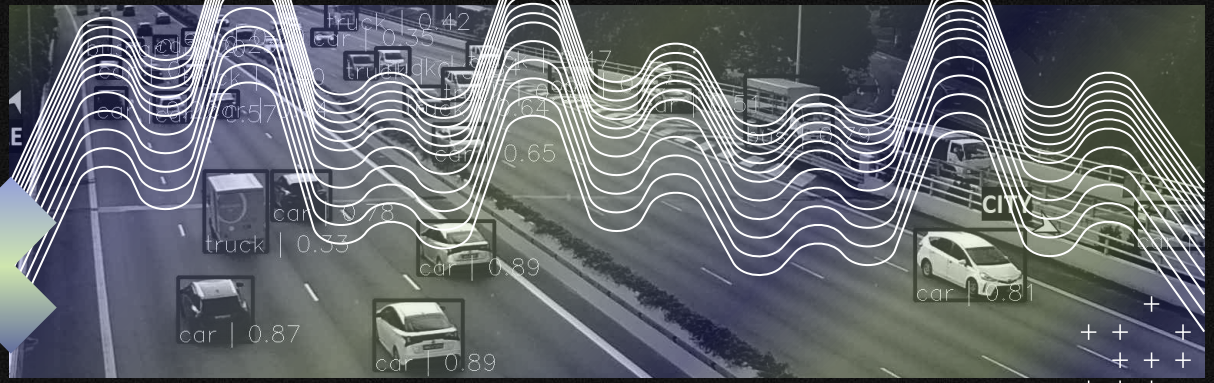

SG Traffic Detection, Monitoring, and Forecasting

Gilbert Sebastiano

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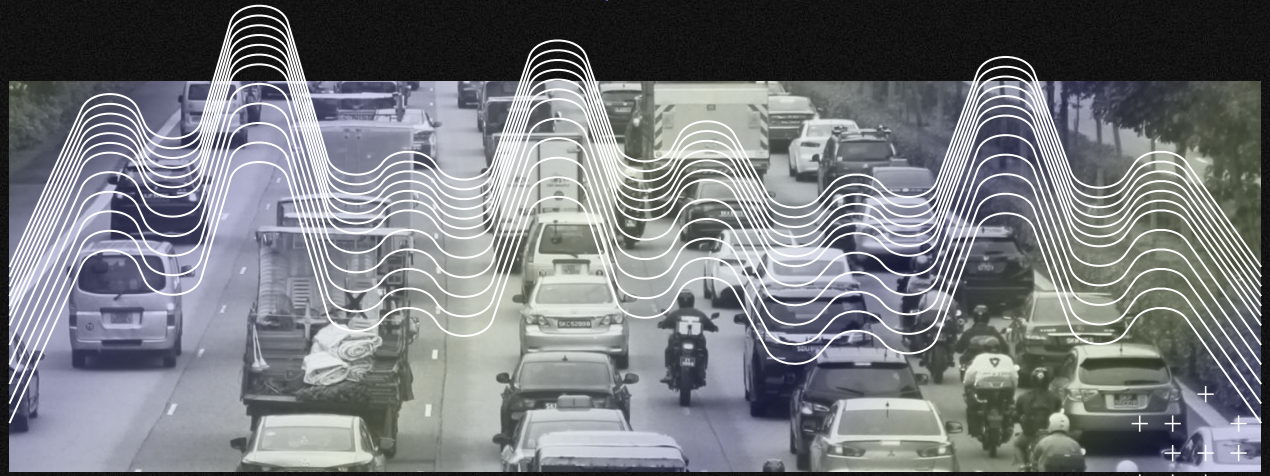
github.com/gilbertsg

