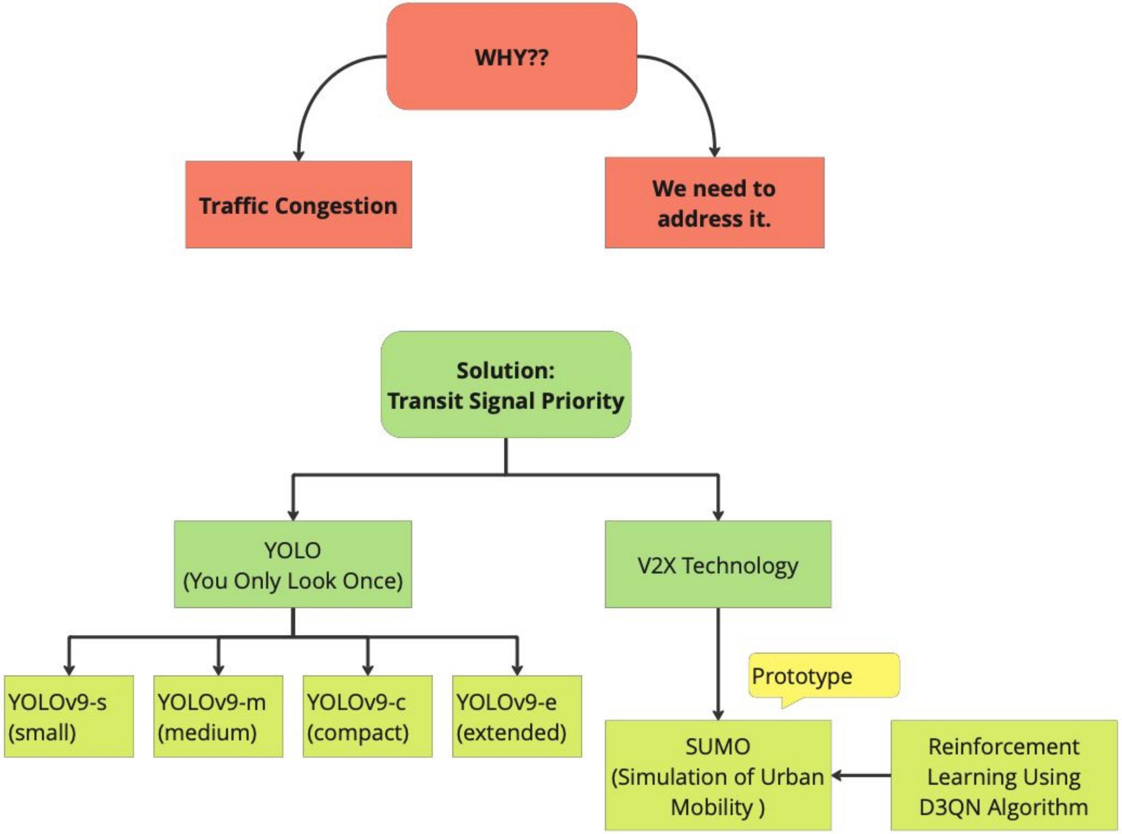
Business Question

Executive Summary



Current Traffic Management Challenges:

- ***Congestion***: Urban areas often face severe traffic congestion during peak hours, leading to delays and frustration among commuters.
- ***Safety Concerns***: Accidents and collisions due to human error or inadequate traffic control measures pose risks to both motorists and pedestrians.
- ***Environmental Impact***: Traffic congestion contributes to increased air pollution and carbon emissions, impacting environmental sustainability.

Executive Summary

2. Smart Traffic Management Using YOLO:

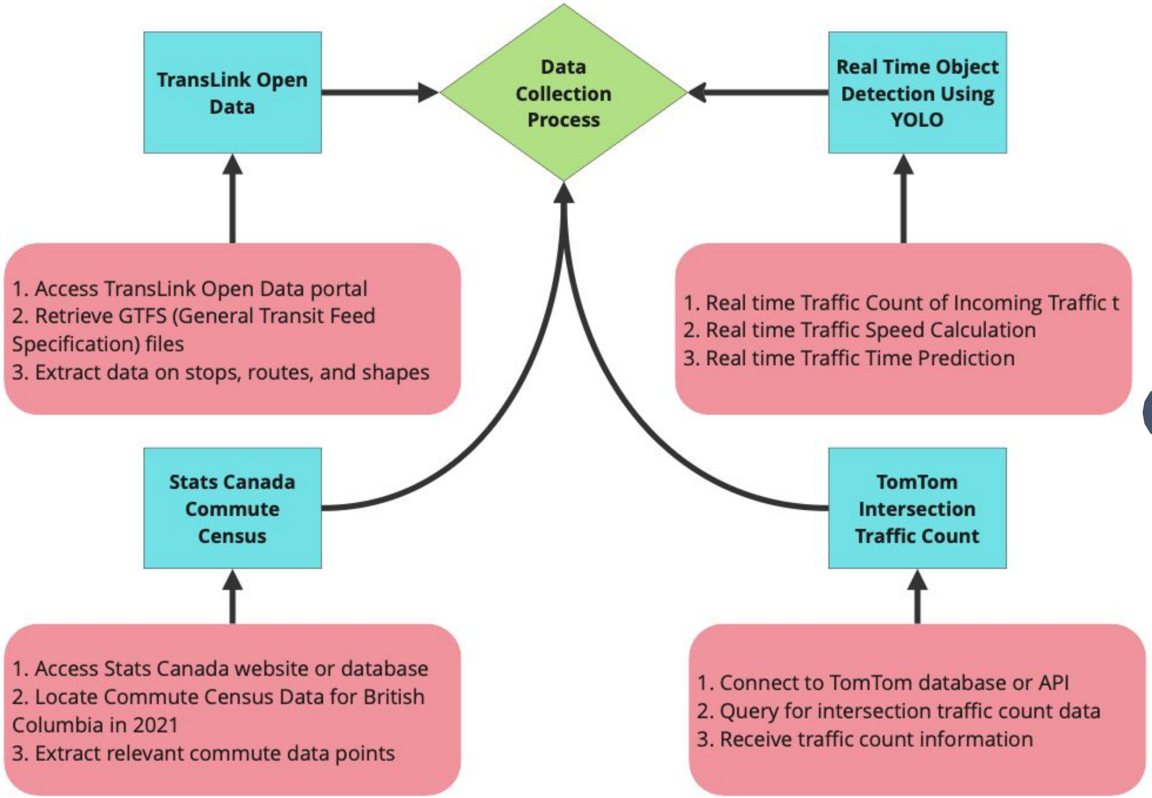
- ***Traffic Flow Optimization*****:** By analyzing real-time traffic conditions, YOLO can optimize traffic signal timings to minimize congestion and improve traffic flow.
- ***Adaptive Signal Control*****:** YOLO enables adaptive traffic signal control systems that adjust signal timings based on current traffic patterns and demand.
- ***Enhanced Safety Measures*****:** YOLO-based systems can detect and alert authorities to potential safety hazards, such as accidents, pedestrians in hazardous areas, or vehicles violating traffic rules.

3. Benefits of V2X Technology:

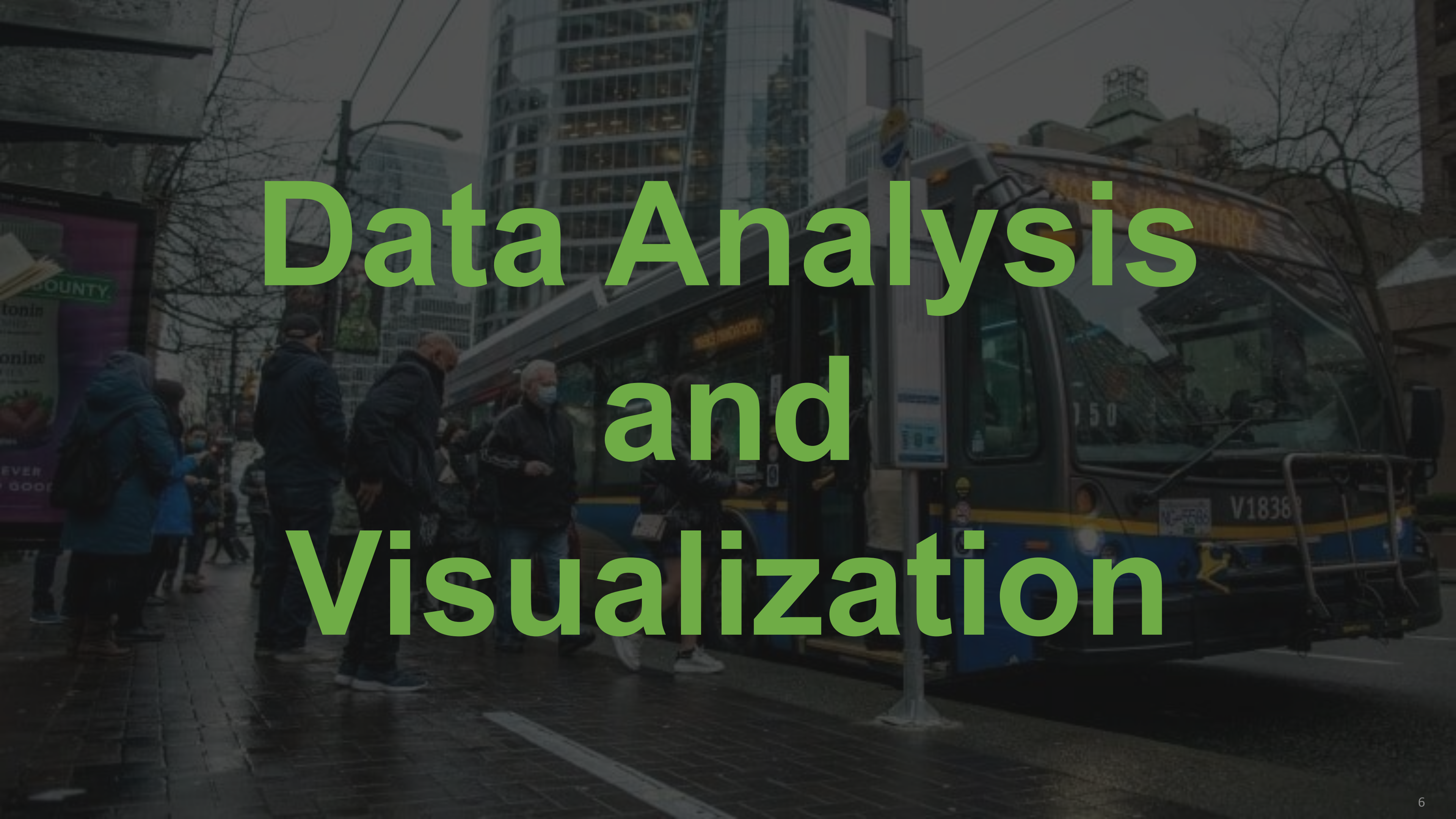
- ***Enhanced Traffic Efficiency*****:** Enable traffic management systems can dynamically adjust traffic signals and lane assignments based on real-time traffic data, further improving traffic efficiency and reducing congestion on road networks.
- ***Improved Safety*****:** Enables vehicles to communicate with each other (V2V) and with infrastructure such as traffic lights and road signs (V2I). This communication allows vehicles to exchange information about their position, speed, direction, and other relevant data in real-time.

