



**VIRTUAL EXPERIENCE
OCTOBER 11-14**



Improving Pedestrian Safety using Computer Vision, Machine Learning and Data Analytics

A Technical Paper prepared for SCTE by

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1. Abstract

Pedestrian fatalities are on the rise, with more than 6,000 pedestrians killed each year in the United States.[1] There are several technologies and use cases that can help cities make the roads and highways safer. The Smart Intersection proof of concept (POC) deployed by Spectrum is one such example that demonstrates how cities can use technology for protecting pedestrians.

The Smart Intersection proof of concept uses computer vision, edge and near-edge computing to detect and monitor the pedestrian and vehicle movement at the intersection. The anonymous pedestrian and vehicular traffic data is stored in the cloud for further analysis, planning and design of the components of the intersection, including stop signs, traffic/pedestrian light timing, crosswalks and sidewalks to improve pedestrian safety.

This paper discusses the Smart Intersection architecture, machine-learning (ML) model and computer vision technology. The paper also explains the collection, storage, visualization and analysis of metadata on pedestrian and vehicle movement at the intersection.

2. Introduction

As cities around the world grow at an unprecedented rate, there has been an uptick in traffic accidents. Pedestrians are the most vulnerable users of the roads. As per the National Highway Transport Safety Administration, “pedestrian fatalities in crashes increased 44 percent in the last decade (2009 to 2018), with the pedestrians’ share of traffic fatalities increasing 32 percent, from 13 to 17 percent.” [2]

One initiative cities are working on is Vision Zero. The goal is to bring the number of fatalities or collisions in an intersection to zero. Data collected from road sensors and cameras can help cities better understand everything from crosswalk signal timing to traffic patterns that may lead to these collisions.

Data-driven decisions are essential for improving public safety. This paper discusses smart intersection use cases, technology, and the methodology used to collect and analyze a broad array of traffic data to draw actionable insights to make the intersection safer for pedestrians.

In the Smart Intersection POC, we are using several IoT sensors, edge computing, computer vision, wired and wireless connectivity, cloud services for data storage, analysis and visualization to help a city improve pedestrian safety.

3. Computer Vision

Computer Vision is a field of study that trains and enables computers to process images and extract information similar to the human visual system. Recent advancements in algorithms, computational power, and the availability of large datasets of digital images have helped improve computer vision capability.

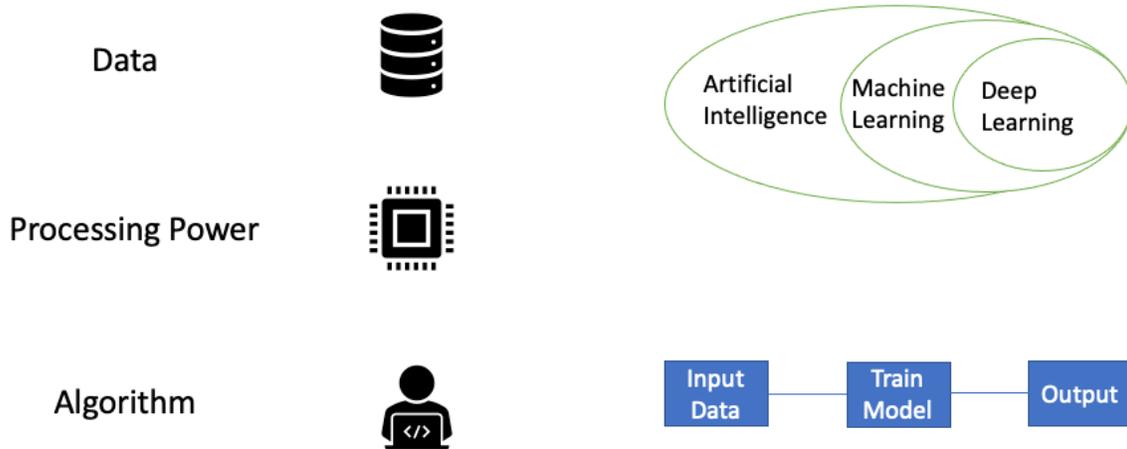


Figure 1 - Computer Vision Components

4. Architecture

The Smart Intersection POC uses cameras attached to the light poles and has the option to use fiber or wireless connectivity to backhaul the data. The switch inside the light pole has multiple Power over Ethernet (PoE) ports providing power to the cameras.

The cameras use edge computing technology with high computing power offered by the graphical processing unit (GPU) to process computer vision. A near-edge server with additional computational power is used for more advanced image processing and machine learning.

The traffic metadata is sent to the cloud for storage, analysis and visualization and can be accessed via a dashboard using a web browser.