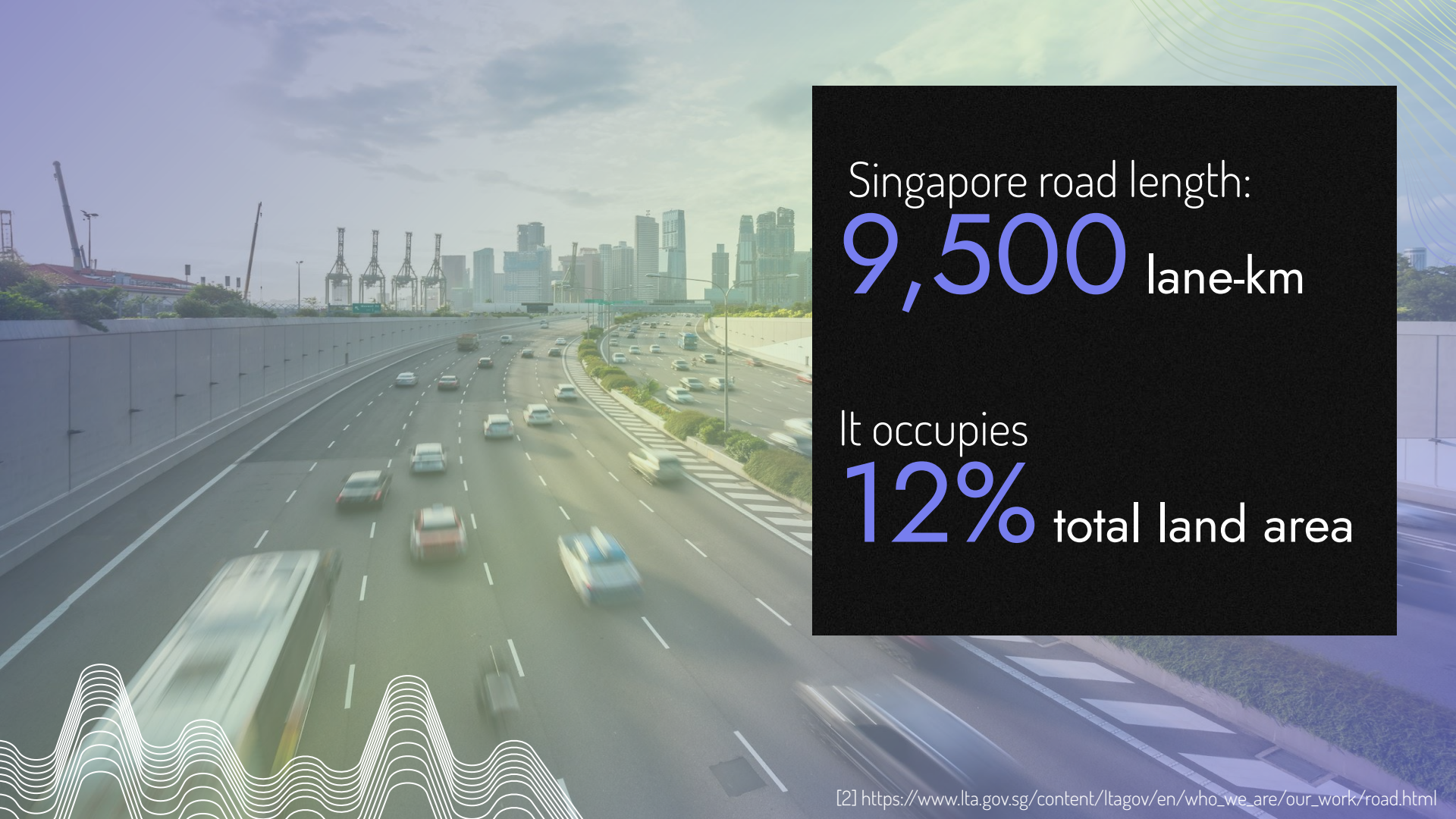
linkedin.com/in/gilbertsg

Number of motor vehicles in Singapore:

988,755



[1] https://www.lta.gov.sg/content/dam/ltagov/who_we_are/statistics_and_publications/statistics/pdf/MVP01-1_MVP_by_type.pdf



Singapore road length:

9,500 lane-km

It occupies

12% total land area

[2] https://www.lta.gov.sg/content/ltagov/en/who_we_are/our_work/road.html

Average congestion level

29%

(extra travel time in rush hour traffic)

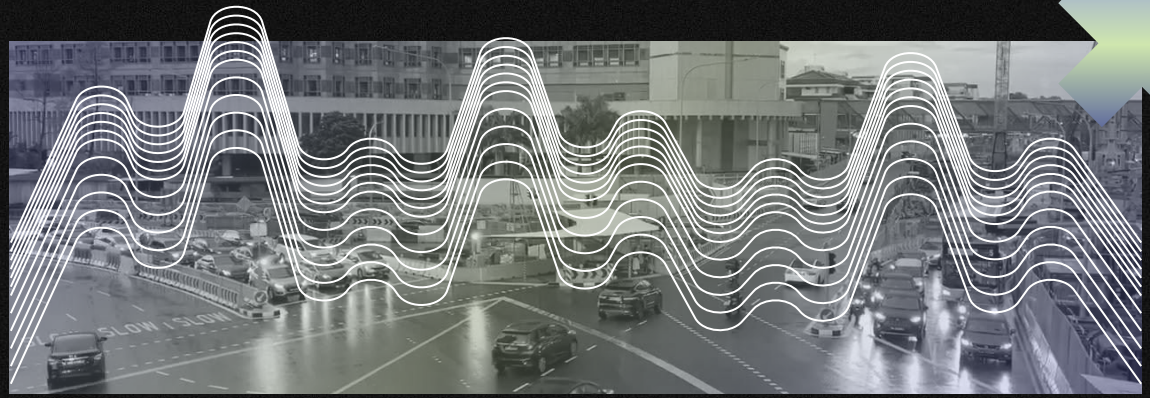
By travelling in rush-hour, Singaporeans wasted

105 hours / year

Congestion rank

88th out of 405 cities

[3] https://www.tomtom.com/traffic-index/ranking/
[4] https://www.tomtom.com/traffic-index/singapore-traffic/

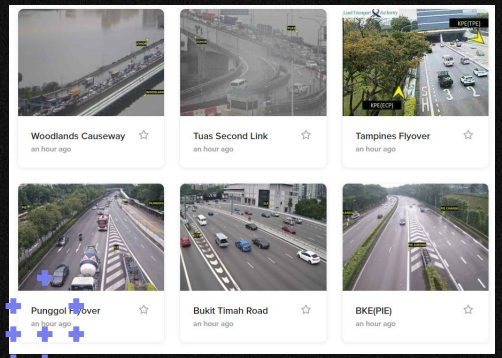


Traffic Monitoring

Commuters and government agencies need to monitor traffic conditions and get traffic forecasts