Data Collection Flow

Data Collection Flow

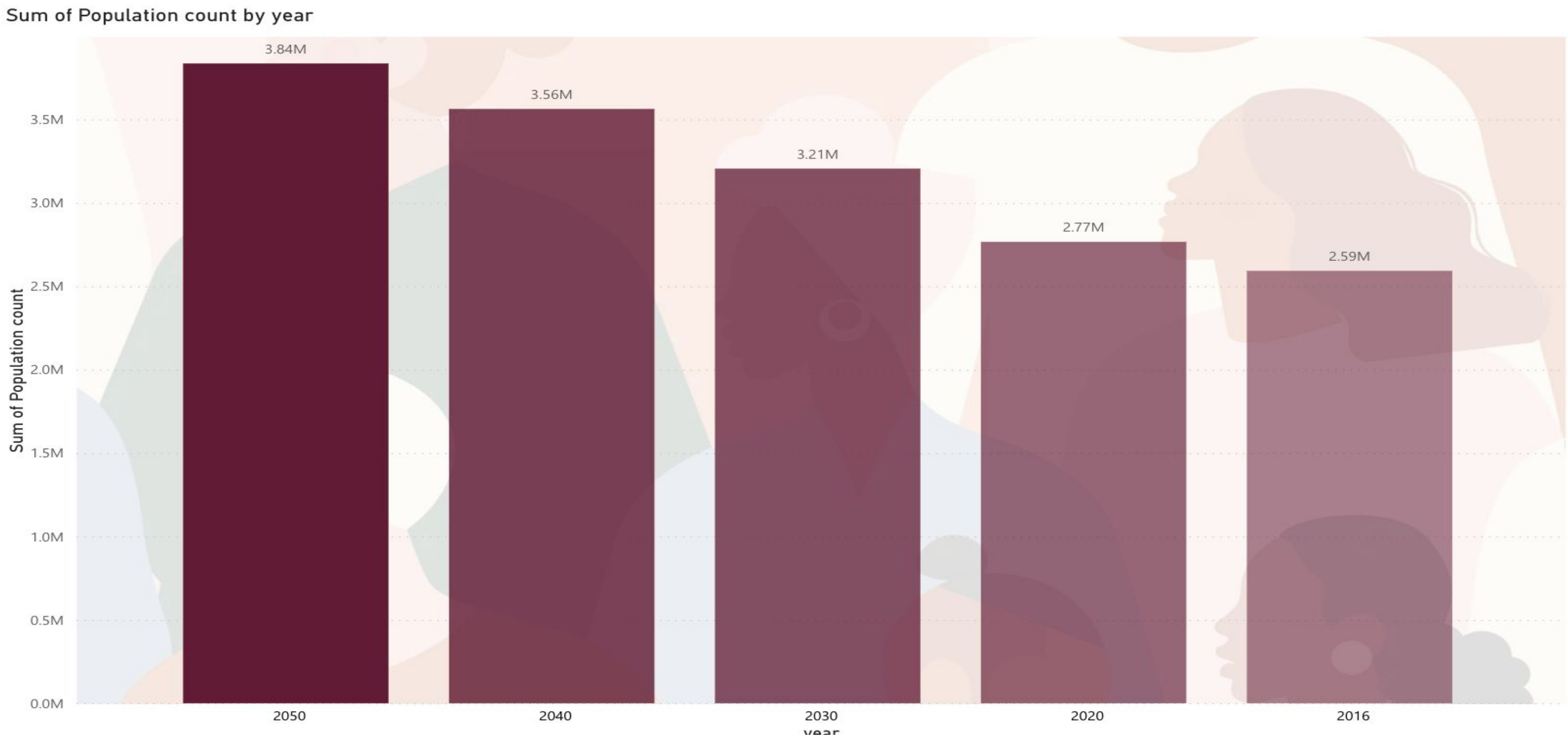


- We utilized data from Stats Canada for Metro Vancouver's population trends and transport behaviors.
- Real-time car count data from TomTom was analyzed for traffic insights.
- Translink's public transport data was used to assess bus stop routes and schedules.
- Additionally, we employed YOLO V9, an advanced object detection model, to count vehicles at intersections and estimate travel times accurately.



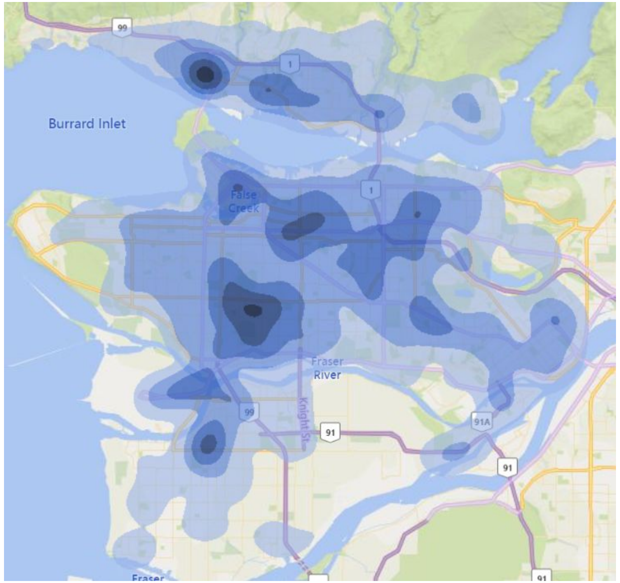
Data Analysis and Visualization

Population Census Data (Year 2016 & 2021)



Source: [metro vancouver]

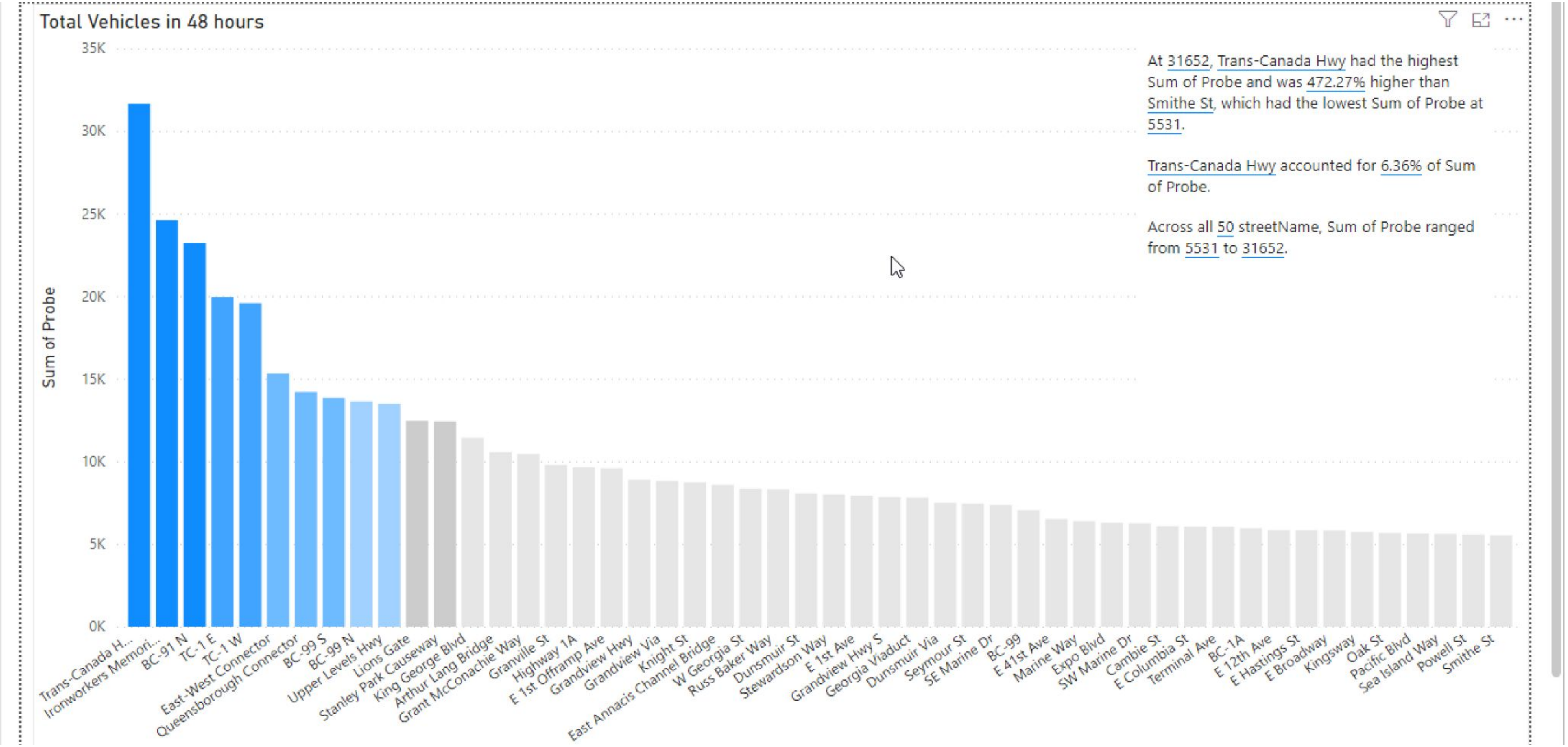
Vehicle Count At Particular Location in BC, Canada



- Here, during the evening, when traffic is at its worst, we have imported the Tomtom data for a single day.
- We have also created a heat map and clustered graph based on the number of cars.
- In this instance, we have selected a single cluster, and the data shows that there are 1116 distinct locations with 2549 automobiles overall. The heat map indicates that the area above, which includes South Vancouver, East Vancouver, North Vancouver, and Downtown, is extremely dark.

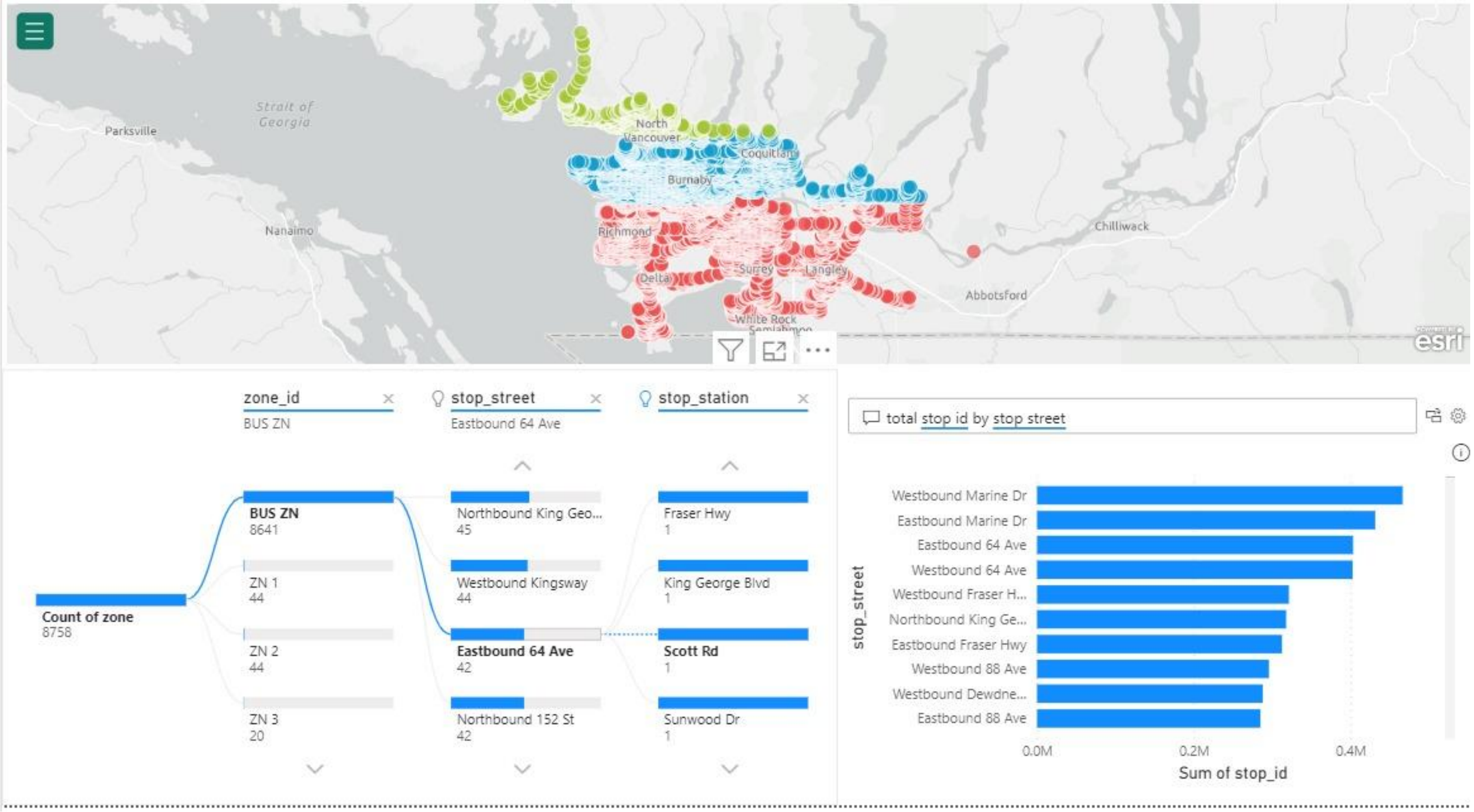
Source: [Stats Canada]

Total Vehicles in 48 hours For Oct 2023 in BC, Canada



Source: Tomtom

Zone and Bus Stop Classification in BC, Canada



Source: [TransLink]

STRATEGY

TSP System requires a clear architecture framework and efficient data flow process