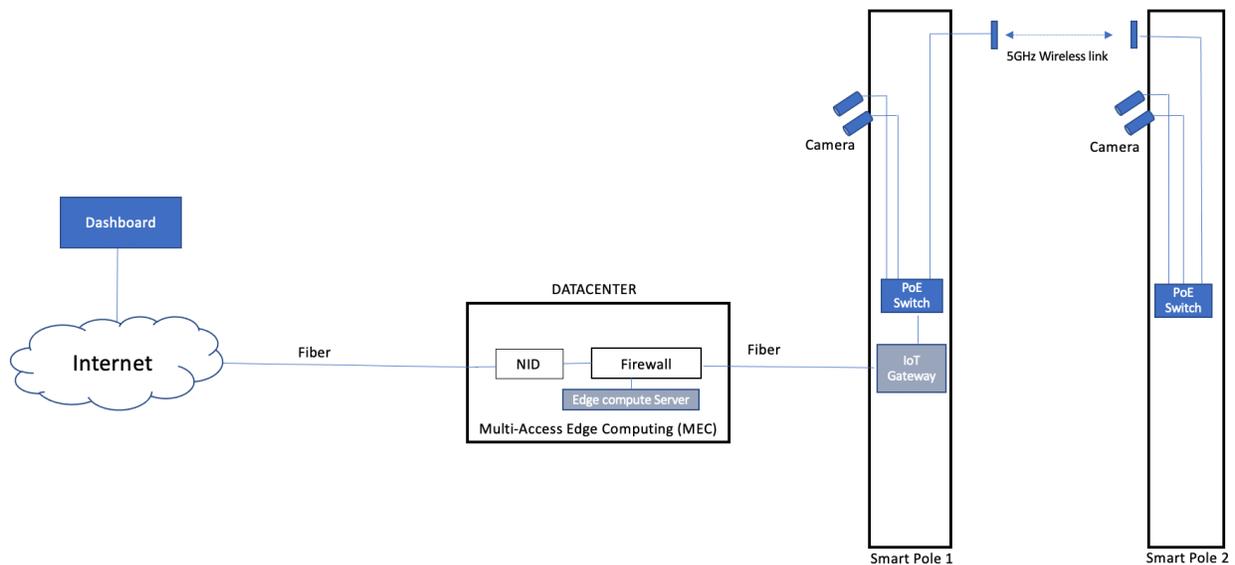


Figure 2 - Architecture

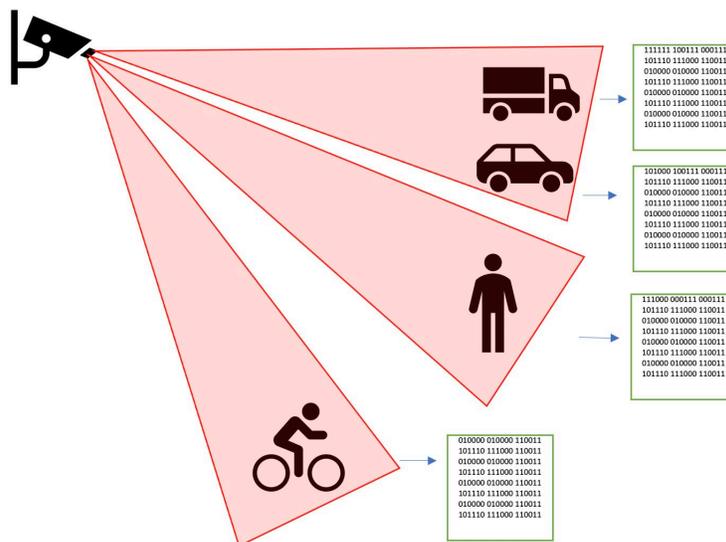


Figure 3 - Digital Image

The Smart Intersection proof of concept uses computer vision and edge computing to detect the presence of a pedestrian. The camera's technology can be used to set the zone within the view of the camera that needs to be monitored for pedestrian activity. The images are anonymized by deleting the image after extracting the metadata and only the metrics are leveraged for analysis. The anonymous pedestrian and vehicular traffic data is also stored in the cloud for further analysis, planning and design of components of the intersection, including stop signs, traffic/pedestrian light timing, crosswalks and sidewalks to improve pedestrian safety.

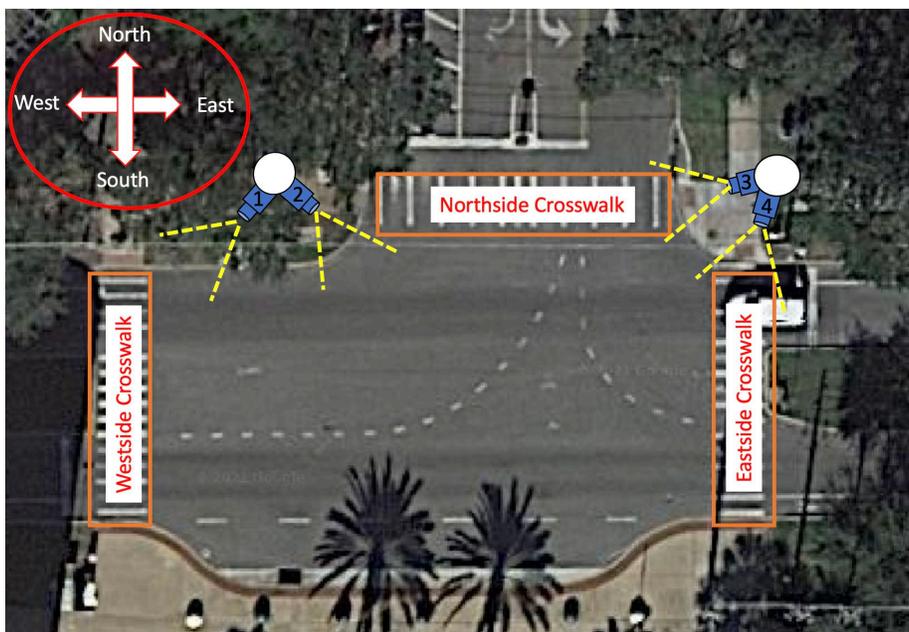


Figure 4 - Smart Intersection

Using computer vision, the cameras are able to detect the presence of pedestrians, bicycles and vehicles at the intersection and also determine the direction of travel.