Limitations of

Existing Solutions

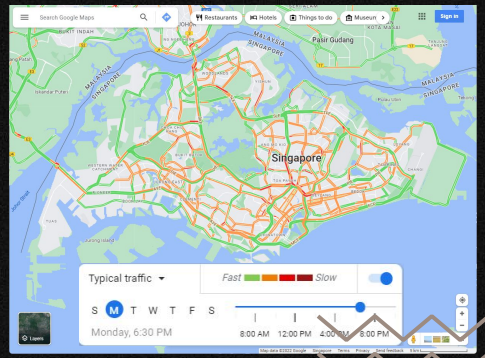


Traffic Images

Need to estimate traffic count

No historical info

No forecast

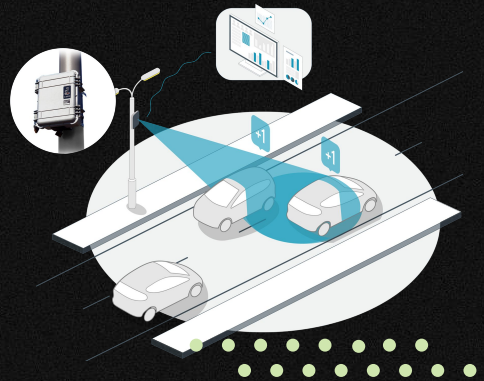


Google Maps

Crowd-sourced information
(inaccurate and vulnerable to attack)

Low resolution

No forecast



Traffic Sensors

Requires large upfront investment
(high equipment cost)

Problem Statement

Develop a solution for **detecting**, **monitoring**, and **forecasting** **vehicle traffic count** in Singapore Expressways

- **Stakeholders:**
  - **Commuters** → make travel time/route decision
  - **Government** → traffic survey and regulatory decisions

Project Outline

Acquisition

Obtain traffic images from LTA **API**

Detection

Use **Computer Vision** to detect vehicles

Analysis

Time series analysis to infer traffic trends

Forecasting

Time series modelling on vehicle count

Deployment

Develop traffic monitoring **app** and **data pipeline**

01

Acquisition

Obtain traffic images from LTA API

Data Acquisition

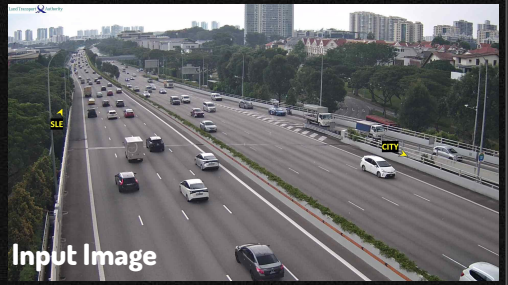
- **Traffic images** provided by **LTA Datamall**
- Scope for analysis:
  - **Location:** 22 cameras in SG Expressways
  - **Duration:** W1 October → W2 November
  - **Interval:** 5 minutes
  - **Total images downloaded:** 195,093 images *(~14.6 GB)*