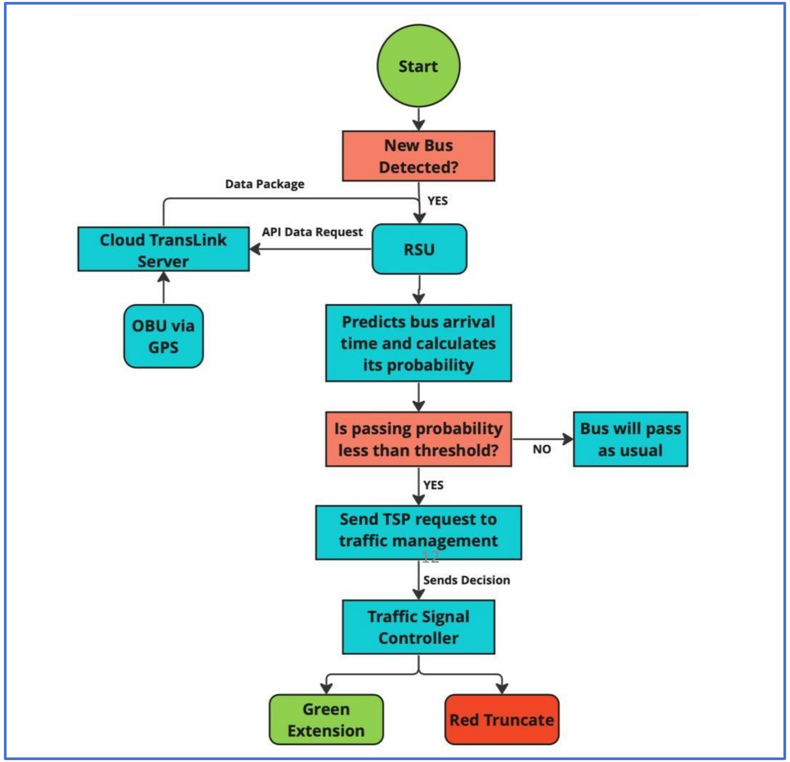
An efficient data flow diagram allows Govt to leverage data and the TSP system to be optimized

Data Flow Process

An optimized data flow diagram that aligns with TransLink's data management resources

Cloud Server

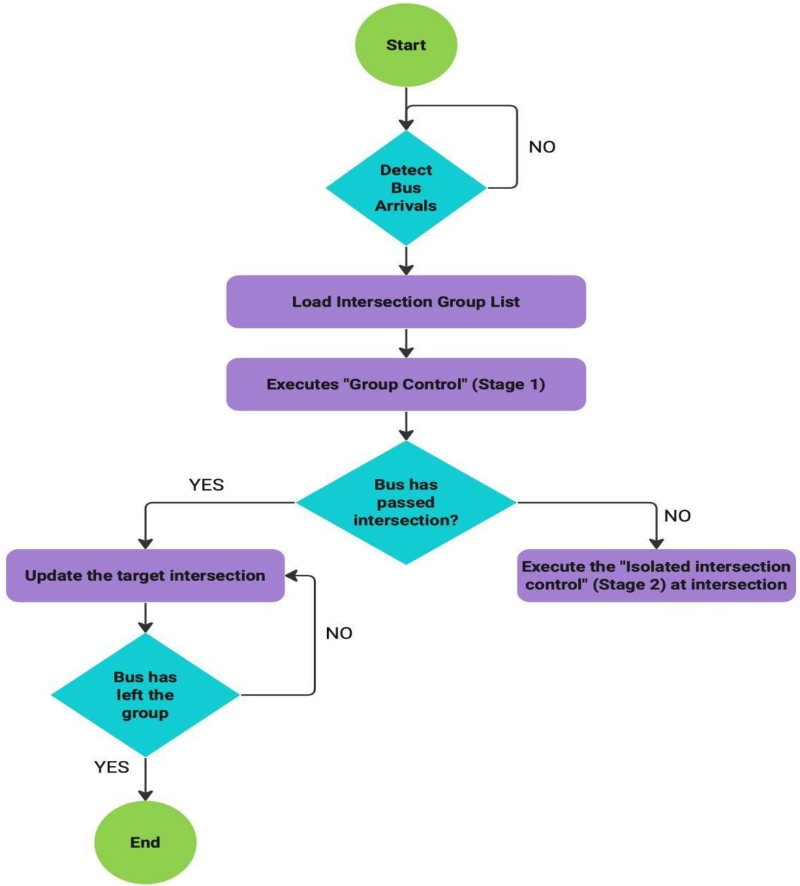
Scalable and cost effective solution for storing data



TSP Simulation Using SUMO (Simulation Of Urban Mobility)

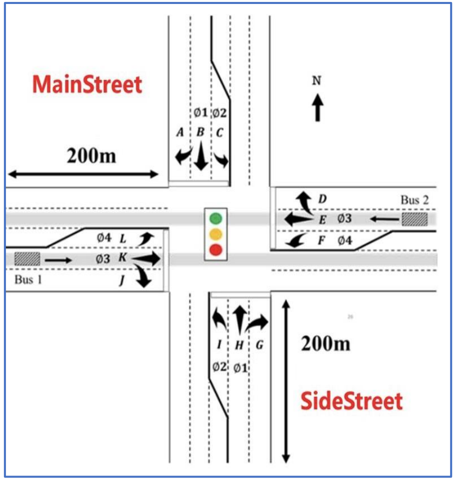
In the simulation, the TSP strategy operates as follows:

- Continuously monitor the bus's position at each time step, assessing its proximity to trigger points.
- Compile a list of intersections within the designated group and implement "Group Control."
- Sequentially apply isolated-intersection control within the specified group.



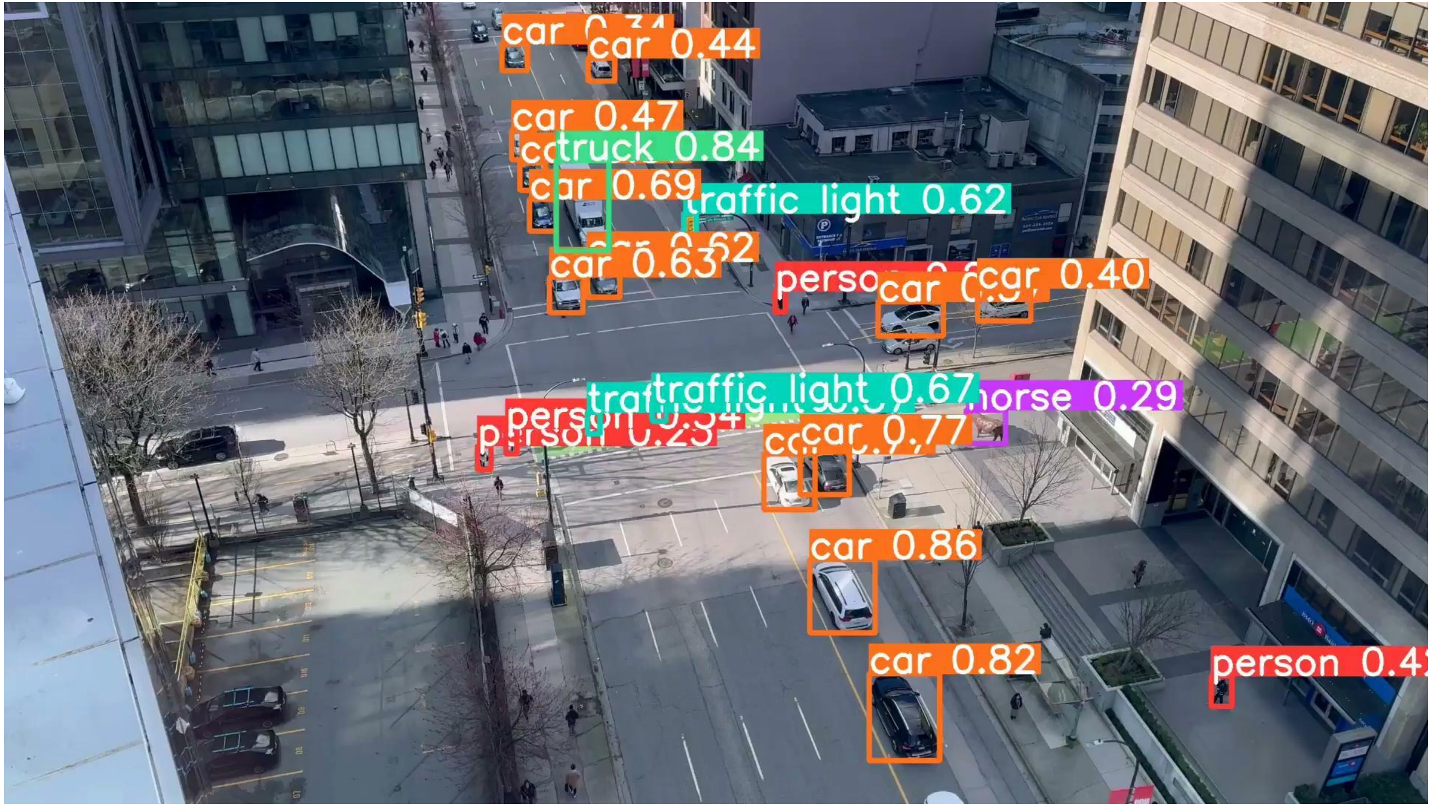
YOLO PROTOTYPE

Original Real-time Video Frame



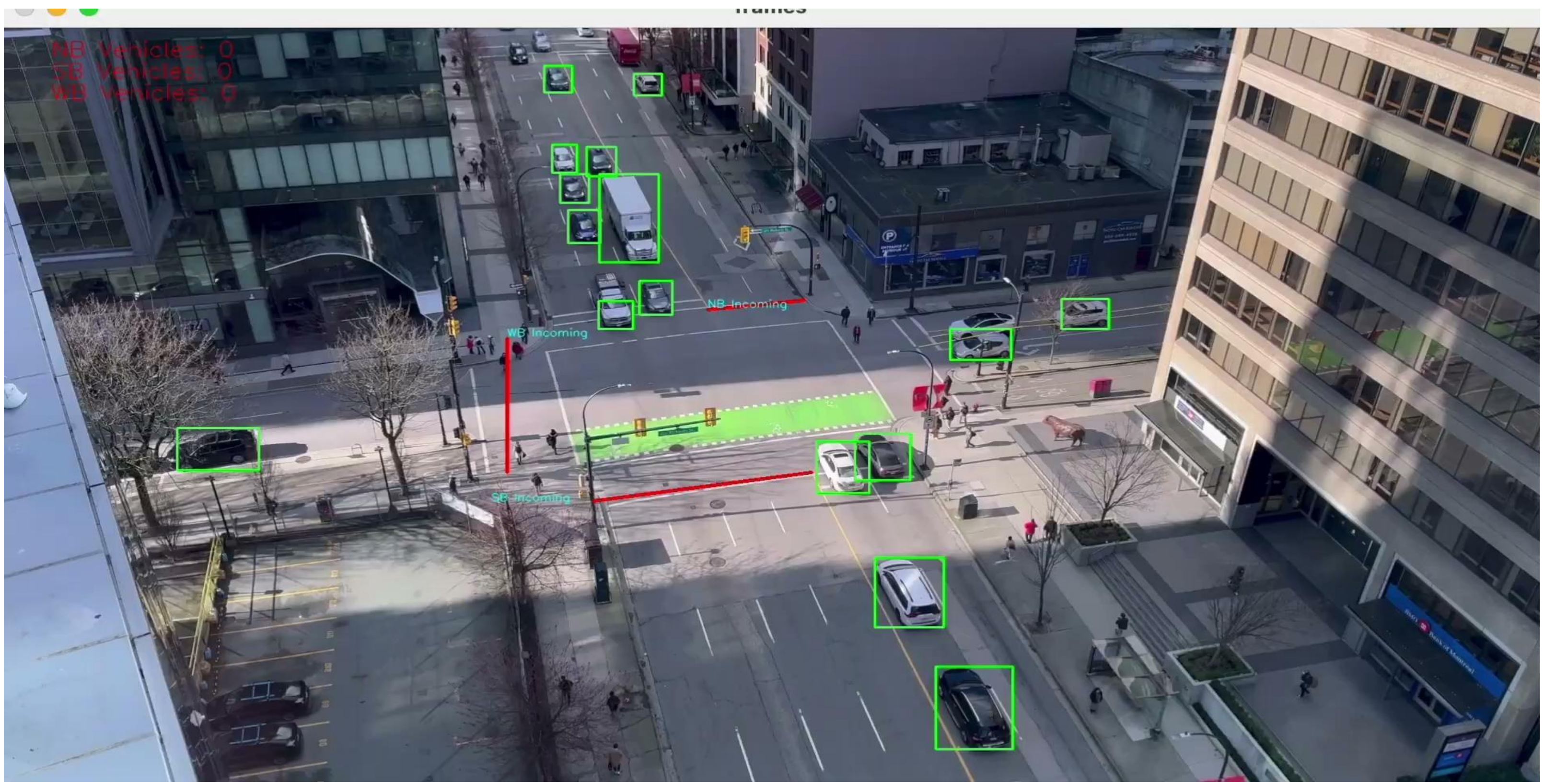
Disclaimer: This video has been captured by us exclusively for the purpose of implementing our project.