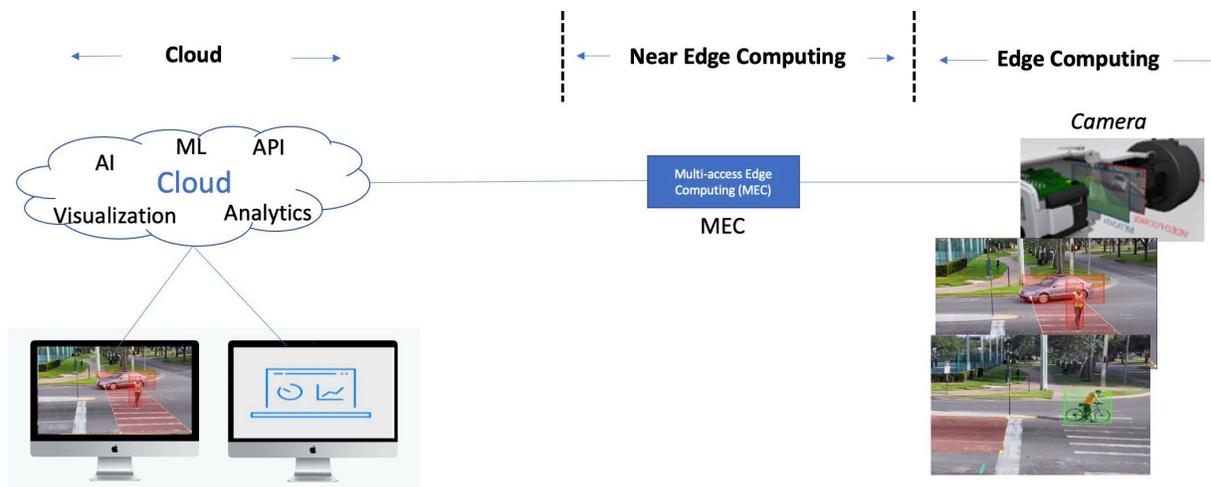


Figure 5 - Computer Vision

The Smart Intersection POC uses a computer vision machine-learning model to train the camera to process complex images such as pedestrians using a walking aid, pedestrians walking with pets or identify different types of vehicles.