02

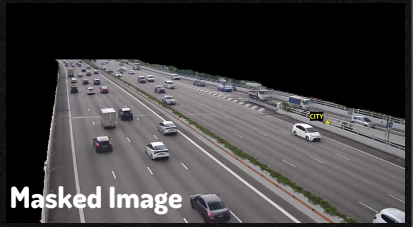
Detection

Use **Computer Vision** to detect vehicles

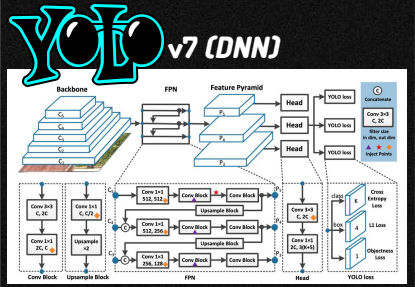
Image Detection Process

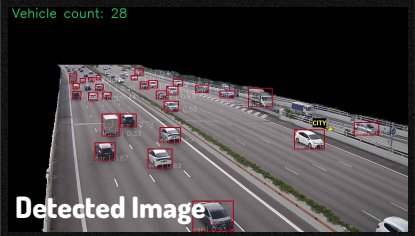


Input

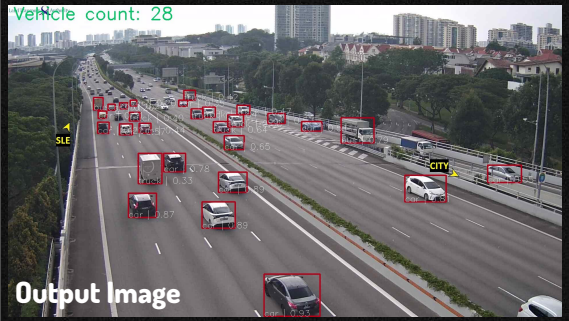


Masking



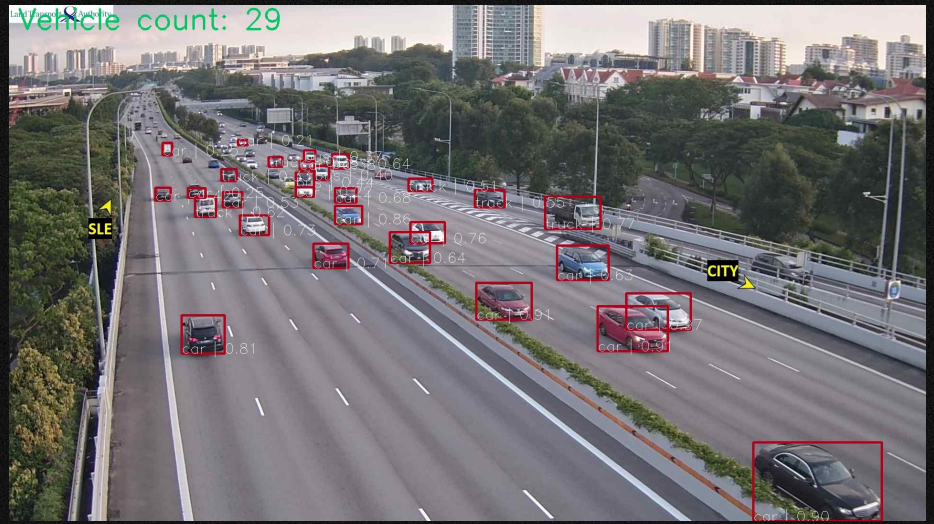


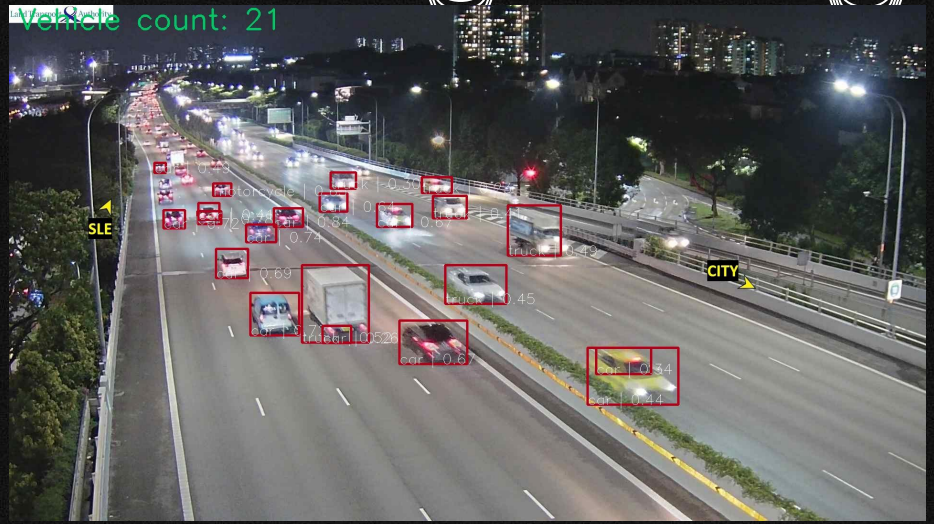
Detection



Output

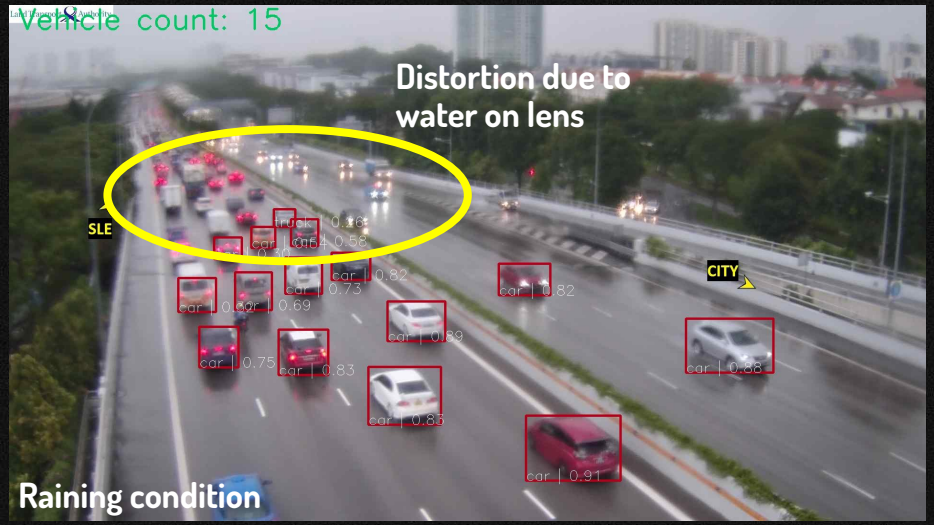
Performance & Accuracy

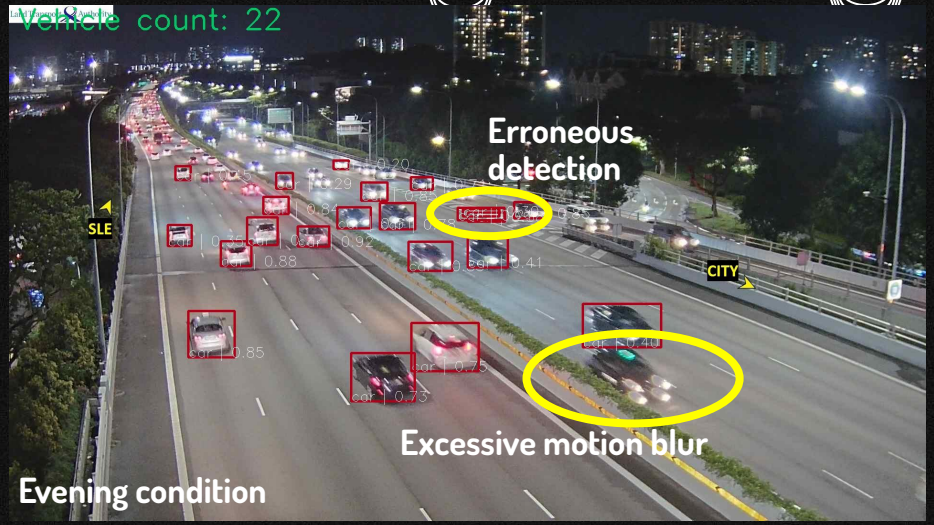




- Detection speed: **1.0 - 1.4 frames per second** (using AMD Ryzen 5900X)