Object Detection Inference



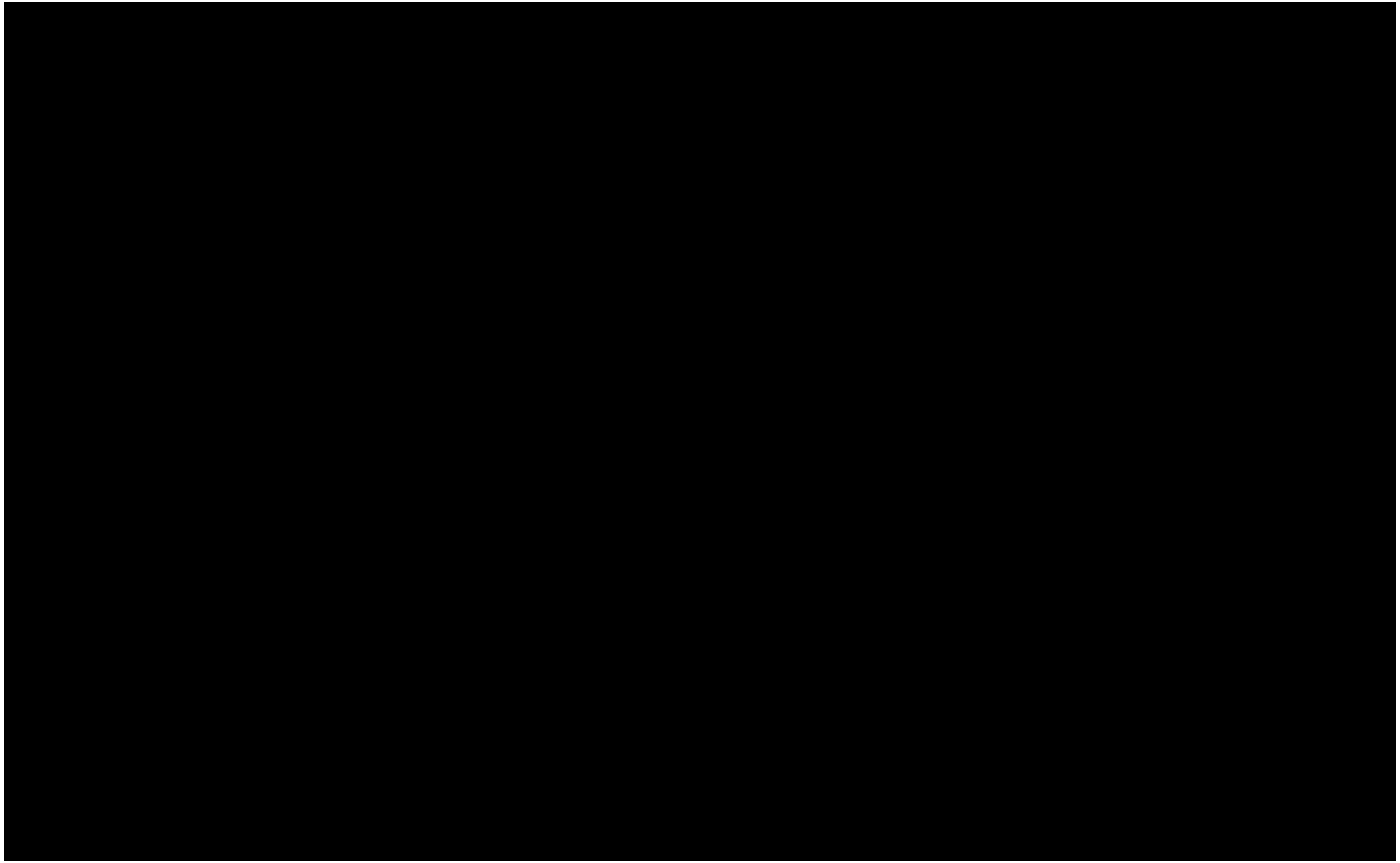
Based on yolov9c model, it has been trained on a MS Coco dataset and inference is the step where the model is used to perform actual detections on real-world data.

Traffic Count for Incoming Vehicles



NB Vehicles: 8
SB Vehicles: 15
WB Vehicles: 1

Incoming Vehicle Speed Calculation



V2X PROTOTYPE

TSP System requires a clear architecture framework to facilitate data flow

What technologies will enable the communication of data between different systems?

Wireless communication technology

Buses can communicate with other vehicles/infrastructure technology

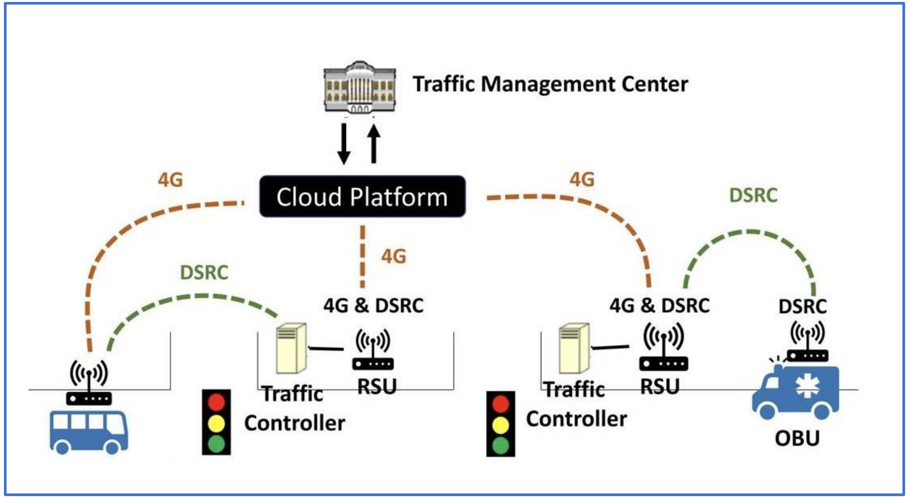
Wi-Fi — **5G**

Real-time communication with cloud servers
Ensures **timely updates and information exchange.**

Dedicated short-range communication (DSRC)

Well suited for fast moving dynamic environment
(TransLink bus)

System Framework



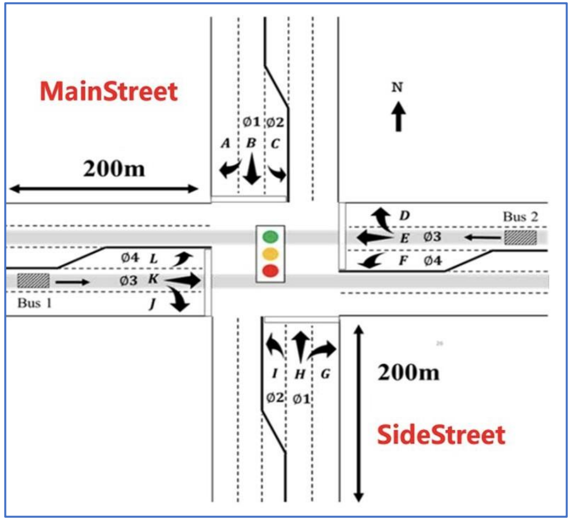
TSP simulation using SUMO (Simulation Of Urban Mobility)

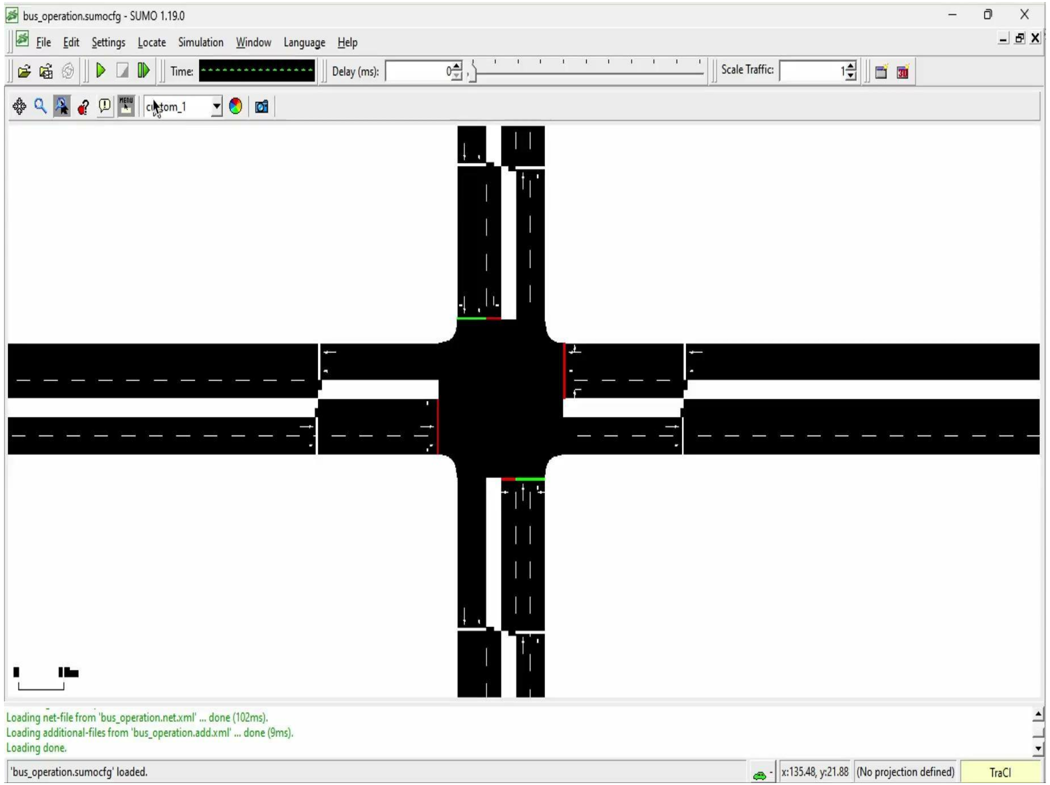
An In-depth Analysis Using SUMO Simulation In A Real-world Scenario