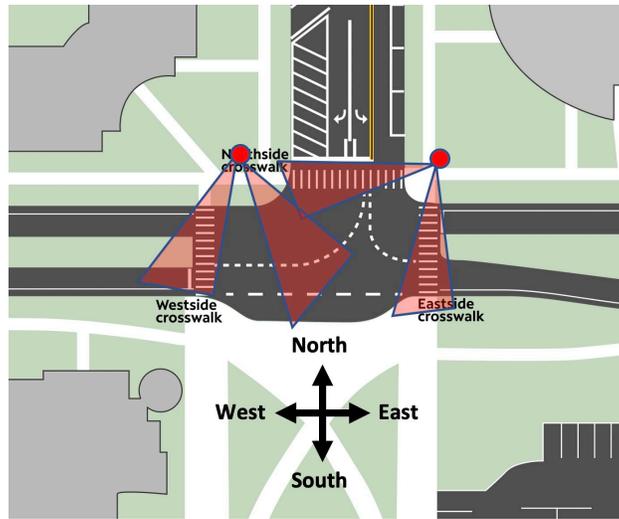


Figure 6 - Camera position

Computer Vision Model Training and Prediction

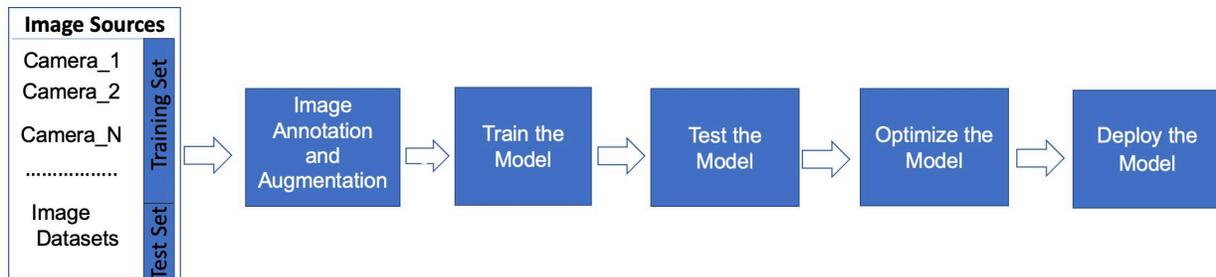


Figure 7 - Computer Vision Training Model

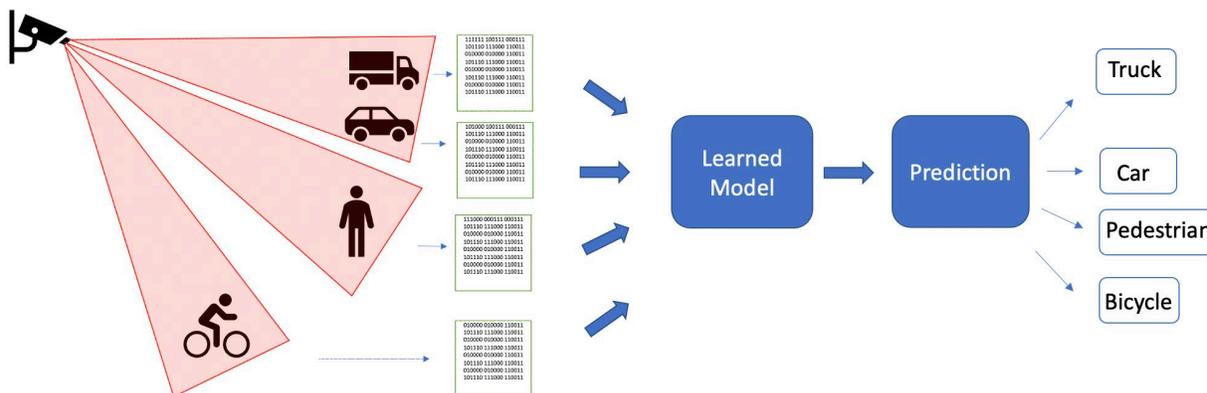


Figure 8 - Learned Model Prediction

5. Data collection and analysis

It is not just the collection of data through the deployment of sensor technology that makes a city smarter; it's also the ability to analyze, to draw insights and make informed decisions. In the Smart Intersection POC, only the metadata is sent to the cloud for storage and analysis. As discussed earlier, for privacy reasons, the image is deleted after extracting the metadata.

When it comes to data, privacy is, of course, very important, especially if the data collected has personally identifiable information (PII). Such data should be handled as per the agreement with the city, and it must also meet regulatory compliance.

Traffic Flow Metadata

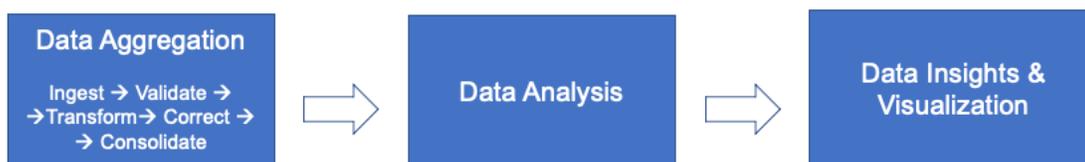


Figure 9 - Data Model

5.1. Pedestrian count data and direction of travel

The camera collects the following metadata on pedestrian movement:

- Number of pedestrians crossing the crosswalk
- Direction of pedestrian movement (e.g., north, south, east, west)
- Jaywalking

