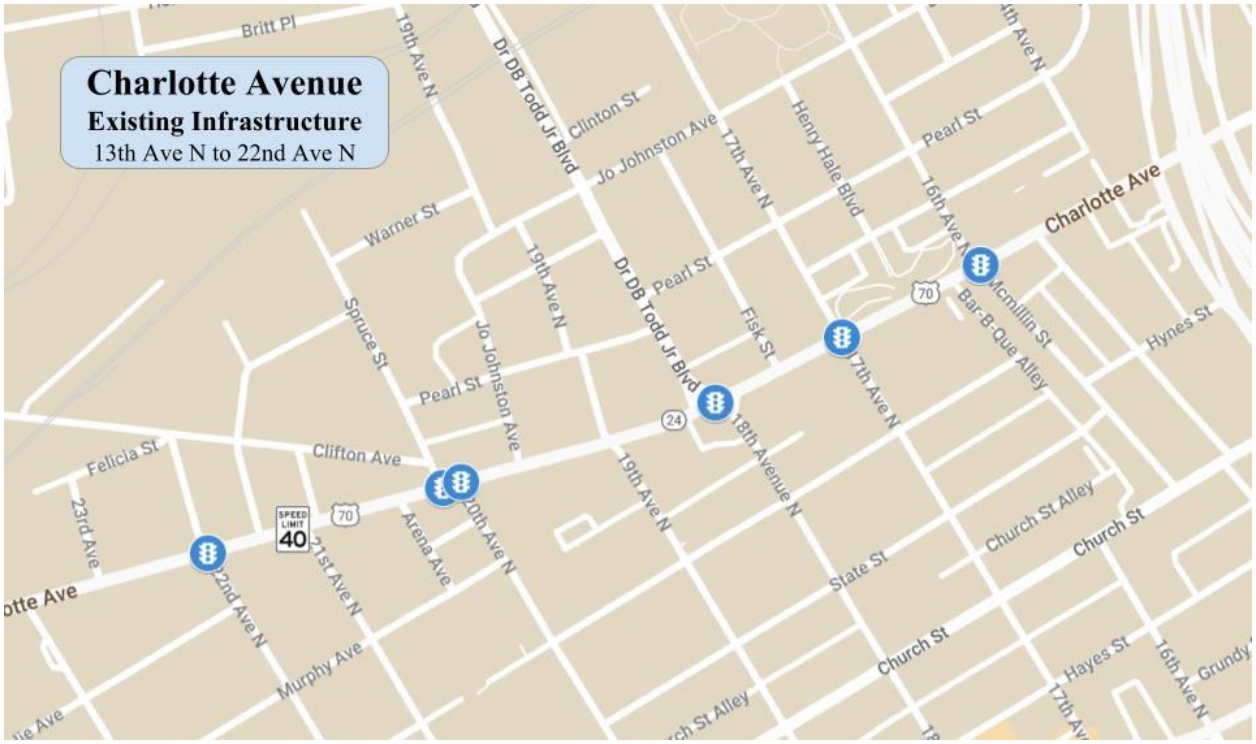

Figure 1. Locations of existing infrastructure on Charlotte Ave between 13th Ave N and 22nd Ave N. Speed limit signs and traffic signal locations are shown.

Figure 2. A cross-section of Charlotte Ave at 21st Ave N. The red arrows point to the locations of the only posted speed limit signs along this section of Charlotte Ave.

Figure 3. Proposed locations for implementation of Glow Safely, cameras, and VSL signs. These are overlaid with the existing infrastructure.

Requirements For Solution

Nashville has a Vision Zero action plan to eliminate all pedestrian collisions and create safe streets for everyone. According to the action plan, identified issues include lighting, speeding, and lack of pedestrian and bike friendly infrastructure. We plan to improve upon all these issues, and in order to do that, we sourced the following information:

- The state of existing cameras along the Charlotte Avenue corridor
- Speed limit sign locations
- Raised concerns from local residents, such as the desire for no additional police enforcement
- If our solution can be integrated into Nashville's existing ITS infrastructure

Objective

The objective of our report is to create an ITS solution that addresses the issues with pedestrian safety, specifically hit and runs, along Charlotte Avenue. We will develop a system that utilizes pedestrian detection and connected vehicle technologies to automate detection of nearby pedestrian and bike presence and crashes. This information will then be sent to drivers in order to increase their awareness and therefore reduce the number of hit and runs utilizing C-V2X technology in the long run.