Simulation Overview

Simulation considered the following traffic condition

A single intersection	2 – 3 lanes per roadway



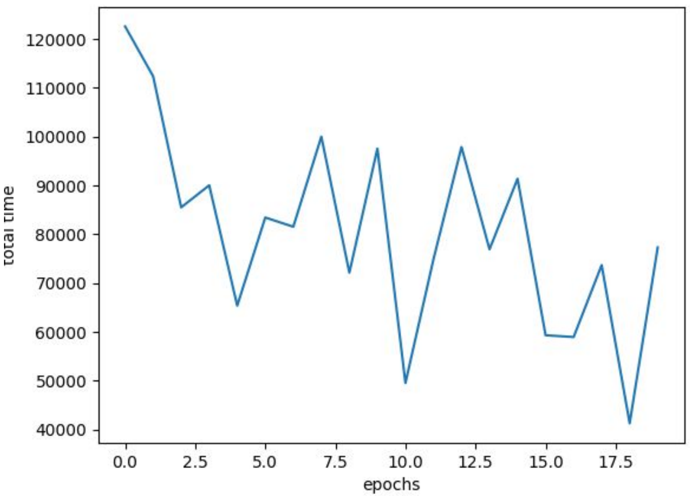


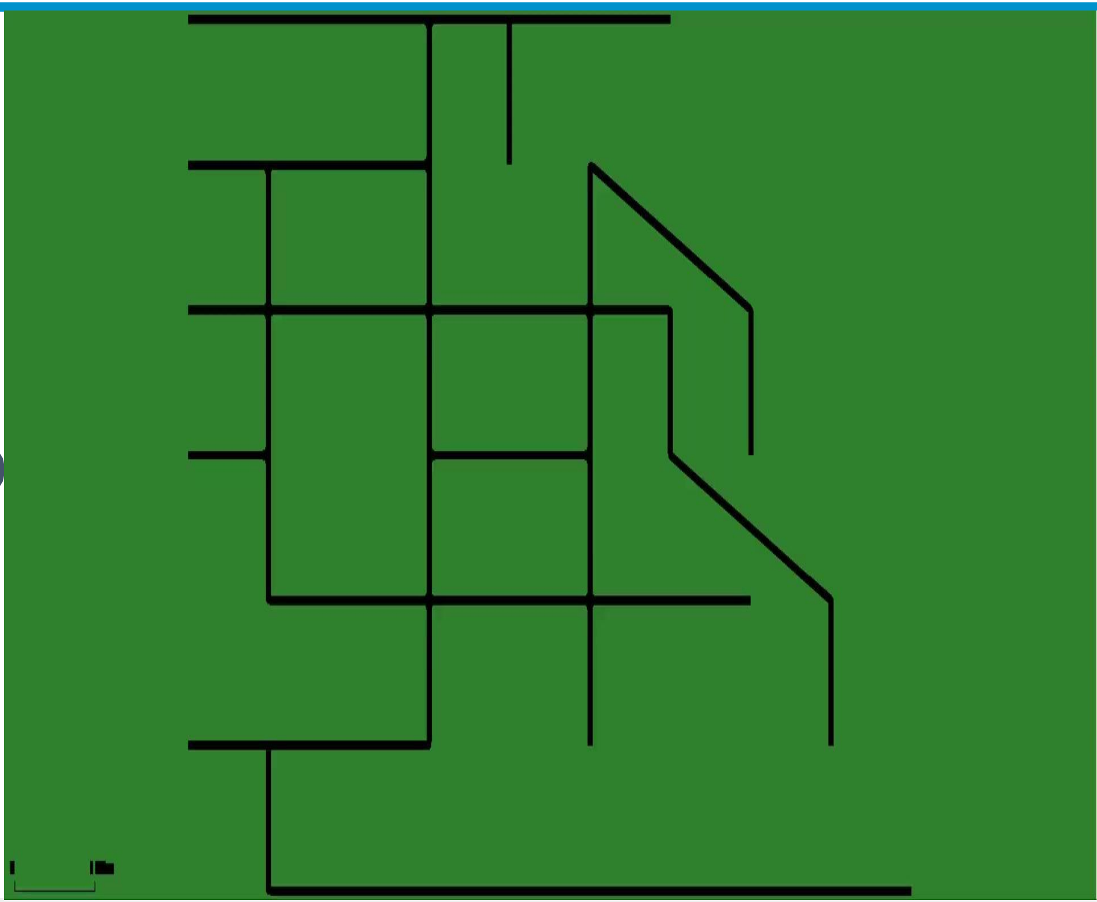
TSP simulation using SUMO (Simulation Of Urban Mobility)

An In-depth Analysis Using SUMO Simulation In A Real-world Scenario

Reinforcement learning overview

- In RL the specific algorithm used is **3DQN**.
- The inputs for the RL algorithm is the data received by V2X and generated by our Yolov9 architecture.





LIMITATIONS & FUTURE SCOPE

Current Limitations And Future Work

LIMITATIONS

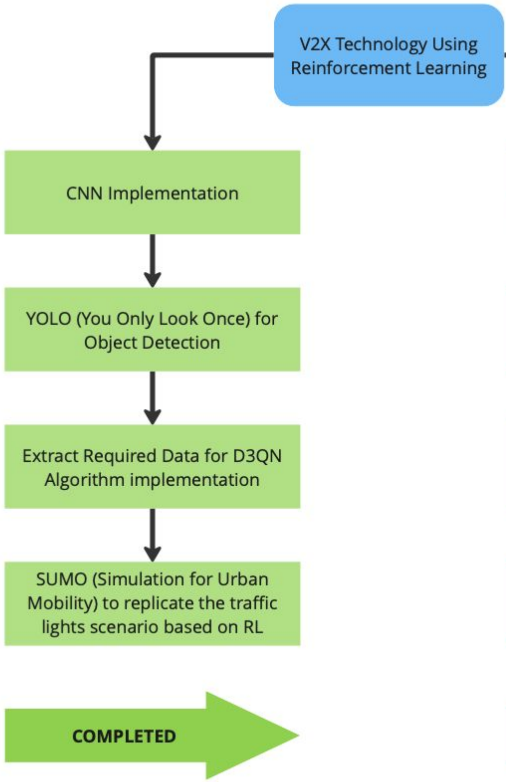
Real-time data can only be collected from **buses and road side units**

System is currently only used to **prevent bus delays**

Infrastructure Dependency:
- Effectiveness depends on the availability and implementation of compatible infrastructure.
- This may not be available in all municipalities.

Continuous Monitoring:
- Continuous maintenance of technical hardware is required.

FUTURE WORKS



Source: Deep reinforcement learning for transit signal priority in a connected environment. Transportation Research Part C: Emerging Technologies, 142.

Current Limitations And Future Work

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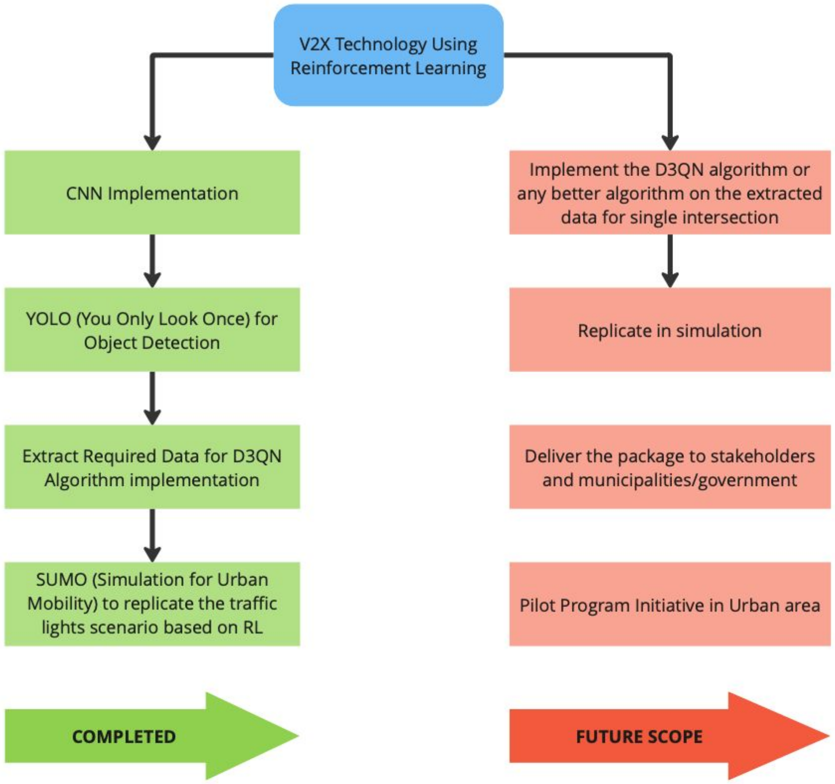
FUTURE WORKS



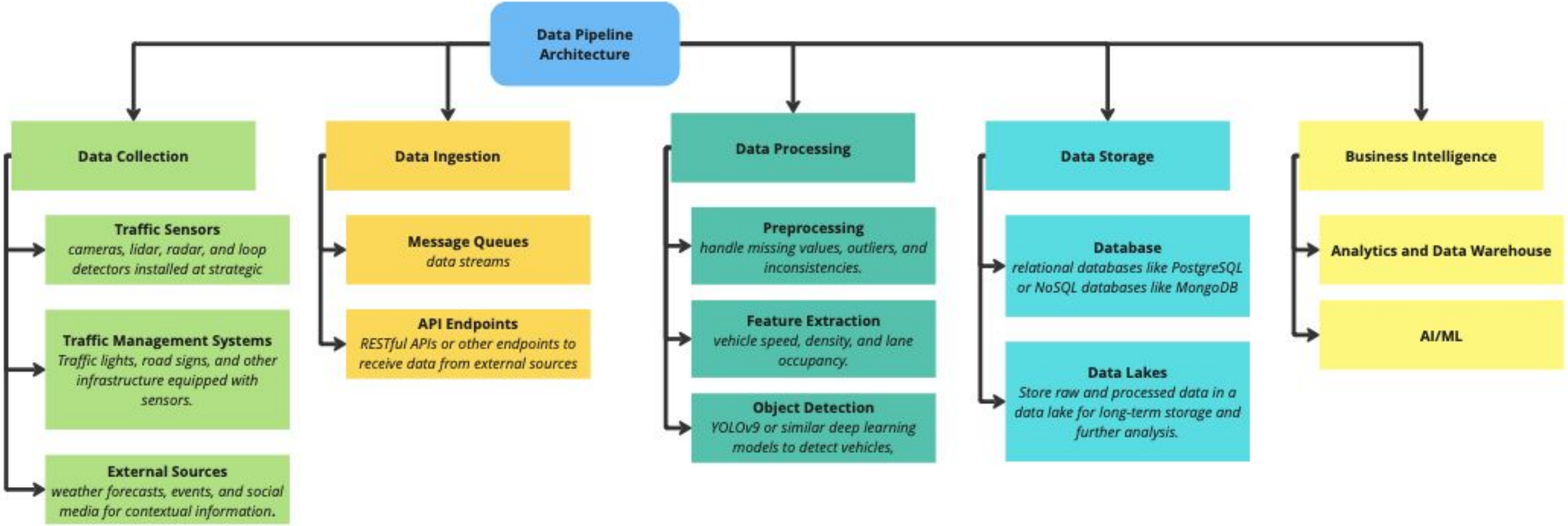
Source: Deep reinforcement learning for transit signal priority in a connected environment. Transportation Research Part C: Emerging Technologies, 142.

APPENDIX

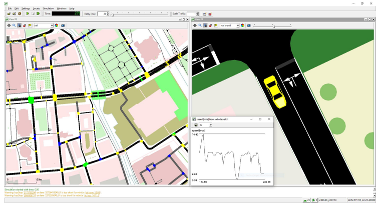
Appendix

1. Data Pipeline Architecture
2. Data Pipeline TechStack
3. V2X Network Architecture
4. YOLO Architecture
5. TSP Data Flow Process
6. Intersections Clustering
7. Hardware Components
8. Data Integration and Management: TransLink

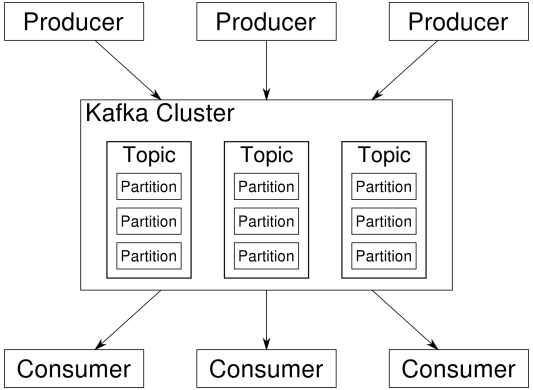
Data Pipeline Architecture



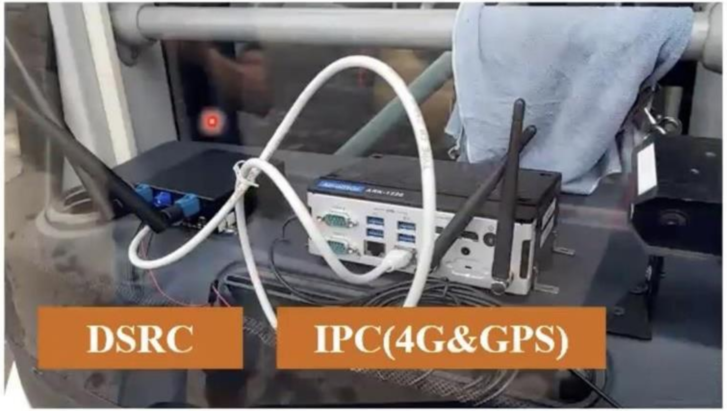
Data Pipeline Tech Stack



Tech Stack:
Data Collection & Ingestion: Apache Kafka, RESTful APIs
Data Processing: Python (Pandas, NumPy), OpenCV for YOLOv9 object detection
Data Storage: PostgreSQL, Apache Hadoop (HDFS)
Data Analysis: Python (TensorFlow, PyTorch) for Reinforcement Learning, scikit-learn for statistical analysis
Data Visualization: Grafana, Leaflet
Simulation Integration: SUMO, TraCI (Traffic Control Interface)



Hardware Components



RSU(road-side unit)

The RSU is used to communicate with vehicle and send the control order to traffic controller.