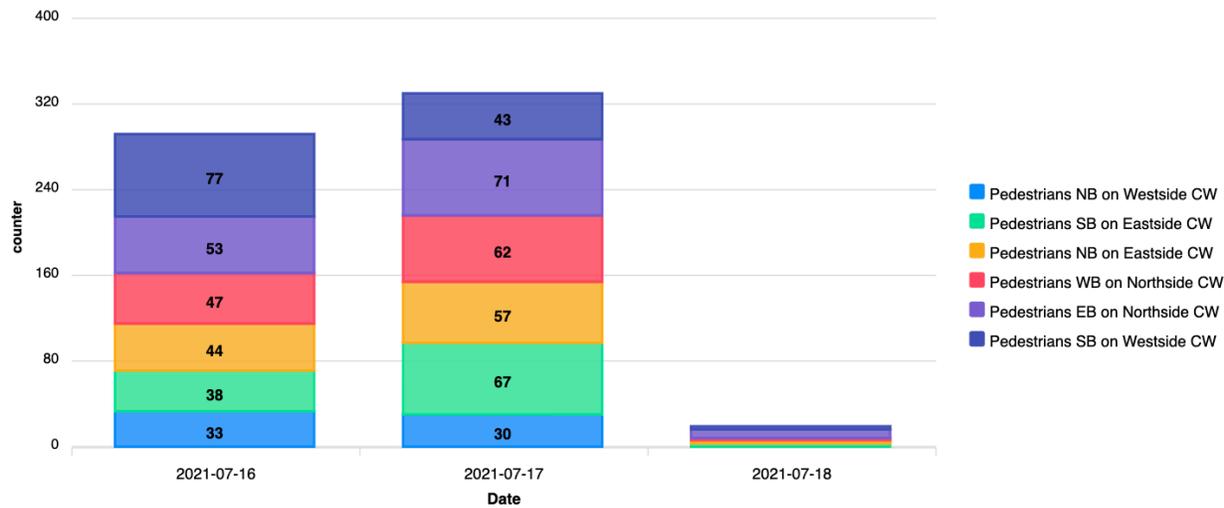


Figure 10 - Pedestrian Traffic Per Day

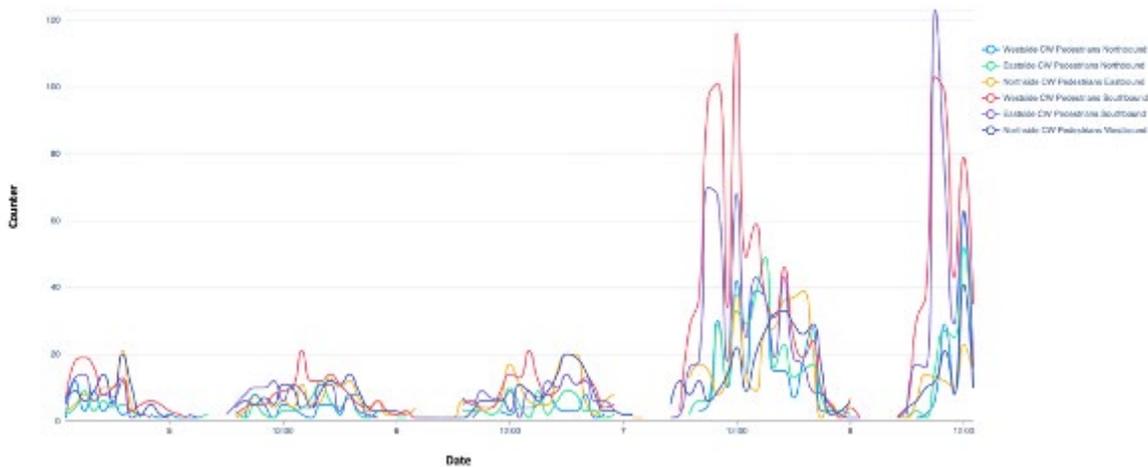


Figure 11 - Pedestrian Traffic Per Hour

The Smart Intersection POC picked up a high number of pedestrians avoiding the crosswalk and jaywalking at the intersection.



Figure 13 - Pedestrian Image

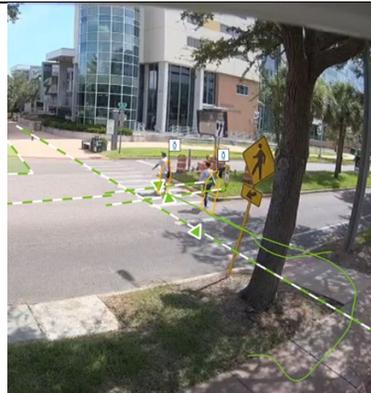


Figure 12 - Jaywalking

5.2. Vehicle count and direction of travel



Figure 14 - Vehicle Image

The camera collects the following metadata on vehicle movement:

- Number of vehicles crossing the intersection
- Vehicle making turn at the intersection

- Vehicle making an illegal U-turn

The following data shows more westbound data.

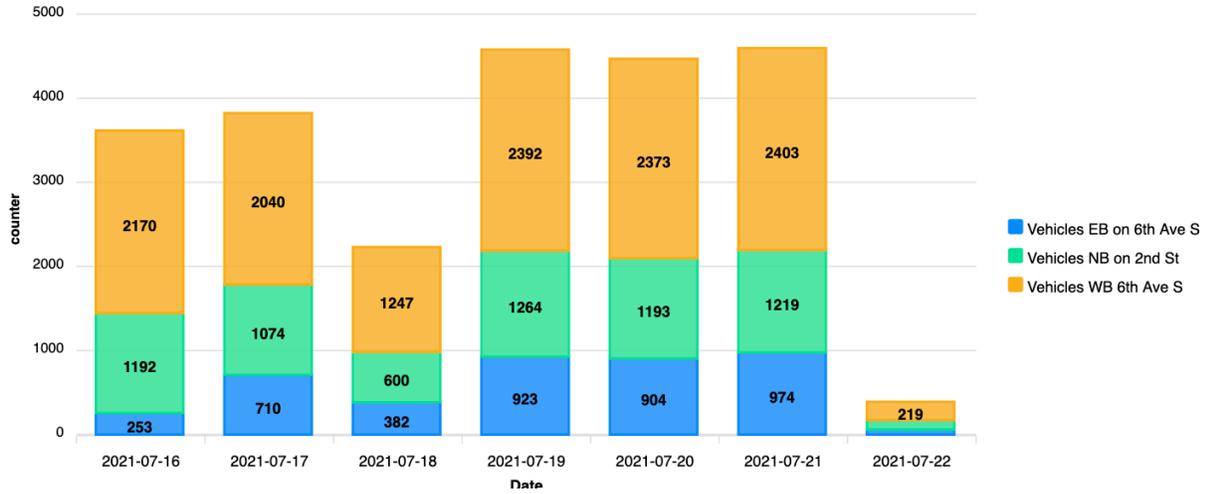


Figure 15 - Vehicle Traffic Per Day

The traffic flow at the intersection shows a consistent and predictable pattern, as shown in the image below. The traffic peaks during a specific time window during the day and shows minimum activity during the night.