Solution Description

Our solution aims to address the pedestrian and bike hit-and-run collision issue plaguing the city of Nashville by implementing a new hit & run mitigation system implementing various ITS solutions for the Charlotte Avenue corridor. Our proposed solution will cover the section of Charlotte Avenue between 13th Ave North and 22 Ave North, as this section of roadway was noted in the Nashville Vision Zero Action Plan High-Injury Network as being an area of concern, due to increased pedestrian and bike collisions.

Along this corridor, a series of cameras will be installed and integrated with current Nashville DOT camera systems with the goal of monitoring pedestrian, bike, and vehicle traffic along the corridor. In addition, multiple variable speed limit signs (VSL's) will be installed at intervals along the corridor, to replace the singular posted 40 speed limit sign on this section of Charlotte Avenue. The plan with these two components is for cameras to detect the volume of pedestrians and bicyclists along the corridor and communicate with VSL signs to adjust the speed limit accordingly. Cameras will be able to detect and identify differences between vehicles and pedestrians with the help of machine learning algorithms such as OpenCV and YOLO (you only look once). When low to medium density pedestrians and bicyclists traffic is detected, the VSL signs will display an adjusted 35MPH speed limit for the section of roadway. For high density of pedestrians and bicyclists, the VSL's will display an adjusted 30MPH speed limit. The speed limit can also be adjusted further if cameras detect that a collision has occurred between a vehicle and pedestrian or biker, to provide traffic calming until the road has been cleared. The main driving point behind the implementation of VSL signs on a low speed corridor is that VSL signs have proven to provide increased safety on highway corridors by "decreas[ing] last second avoidance maneuvers and panic braking, which are both primary factors that contribute to collisions," according to the Washington State Department of Transportation (WSDOT).[5] Since VSL signs have had such success on heavily trafficked roadways, our project plans to test if VSL's will provide safety for pedestrians and bikers as well.

The second, and most likely future use, of our proposed camera system along the Charlotte Avenue corridor will provide drivers in-vehicle alerts about pedestrian presence and collisions. Similar to how applications like Waze and Google Maps provide drivers with live updates about upcoming traffic conditions, police locations, and other important information, implemented NDOT cameras along this corridor will provide drivers with information about bikers and pedestrians for improved decision making. In even more future use, automated or connected vehicles will be able to take collected information from NDOT's system and make decisions of speed and avoidance measures without driver interference.

A final piece of our hit-and-run mitigation system is the installation of a new technology called *Glow Safely* at intersection crossings. This technology, developed by students at UMass Amherst, provides increased safety to pedestrians crossing during dimly lit conditions by providing motion activated lights along crosswalks. Increased lighting was a key point mentioned in Nashville's Vision Zero Action Plan and this improved lighting will help drivers to be able to better visualize pedestrians and bikers as they drive along Charlotte Avenue.

To supplement our research into hit-and-run mitigation strategies, public engagement forums and surveys published in the NVZ Action Plan found that top concerns surrounded the lack of pedestrian-centered

infrastructure including sidewalks and protected bike lanes, distracted drivers in combination with high vehicle speeds, and people ignoring traffic laws.[4] Moreover, fears of police encounters were thought to be motivators for drivers fleeing the scene, with sentiments of wanting less policing in solutions expressed. Since the use of machine-learned cameras may raise fears about the misuse of them to monitor residents, we also propose utilizing RAdio Detection And Ranging (RADAR) technology in place of cameras to detect pedestrians and bicyclists.

RADAR sensors use the reflection of low-energy microwave radio waves to determine the distance between obstacles and the sensor, allowing for a constant scan of the road for any collisions or risk situations within the detection zone.[5] Recent car models have incorporated RADAR technology to keep drivers centered in their lane as well as detect surrounding obstacles in the car's vicinity. There are two main types of radar sensing systems used in transportation applications: the Doppler system which uses the frequency shift of the reflected waves to track the number of vehicles and determine speed very accurately, and the frequency-modulated continuous wave radar which radiates a continuous wave radar to measure flow volume, speed and presence.[6] As RADAR systems are often used in applications for managing traffic lights, we propose using it as an alternative to machine-learned cameras to manage the VSLs.