- Able to detect **majority of vehicles** in ROI in both **day and night** condition

Known Issues





Potential Solutions:

- **Custom training** the YOLOv7 model (smaller vehicles ad night-time detection)
- Improvement on **traffic cameras** (rain cover, hydrophobic lens, higher camera sensitivity)

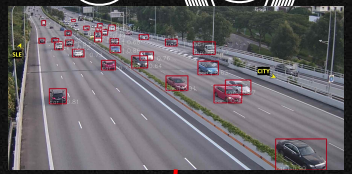
03

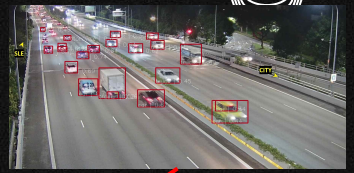
Analysis

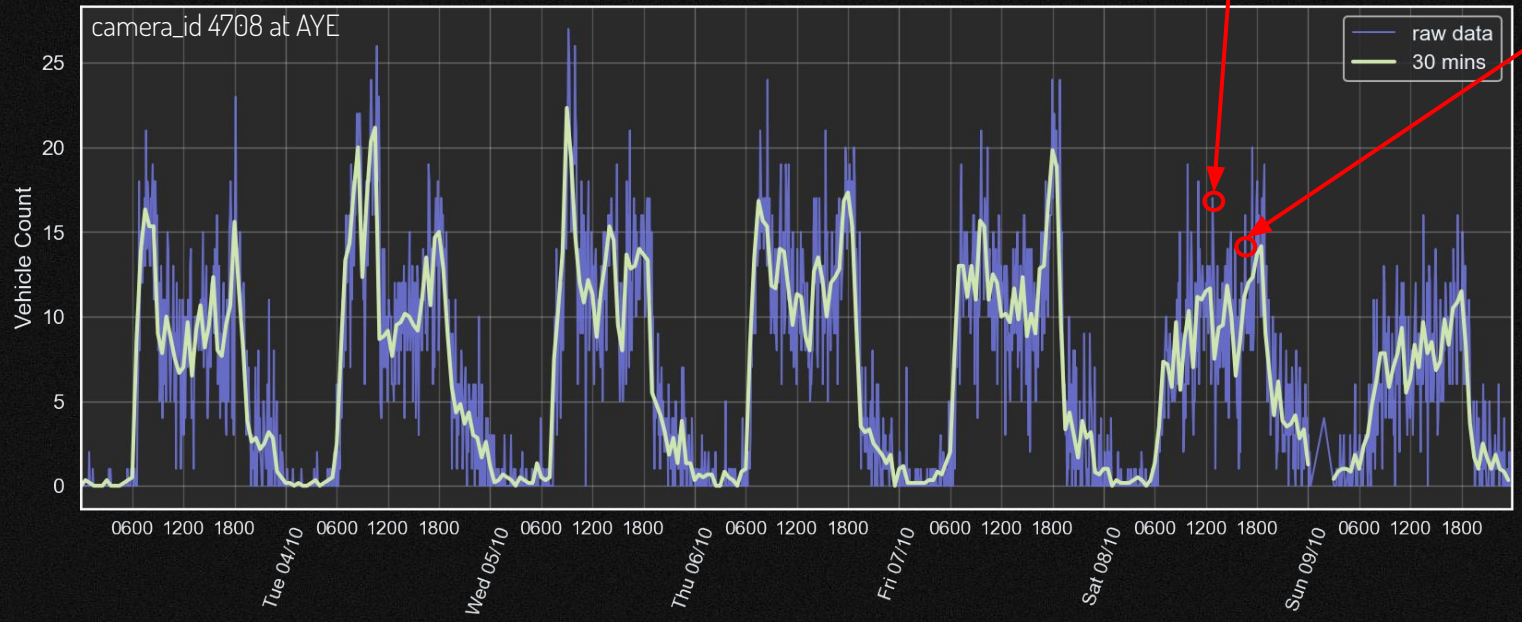
Time series analysis to infer traffic trends

Data Processing

- **Count frequency** = 5 minutes
- Raw data is **noisy**
- Use **temporal aggregation** of 30 minutes