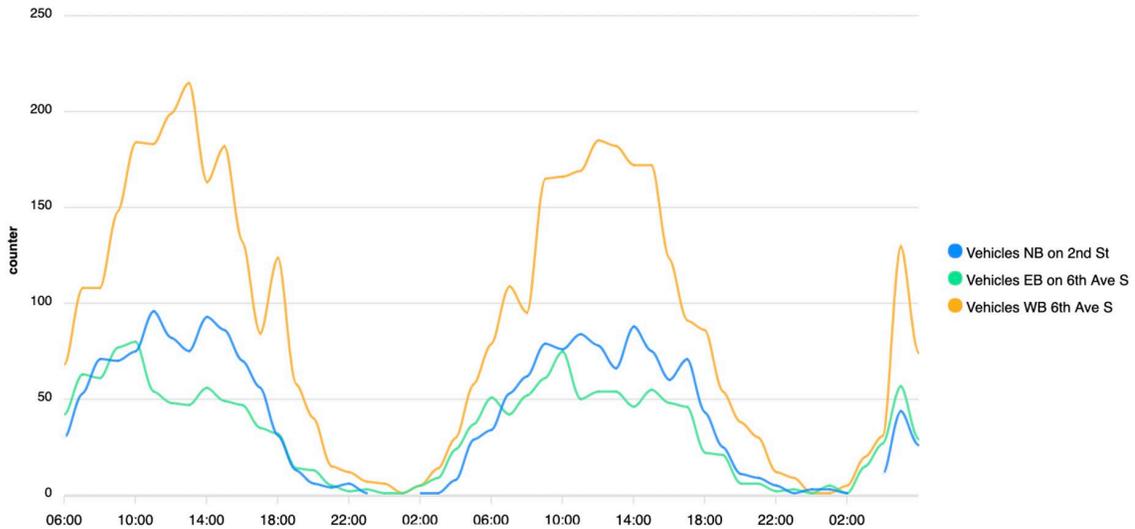


Figure 16 - Vehicle Traffic Per Hour

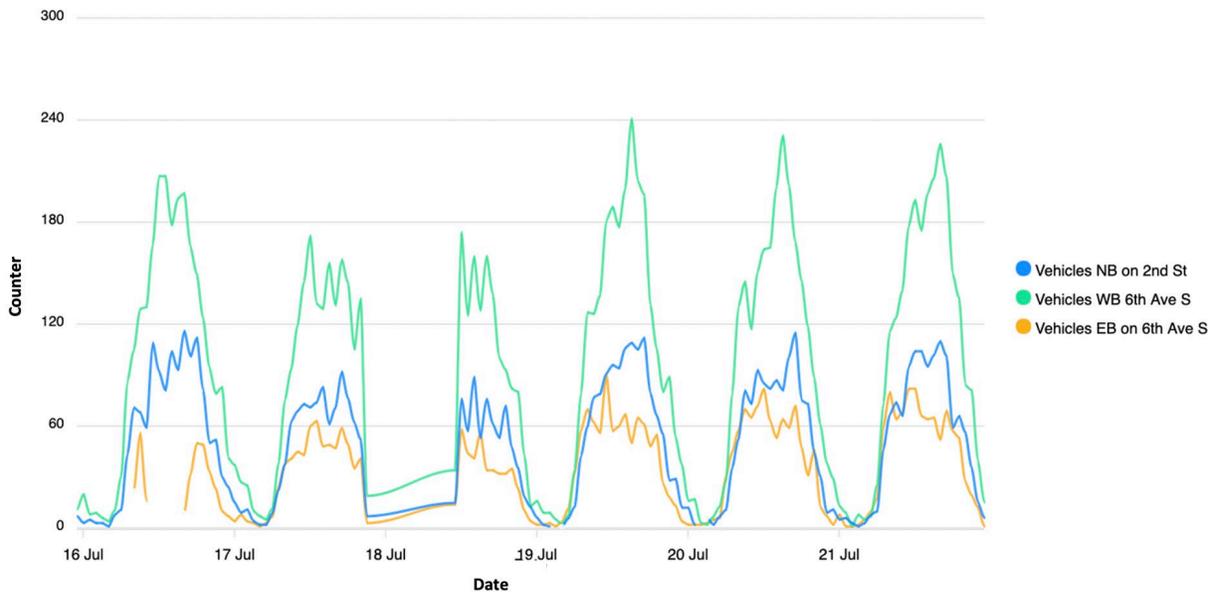


Figure 17 - Vehicle Traffic Per Direction

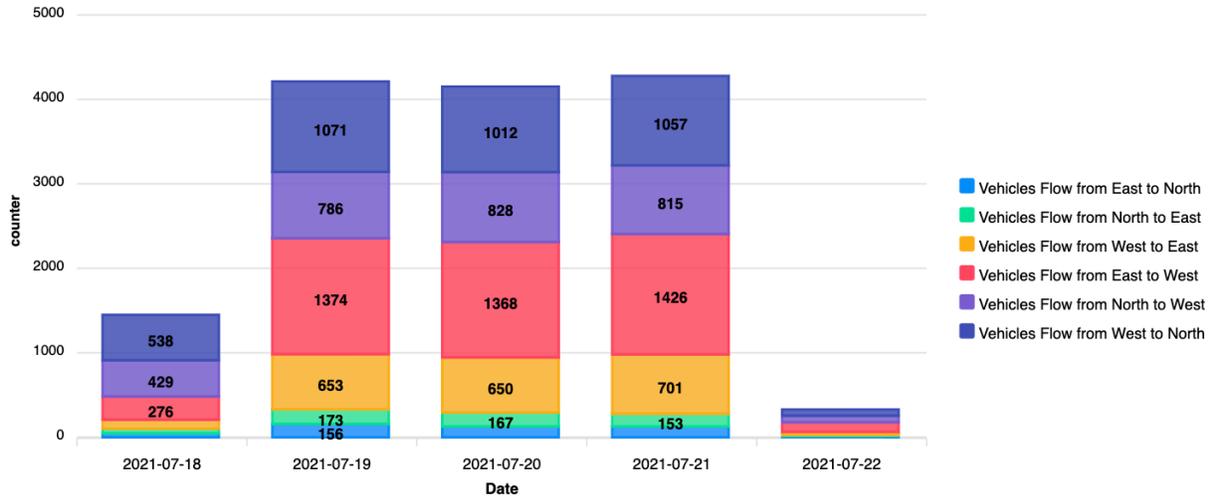


Figure 18 - Traffic Direction of Flow

The Smart Intersection POC even picked up illegal U-turns, putting pedestrians at risk.