Physical infrastructure to be installed:

- Cameras at key locations along Charlotte Avenue (with considerations of installation and power supply)
- mmWave radar for intersection pedestrian monitoring (with considerations of power supply and computational time for machine learning algorithms)
- VSL signs (considering power supply)
- *Glow Safely* at intersections for driver visibility, a project by students at UMass Amherst

Computational infrastructure to be installed:

- VSL controller to activate signs based on Pedestrian/Bike presence/crashes
- Connections to Nashville Department of Transportation for monitoring/determining the effectiveness of the hit-and-run mitigation system
- V2X controller to provide drivers with real time information about bike/ped presence and crashes (future application in connected and automated vehicles)

Stakeholders

- Residents of Nashville, Tennessee: the purpose of our solution is to make sure residents of the area feel as safe as possible in order to encourage them to walk or bike.
- Tennessee Department of Transportation (TDOT): our final design must get approved by TDOT in order to be implemented.

[4] Nashville Vision Zero Action Plan 2022-2026 p.19
[5] Variable Speed limit signs improve safety on highways, school zones
[5] Sensor Technologies for Intelligent Transportation Systems
[6] Idlib

- Nashville Planning Commission: the body responsible for planning the physical development of Nashville and approving subdivision requests.

Con-ops for solution

High-level physical architecture

The physical architecture of the system will utilize the installation of two main technologies at intersections – cameras or radars which will then interface with VSL signs and connected vehicles to communicate the presence of pedestrians and bicyclists. These interactions can all be overseen by Traffic Operations Personnel through the Traffic Management Center which will collect system data and be capable of making appropriate adjustments to VSL signs based on the sensed density of pedestrians and bicyclists. Figure 4 shows the high-level physical architecture of the system.