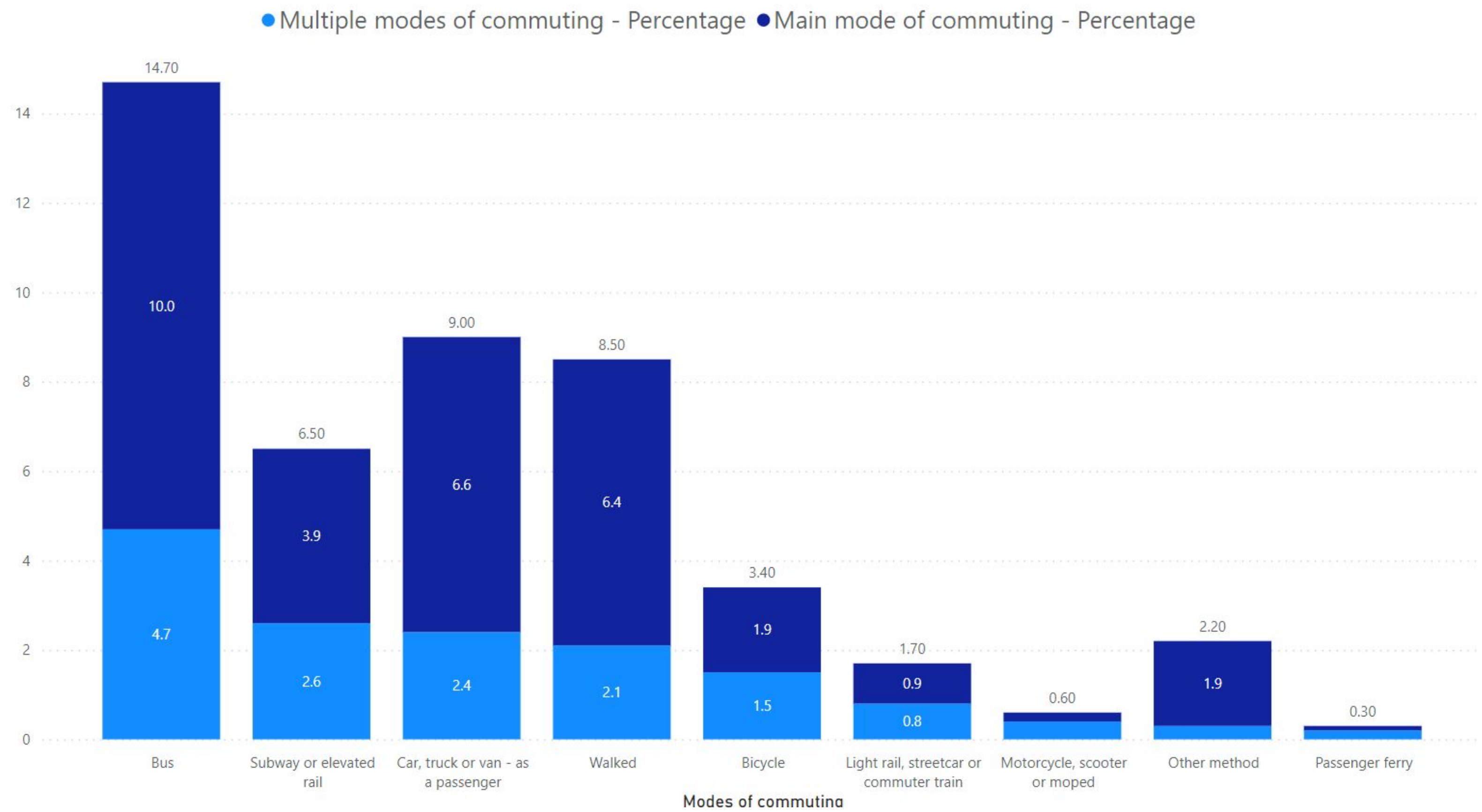
OBU(On-Board Unit)

The OBU contains two parts:

(1) DSRC Module

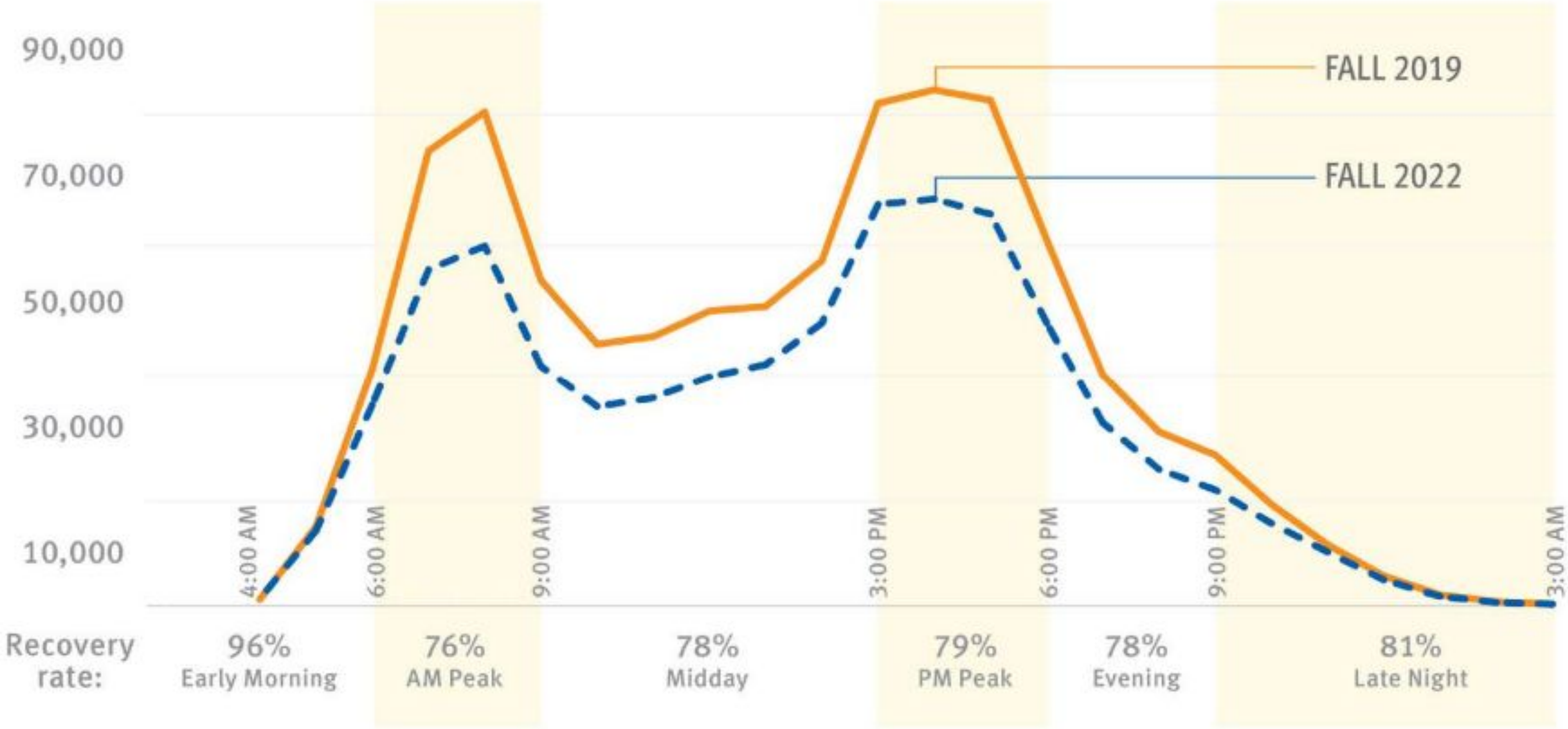
(2) Industrial Computer

Modes of Commuting In Vancouver, Canada



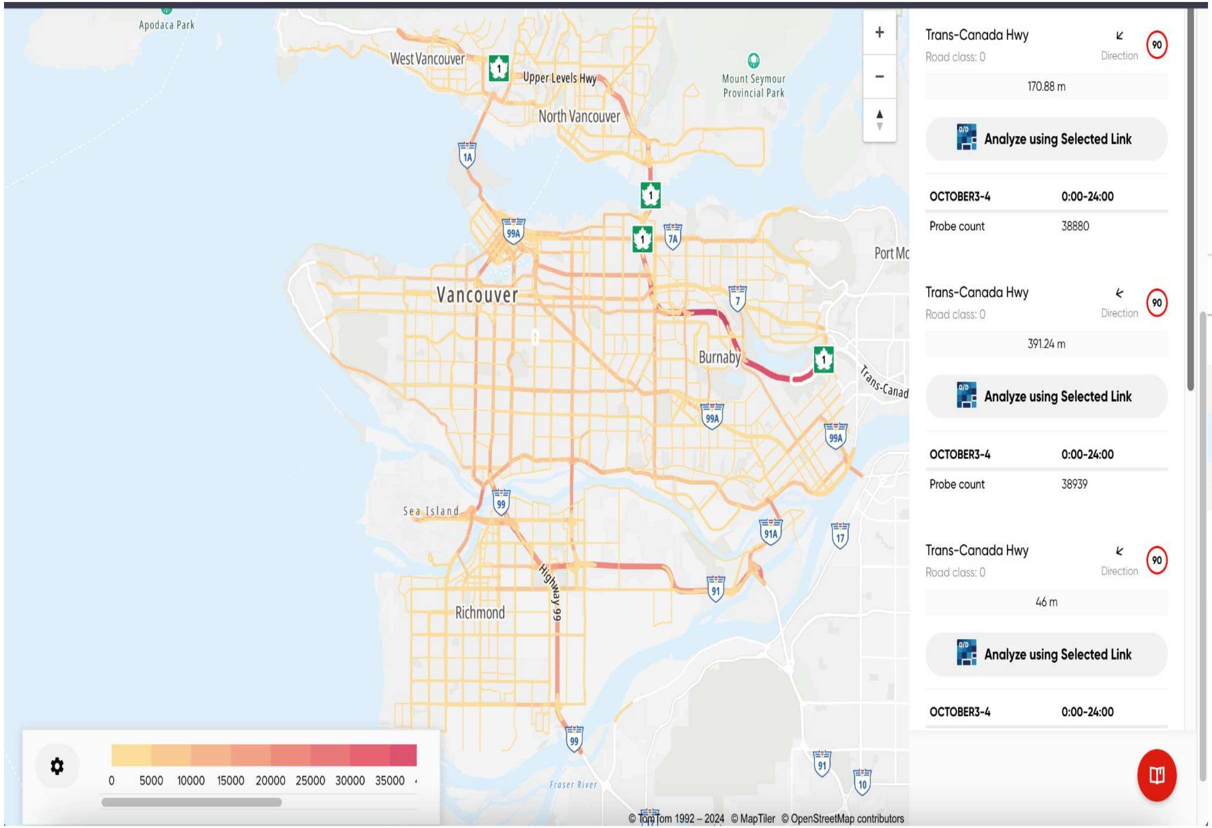
Source: [Stats Canada]

Data Reporting and Visualization: Peak Hours



Source: [TransLink]