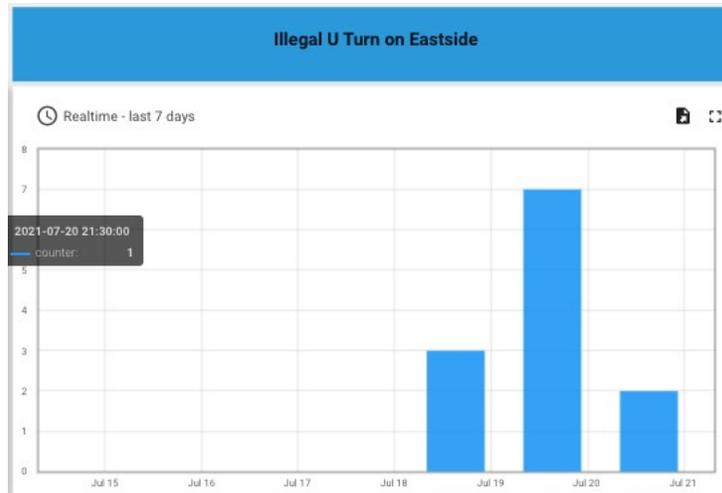


Figure 19 - Illegal U-Turn

5.3. Bicycle count and direction of travel



Figure 20 - Bicycle Image

The camera collects the following metadata on bicycle movement:

- Number of bicycles on the road and crosswalk
- Direction of bicycle movement on the road and crosswalk (e.g., north, south, east, west)