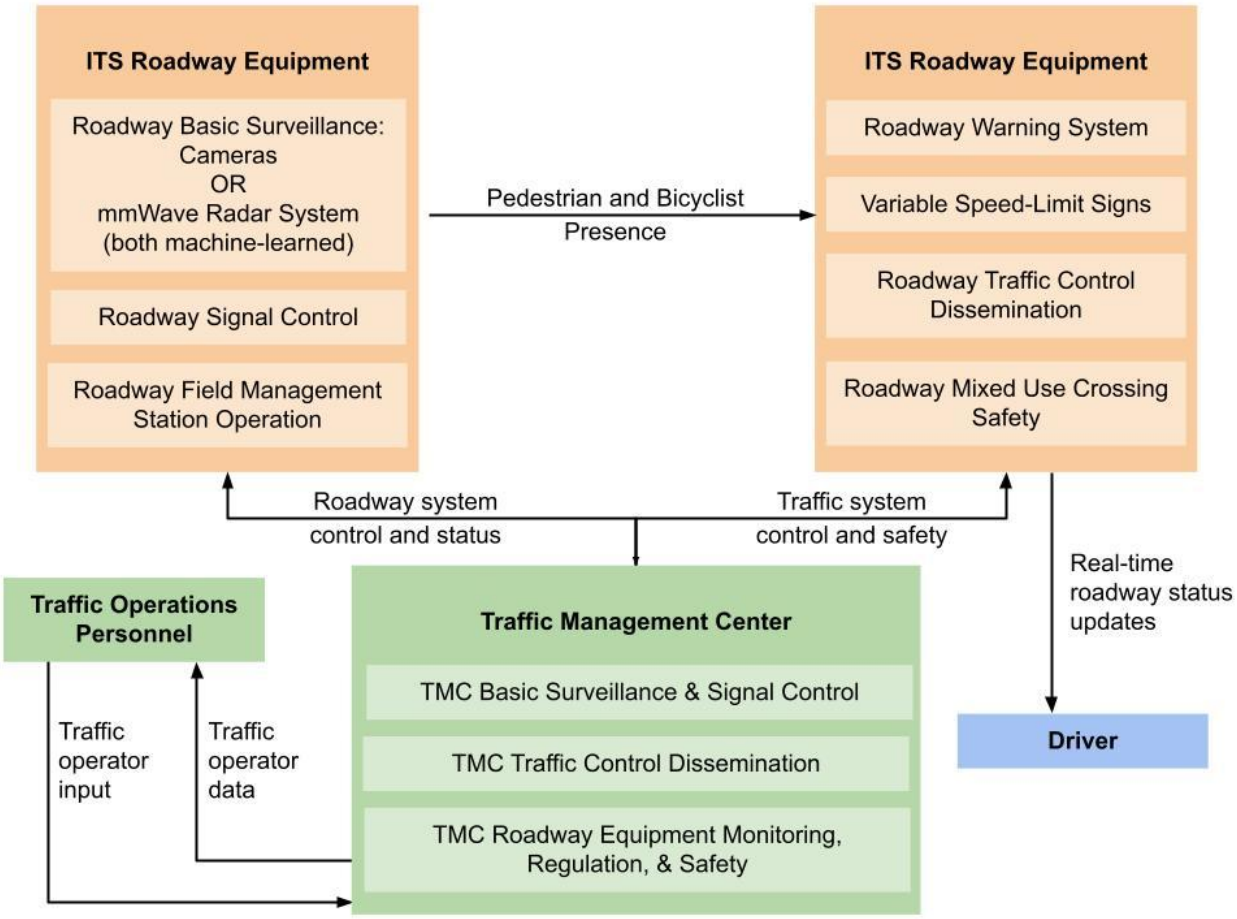

Figure 4. High-level Physical Architecture

High-level functional architecture

The functional architecture, as seen in Table 1, describes the way individual parts of the system seen in the physical architecture will operate. With communication between the different components of the ITS Roadway Equipment and the Traffic Management Center set up mainly prior to installation, the system will be triggered by the presence of pedestrians and bicyclists, with this information being immediately decimated to all relevant parties and field elements. Data collected into the Traffic Management Center will then allow for reviews of system functionality and proper adjustments to be made in the future.

Physical Object	Functional Object	Functional Description
ITS Roadway Equipment	Roadway Basic Surveillance	Collects traffic and road condition data using field equipment such as radars and cameras
	Roadway Signal Control	Includes equipment used to support traffic control at signalized intersections
	Roadway Traffic Control Dissemination	Provides information to drivers using field elements
	Roadway Warning	Warns drivers of incoming hazards such as traffic accidents
	Roadway Field Management Station Operation	Supports direct communication between field management stations and the local field equipment
	Roadway Variable Speed Limits	Includes field equipment used to manage and control variable speed limit systems
	Roadway Mixed Use Crossing Safety	Integrates pedestrian and cyclist information with sensing and warning systems on main vehicle roadways
Traffic Management Center	TMC Basic Surveillance	Allows traffic managers to monitor traffic and road conditions and collected data can be analyzed
	TMC Signal Control	Monitors traffic control equipment and manages traffic flow at signalized intersections
	TMC Traffic Control Dissemination	Collects real-time traffic control related information and distributes the information to vehicles and/or devices
	TMC Roadway Warning	Remotely monitors and controls the systems that warns drivers of incoming hazards
	TMC Roadway Equipment Monitoring	Monitors the status of field equipment. reports failures, and keeps track of replacements of failed equipment
	TMC Variable Speed Limits	Monitors and controls variable speed limit systems, collects data, and sets suitable speed limits
	TMC Intersection Safety	Controls and monitors roadside equipment related to pedestrian and cyclist safety

Table 1. High-level functional architecture

High-level enterprise architecture

The physical and functional objects can also be depicted as resources as seen in the enterprise architecture in Figure 5. Through this perspective of the involved parties and their roles in the implementation, certification, and execution of the system, the requirements from each group for a successful system can be better understood.