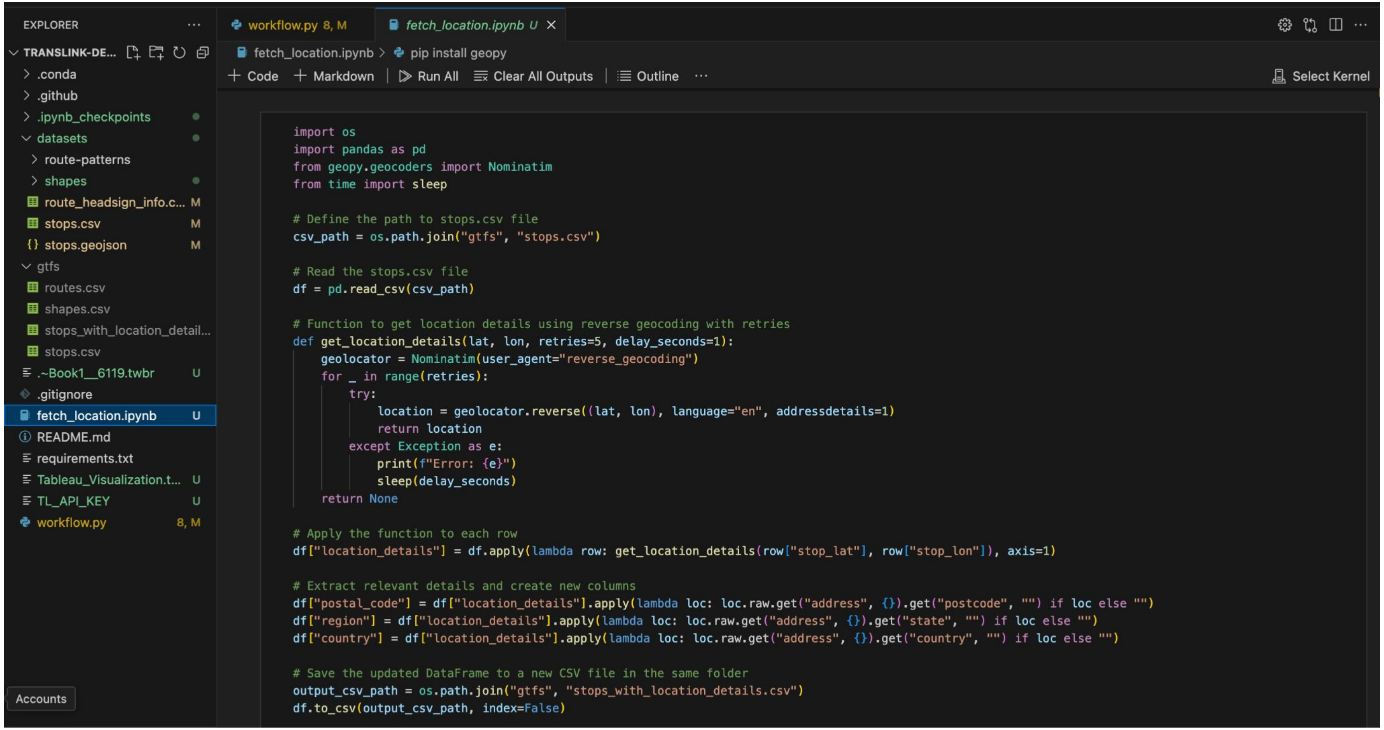
Data Reporting and Visualization



	Street Name	Distance	Latitude	Longitude	Latitude_end	Longitude_end	Probecount
0	Boundary Rd	149.05	49.18590	-122.95721	49.18596	-122.95720	0
1	Boundary Rd	12.54	49.22326	-123.02351	49.22314	-123.02352	6280
2	Boundary Rd	10.06	49.22314	-123.02352	49.22307	-123.02361	6295
3	W King Edward Ave	32.52	49.24912	-123.20460	49.24935	-123.20431	32
4	20th St	6.98	49.20579	-122.95207	49.20584	-122.95213	2747

Source: TransLink

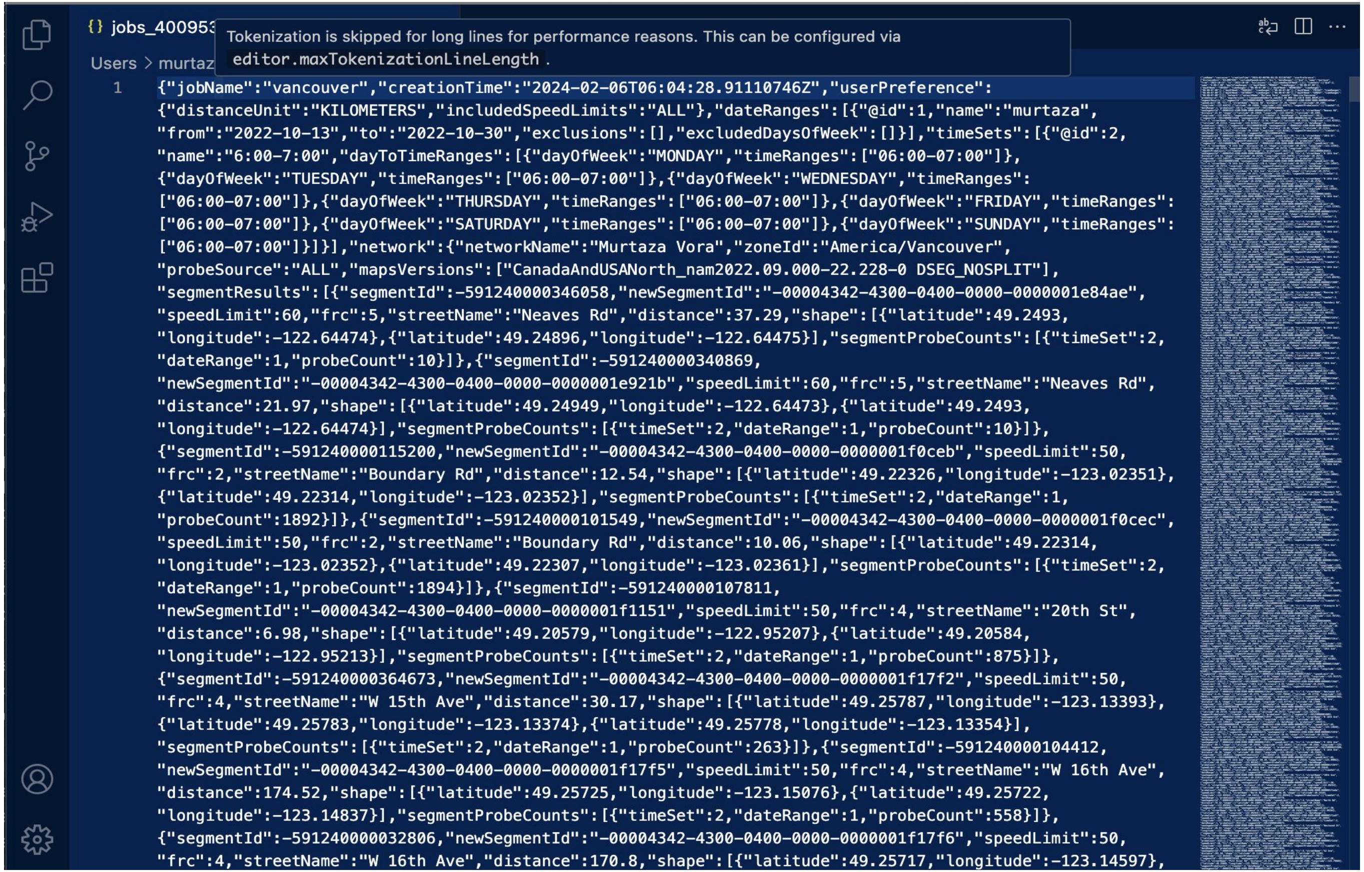
Data Integration and Management: TransLink



- Use python script to fetch TransLink GTFS data from Open data portal.
- Created python script and used Google Map API to fetch exact location based on longitude and latitude.
- Consolidate collected data from different sources.
- Standardize data formats.
- Merge datasets based on common identifiers.
- Validated and cleaned the integrated dataset.
- Store integrated data in a centralized repository for further analysis.

Source: *TransLink*

Data Integration and Management: TomTom



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- The cleaned geojson data obtained from the TomTom website includes:
  - Latitude and longitude coordinates
  - Street names
  - Distance
  - Probe count (number of vehicles)

- This information is crucial for:
  - Identifying significant traffic areas
  - Developing algorithms tailored to address traffic congestion effectively.

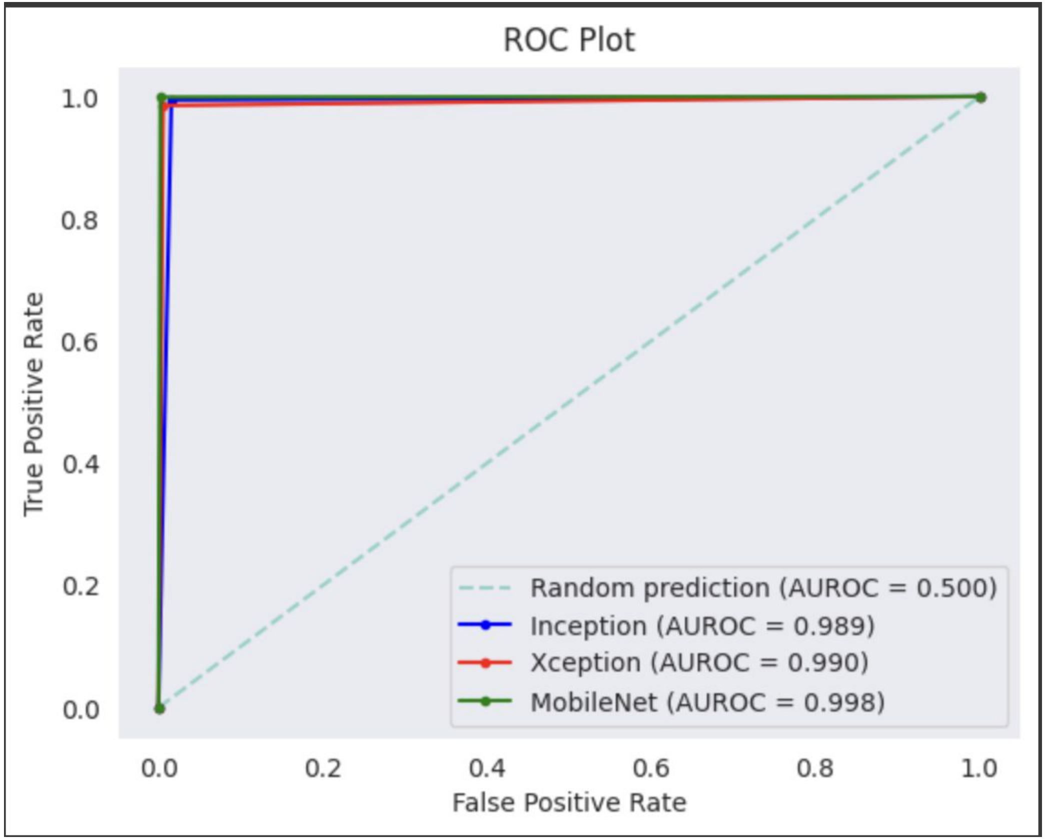
Source: [Tomtom]

Vehicle Detection At Traffic Signals: Convolutional Neural Network

	Model	Test accuracy (%)	Recall (%)	Precision (%)	F1 (%)	AUC
0	Inception	0.989302	0.994344	0.984323	0.989308	0.989324
1	Xception	0.989865	0.985294	0.994292	0.989773	0.989844
2	MobileNet	0.998311	0.998869	0.997740	0.998304	0.998313

	Model	Time	Training accuracy (%)	Validation Accuracy (%)
0	Inception	0 days 00:16:34.274035	0.982970	0.983354
1	Xception	0 days 00:35:22.757873	0.981260	0.985482
2	MobileNet	0 days 00:36:42.785447	0.989615	0.995369

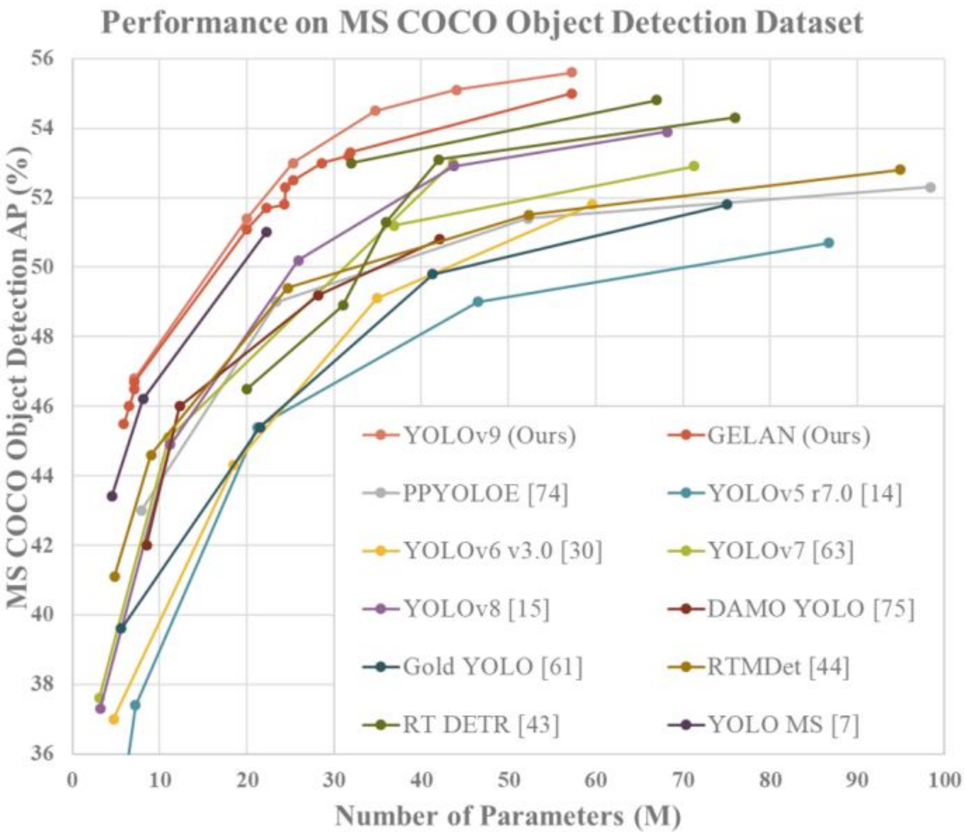
ROC Plot



- Given that all three architectures offer comparable accuracy:

- Opting for MobileNet is advantageous due to its efficiency and speed.
- This makes it ideal for real-world applications such as:
  - On-device inference for autonomous vehicles
  - Smart surveillance systems
  - Traffic monitoring systems.