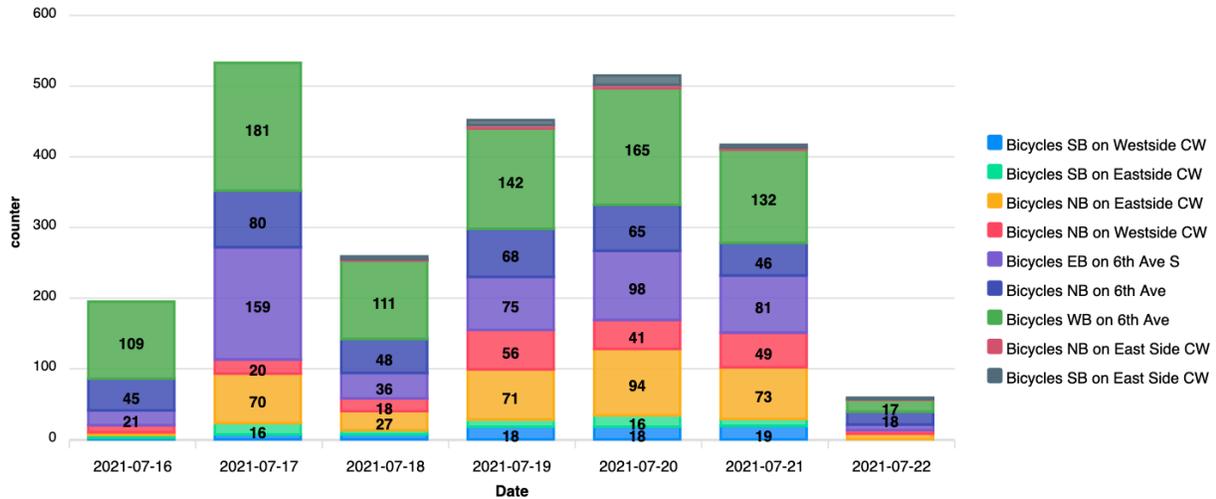


Figure 21 - Bicycle Traffic Per Day and Direction of Flow

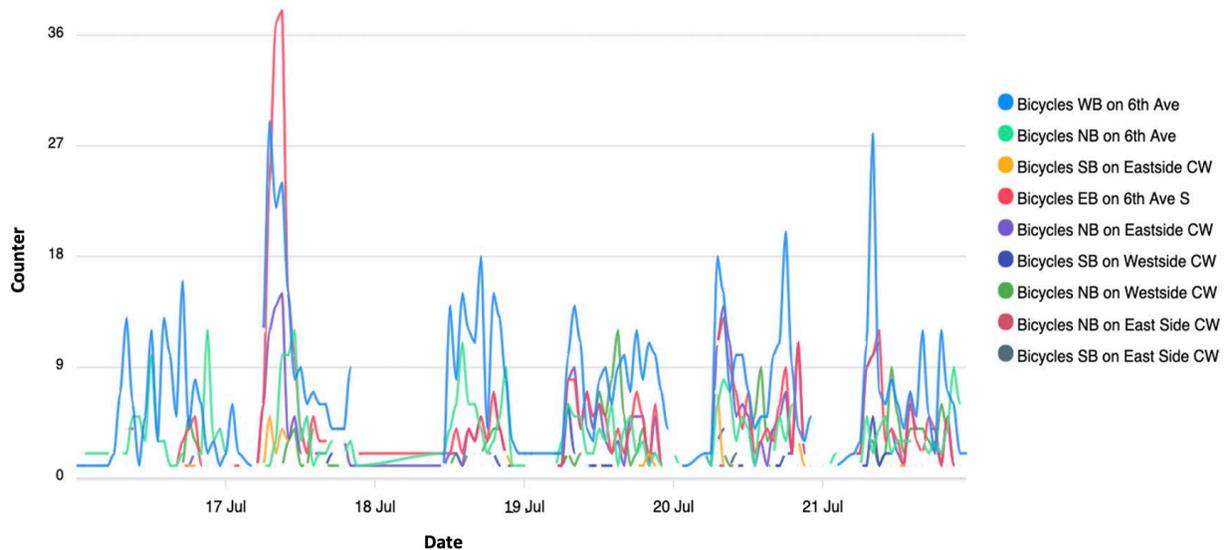


Figure 22 - Bicycle Traffic Per Direction

5.4. Data summary and forecast

This data is currently being used to train and develop a data model to forecast the traffic at the intersection.

P90: The true value is expected to be lower than the predicted value 90% of the time.

P50: The true value is expected to be lower than the predicted value 50% of the time.

P10: The true value is expected to be lower than the predicted value 10% of the time.



Figure 23 - Traffic Forecast

The city is using this anonymized pedestrian, bicyclist and vehicular traffic data to study all traffic activity at the intersection. Analyzing this information is helping the city to draw insights and help city planners redesign intersections to improve pedestrian safety.

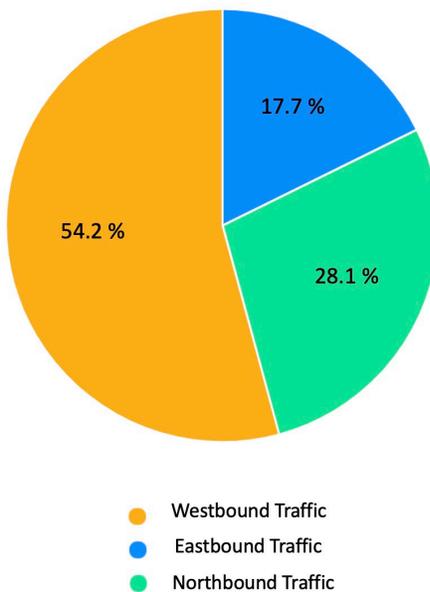


Figure 24 - Overall Traffic Flow by Direction

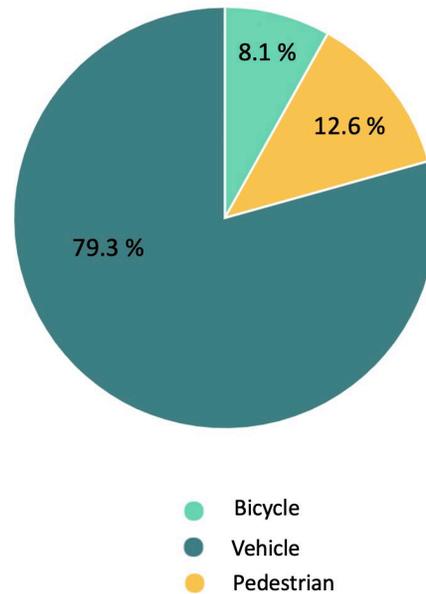


Figure 25 - Percent of Pedestrian, Bicycle and Vehicle Traffic

6. Conclusion

Designing an effective intersection requires an understanding of what activity actually happens within the intersection. The Spectrum Smart Intersection POC exponentially increases that level of understanding over manual methodologies that simply produce a count of pedestrians or vehicles. The POC is collecting, anonymizing, analyzing and visualizing data sets covering pedestrians, bicyclists, vehicles, direction of travel, time of day, counts of accidents and near-accidents and more.

The traffic activity data is helping the city to design and optimize intersections that focus on optimizing pedestrian safety while also streamlining traffic flow through intersections. These types of implementations allow a city to truly emerge and leverage technology on their path to becoming a smart city.

As we collect more data and datasets get richer over time, we expect to draw more insights and forecast traffic. Using the training data sets, we can train the computer vision model and capture additional metadata on the type of traffic at the intersection so that cities can have richer insights and move them closer to the goal of Vision Zero.

Abbreviations

CW	crosswalk
EB	eastbound
IoT	Internet of Things
MEC	Multi-access Edge Computing
NB	northbound
POC	proof of concept
EB	eastbound
PoE	Power over Ethernet
WB	westbound

Bibliography & References

1 “Traffic Safety Facts”, NHTSA’s National Center for Statistics and Analysis, National Highway Transport Safety Administration.

<https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813079>

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<https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813089>