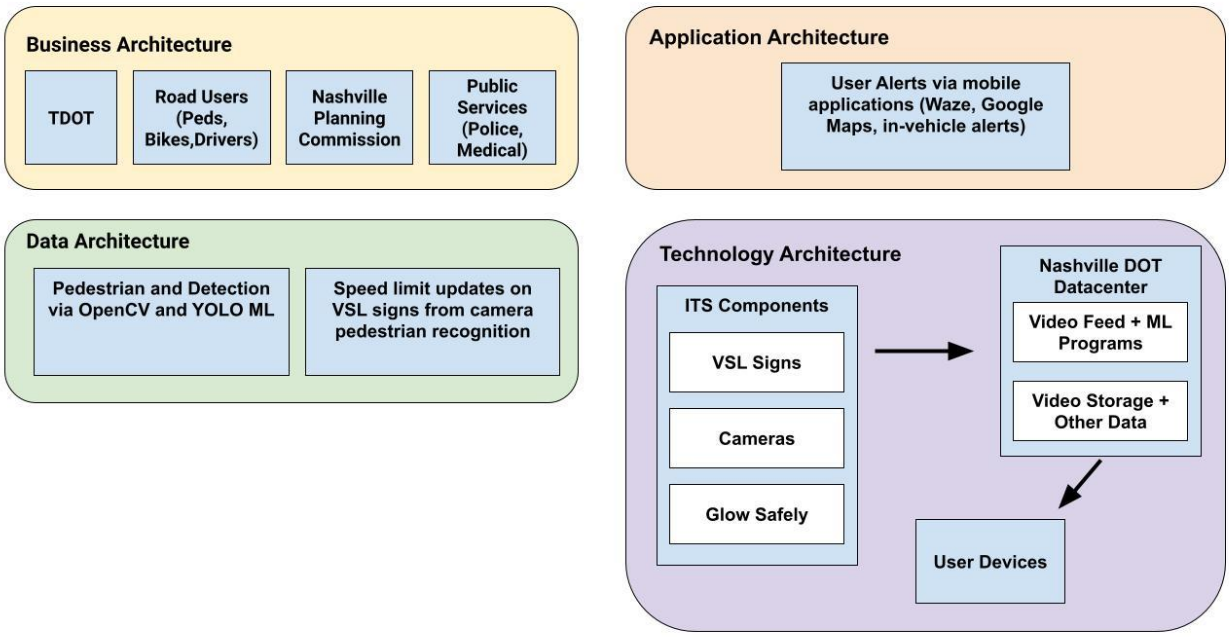

Figure 5: High-level enterprise architecture

Cost Breakdown and Timeline

Timeline:

Description	Anticipated Duration
Installing cameras	25 hours
Installing radars	40 hours
Installing VSL signs	15 hours
Installing Glow Safely	50 hours
Total Time Required	**90-105 hours**

Table 2. Time estimates of instillation

Costs:

Description	Quantity	Unit Cost	Total Cost
Traffic Cameras	5	$3,000.00	$15,000
Solar Powered VSL Signs	3	$5,000.00	$15,000
mmWave Radar System (assembly required)	5	$622.95	$3,114.75
Glow Safely	18	$700	$12,600
Labor		–	Cost determined at construction
Total Overall Cost (using mmWave radar)			**$30,714.75**
Total Overall Cost (using cameras)			**$42,600**

Table 3. Cost Estimate

Anticipated impacts

Operational benefits

With the incorporation of our camera detection system along with VSL signs and Glow Safely, drivers will now be preemptively alerted to pedestrian presence and be prompted to drive more slowly along the corridor. An increased awareness of drivers to pedestrian presence will allow pedestrians to travel more safely along the corridor and therefore reduce the number of hit-and-run incidents that may contribute to congestion.

Safety benefits

The variable speed limit signs in combination with traffic cameras to detect vulnerable road user presence will increase the safety of pedestrians and cyclists. Vehicles will slow down at the activation of the VSL sign. It is widely known that speed is directly correlated with the severity of a crash. A pedestrian struck by a vehicle at 25 mph has an 89% chance of survival, while that chance drops to 35% with a 10 mph increase in speed.[7]

Glow Safely works to mitigate the effects that low-light conditions have on vehicle crashes. In Nashville's Vision Zero Action plan, it is noted that residents suggest lighting is an issue. The system will increase the safety of vulnerable road users crossing at each of the five intersections in the selected area of Charlotte

[7] Nashville Vision Zero Action Plan 2022-2026 p.10

Avenue. Lighting up the crosswalk when a pedestrian or cyclist is present will clearly alert the vehicle, resulting in a decrease in crashes at intersections.

Mobility benefits

Any vehicle crash results in the slowing of traffic and sometimes the closing of a lane. In reducing the number of vehicle crashes, traffic will move smoother and with less stoppages. There are also mobility benefits for pedestrians and cyclists. Glow safely allows vulnerable road users to feel safer while crossing the street.

Environmental benefits

By mitigating the number of pedestrian and cyclist accidents, the people of Nashville will feel safer walking and biking. As a result, people may opt to walk or bike to wherever they need to go rather than drive. An increase in the number of pedestrians and cyclists will decrease the amount of cars on the road, which directly results in a decrease of carbon emissions from vehicles.

Other benefits and concerns

As a non-invasive and visible solution, both cameras and radar are also more visible to drivers, resulting in reactions such as slowing down and using the correct drive lane.[8] There are, however, installation concerns as there is no shoulder for maintenance vehicles to occupy. In 2022, the AADT for Charlotte Avenue at 13th Avenue near 1-40, was 34,007 cars, with 17,877 cars traveling eastbound and 16,130 westbound, classifying it as a principal arterial road.[9] Traffic disruptions from installation and maintenance will cause congestion on the road, although installation at night should prove less inconvenient for drivers.

References

LEDLighting Solutions

https://carmanah.com/articles/variable-speed-limit-signs-improve-safety/

https://www.wkrn.com/news/new-crosswalk-underway-on-charlotte-pike-one-day-after-pedestrian-death/

https://www.arc-it.net/index.html

[8] Sensor Technologies for Intelligent Transportation Systems
[9] Tennessee Department of Transportation