YOLO Architecture



Performance

MS COCO

Model	Test Size	AP^{val}	AP_{50}^{val}	AP_{75}^{val}	Param.	FLOPs
YOLOv9-T	640	38.3%	53.1%	41.3%	2.0M	7.7G
YOLOv9-S	640	46.8%	63.4%	50.7%	7.1M	26.4G
YOLOv9-M	640	51.4%	68.1%	56.1%	20.0M	76.3G
YOLOv9-C	640	53.0%	70.2%	57.8%	25.3M	102.1G
YOLOv9-E	640	55.6%	72.8%	60.6%	57.3M	189.0G

Source: YOLOv9

V2X Network Architecture and Standards System

Devices (Device Layer):

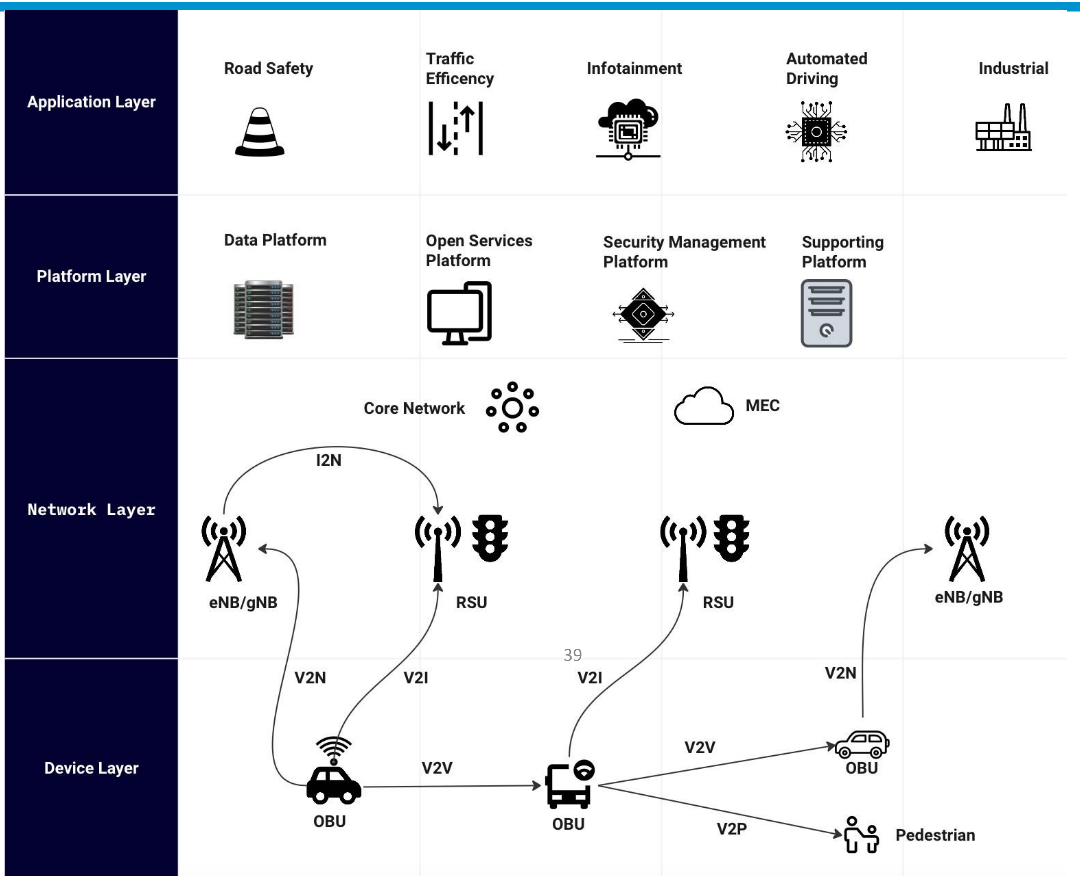
- V2X devices like OBUs, RSUs, and mobile phones facilitate wireless communication.
- Enables sharing of vehicle and traffic status info via V2V, V2I, V2P, and other V2X communications.

Pipe (Network Layer):

- V2X and cellular networks use RSUs, 4G/5G stations, and MEC for efficient connections.
- Supports information exchange among vehicles, road infrastructures, and platforms.

Cloud (Platform and Application Layers):

- Platform layer handles data collection, analysis, and open services management.
- Application layer caters to various V2X applications, offering public and industrial services.



Traffic Signal Priority (TSP) For TransLink Buses As A Mitigation To Congestions

Bus delays can be prevented by giving priority of green traffic signal to buses during peak hours

Key Objective: Reduce bus delays by giving traffic signal priority to TransLink buses during peak-hour traffic jams

TSP system allows TransLink to align with its Timeline and Reliable core value

Without TSP System

Customers are **frustrated** when buses are caught in traffic and delayed.

With TSP System

Significant **tangible benefits** to customers
Clearly **show** TransLink’s improvement efforts

Analy
sis

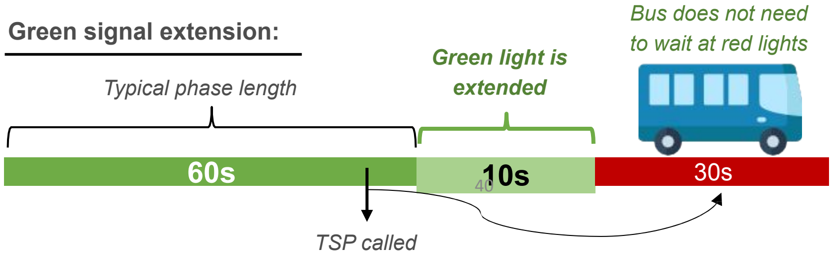
Traffic lights dynamically adjust for TransLink buses that may be running late

Bus approaches during a red light
 TSP system **gives an early green**

Bus approaches during a green light
 TSP system **extends green signal time**

Reduce wait times at traffic lights

Green signal extension:

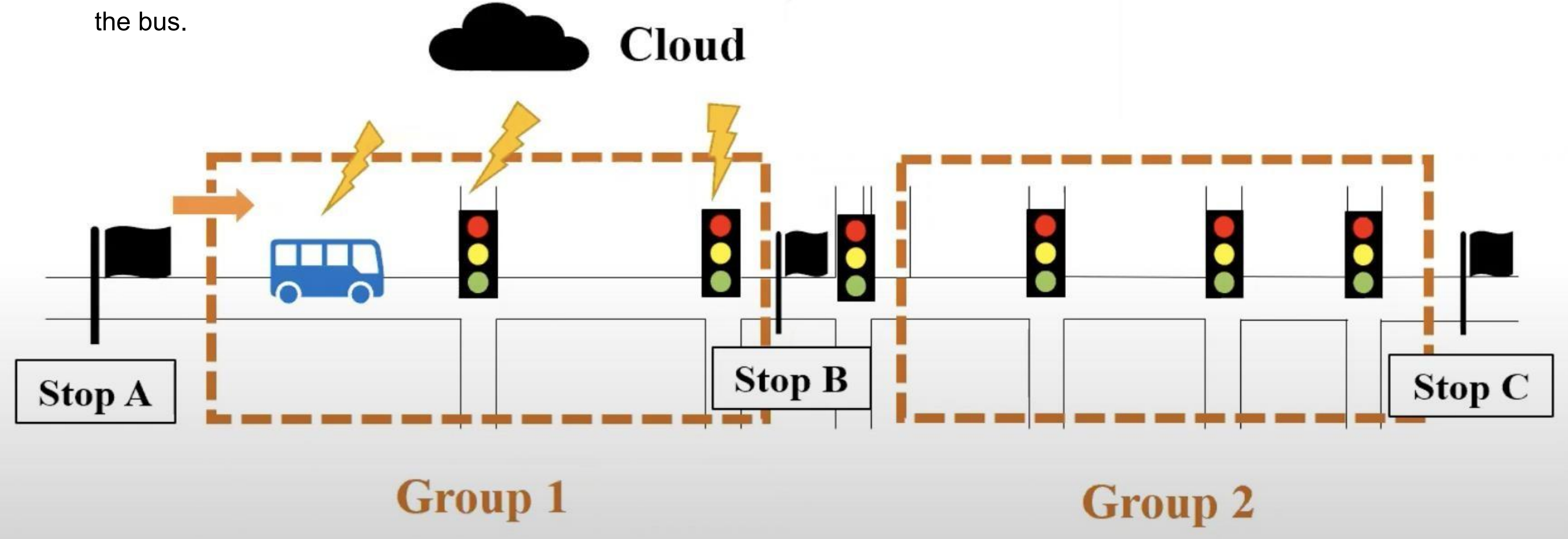


By giving buses traffic signal priority, TSP system can significantly reduce bus delays and increase bus ridership by minimizing buses’ wait times at traffic lights.

Explanation of Simulation's Decision Factors

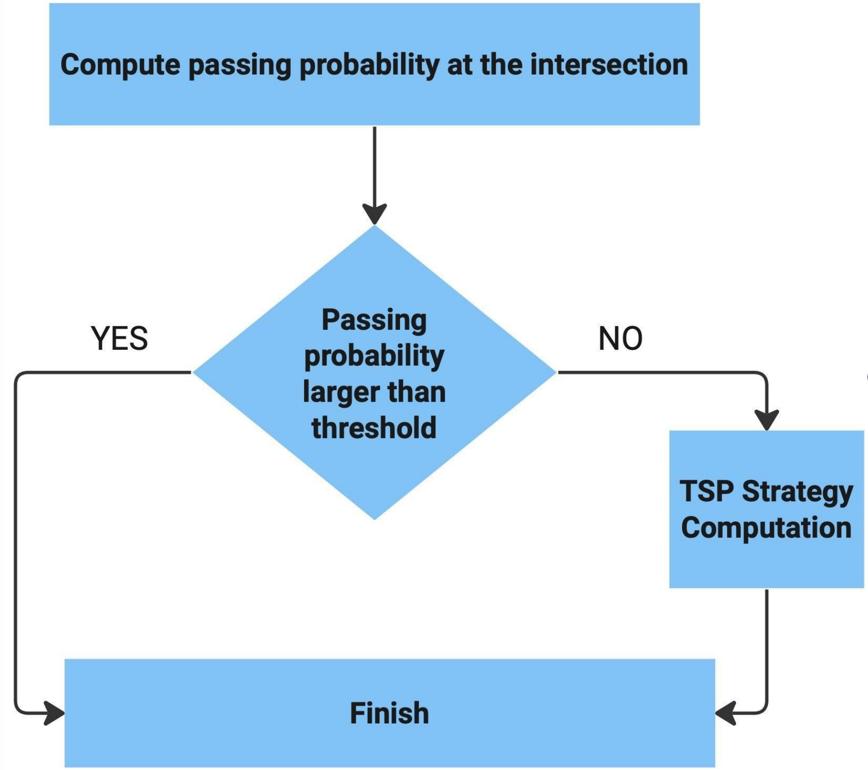
STAGE 1: INTERSECTION GROUP CONTROL

- Definition of "Intersection Group": A collective term referring to the intersections situated between two consecutive bus stops.
- Objective of Intersection Group Control: To establish a synchronized **green wave** that optimally supports the trajectory of the bus.



Explanation of Simulation's Decision Factors

STAGE 2: ISOLATED GROUP CONTROL



In this stage, signal control occurs on a per-second basis. To enhance computational efficiency, we leverage a comprehensive pre-computed matrix.

The RSU (Roadside Unit) executes the control strategy based on the matrix, utilizing indices such as distance, current phase, and remaining time.

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ANY QUESTIONS?