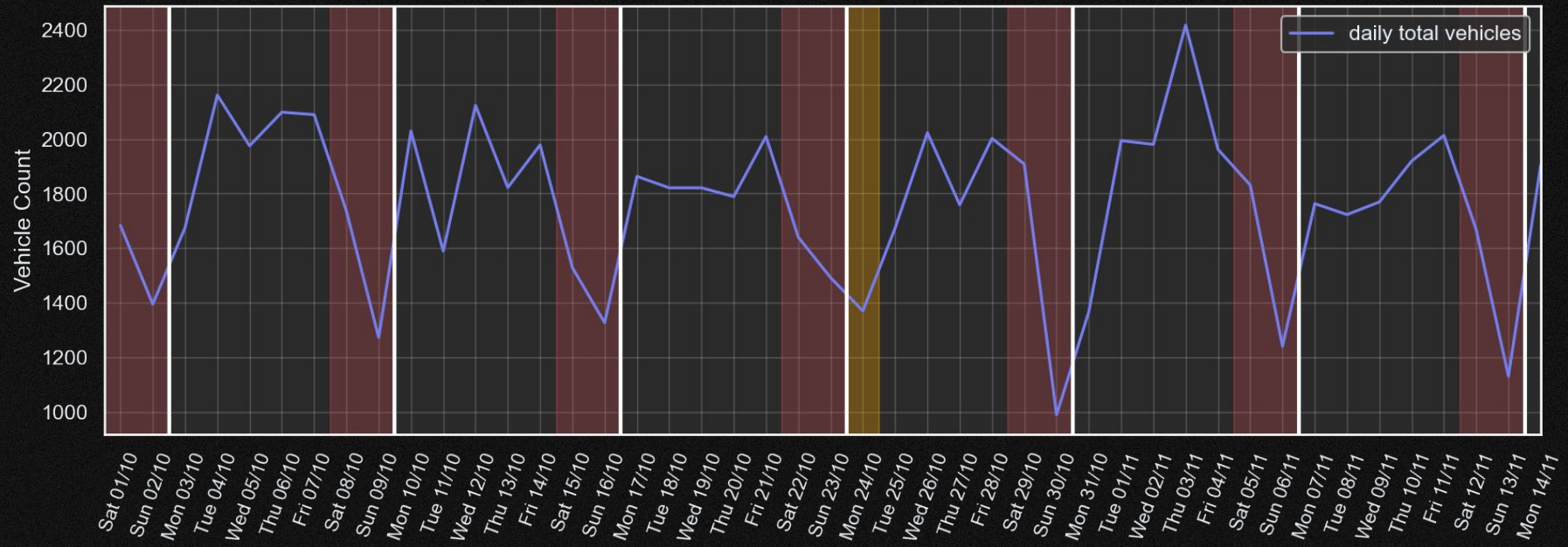






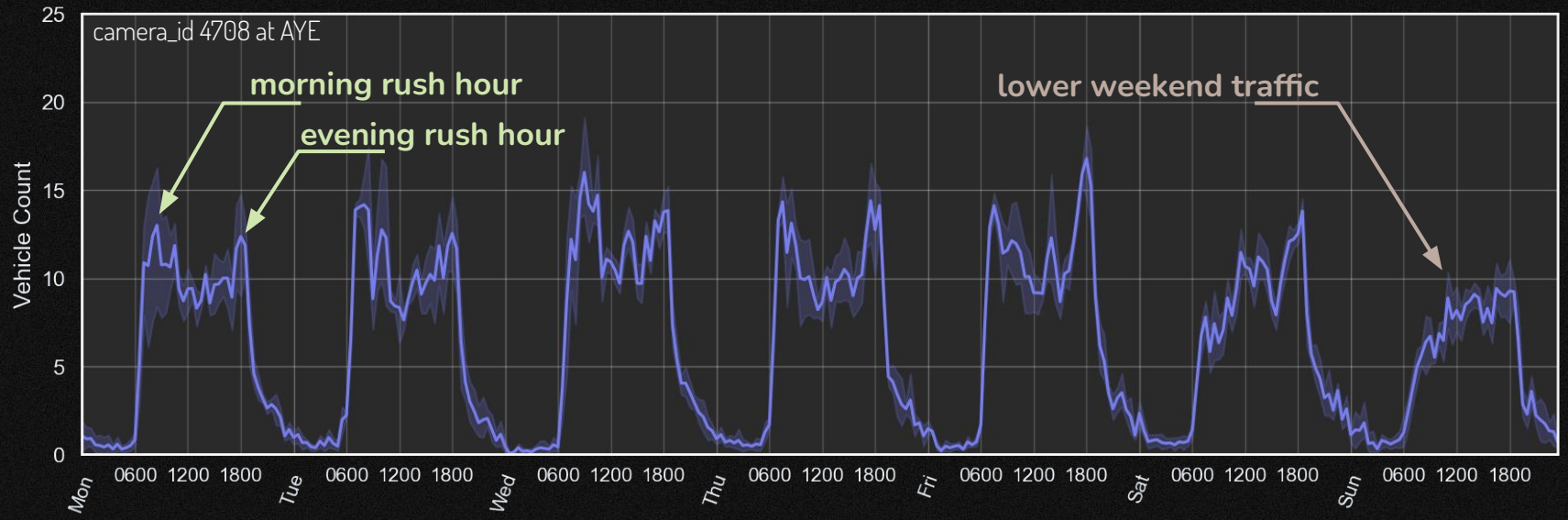
Weekly Pattern

- Lower traffic on weekends
- Effect of public holidays

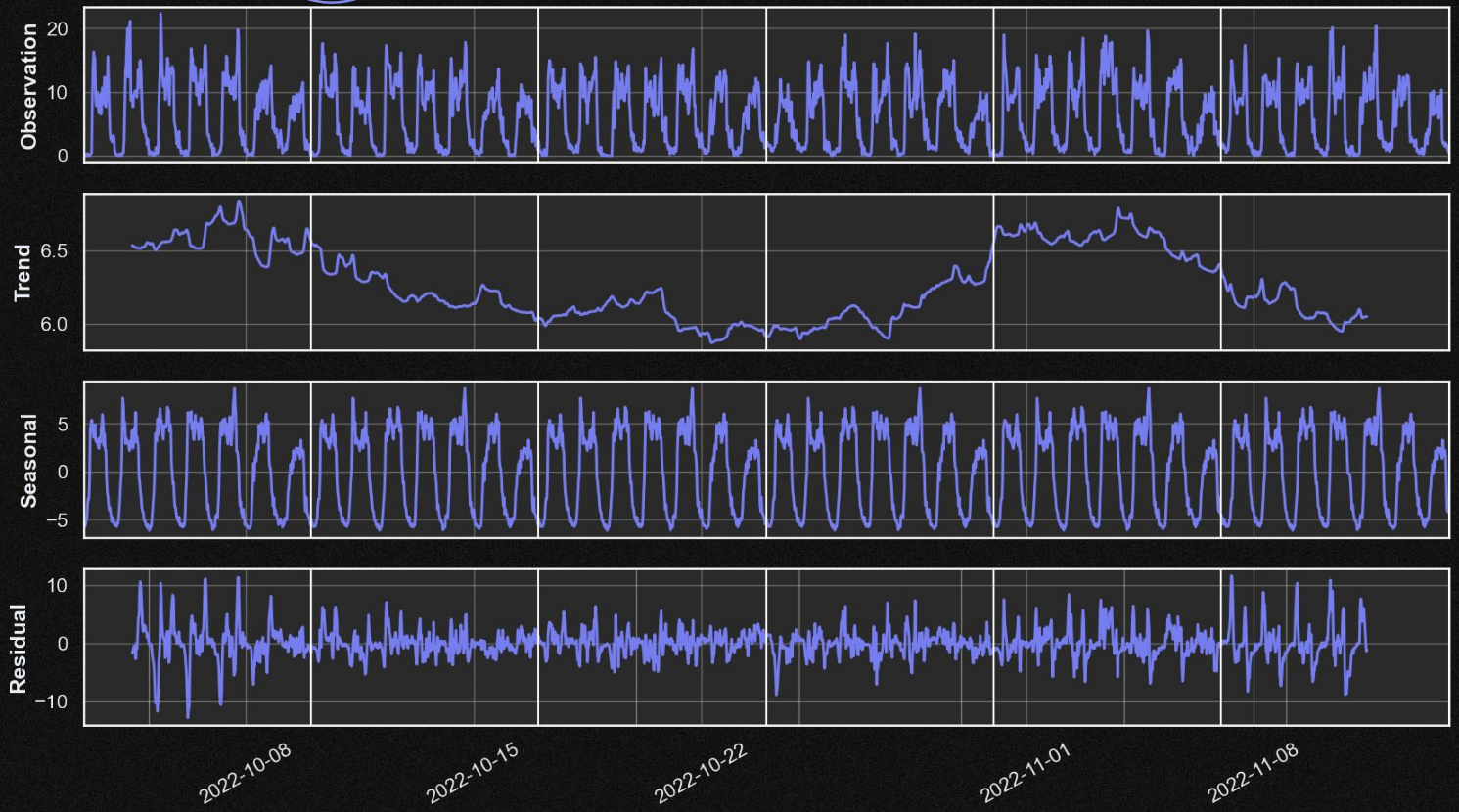


Seasonality

- **Constant/similar pattern** across **different weeks**
  - Constant weekly seasonality, **no trend**
- **Daily pattern:** High traffic at **morning and evening rush hours** (7am and 6pm)
- **Weekly pattern:** Lower traffic on **weekends**



Seasonal Decomposition



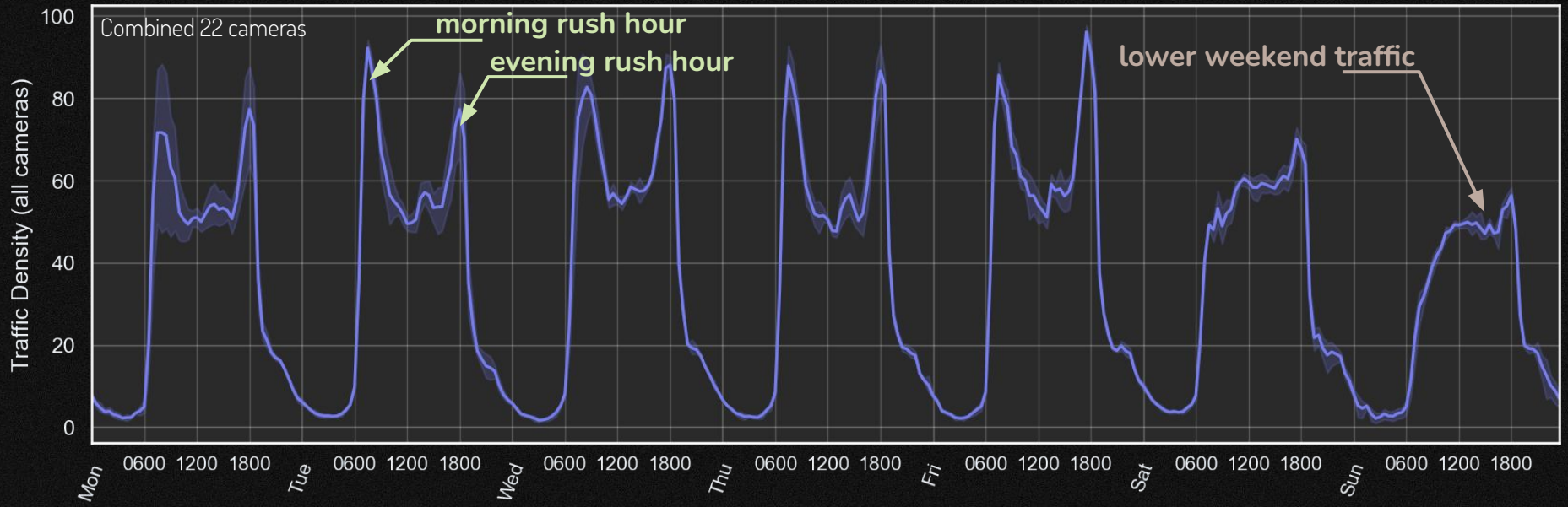
Minor / no trend
(stationary data)

High Seasonality:
Daily and **weekly**
pattern

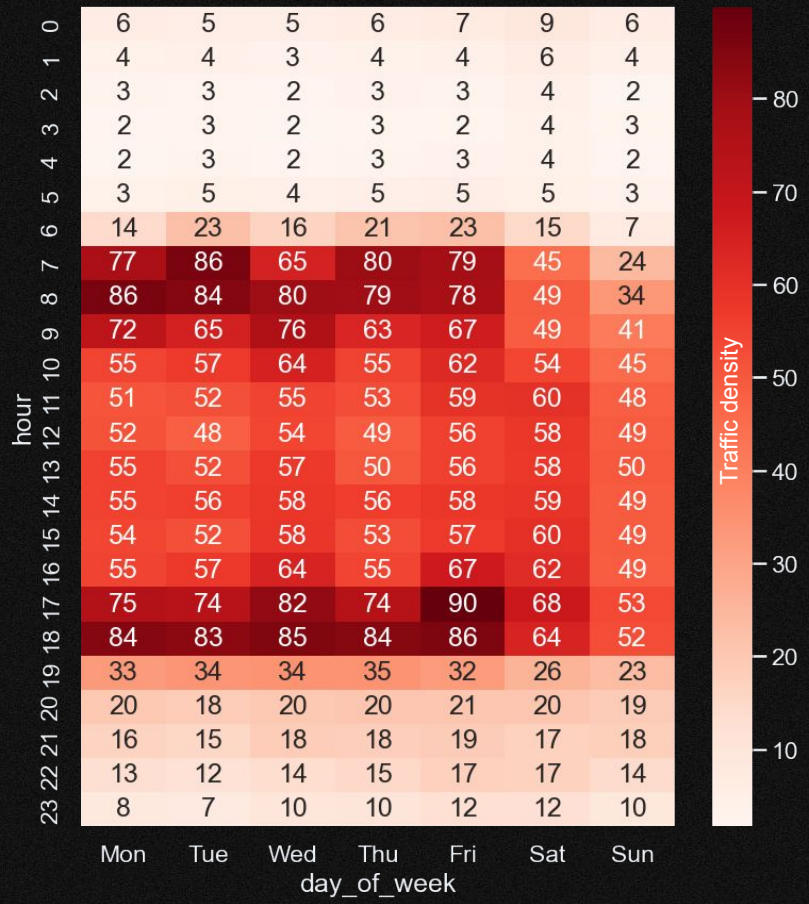
High noise

Daily Traffic Density (across SG)

- **Daily pattern:** High traffic at **morning and evening rush hours** (7am and 6pm)
- **Weekly pattern:** Lower traffic on **weekends**



Daily Traffic Density (across SG)



hour	Mon	Tue	Wed	Thu	Fri	Sat	Sun
0	6	5	5	6	7	9	6
1	4	4	3	4	4	6	4
2	3	3	2	3	3	4	2
3	2	3	2	3	2	4	3
4	2	3	2	3	3	4	2
5	3	5	4	5	5	5	3
6	14	23	16	21	23	15	7
7	77	86	65	80	79	45	24
8	86	84	80	79	78	49	34
9	72	65	76	63	67	49	41
10	55	57	64	55	62	54	45
11	51	52	55	53	59	60	48
12	52	48	54	49	56	58	49
13	55	52	57	50	56	58	50
14	55	56	58	56	58	59	49
15	54	52	58	53	57	60	49
16	55	57	64	55	67	62	49
17	75	74	82	74	90	68	53
18	84	83	85	84	86	64	52
19	33	34	34	35	32	26	23
20	20	18	20	20	21	20	19
21	16	15	18	18	19	17	18
22	13	12	14	15	17	17	14
23	8	7	10	10	12	12	10

- **Very low** traffic flow between **10pm - 6am**
- **Highest traffic** are in morning and evening **rush hours**
- **Low traffic** on **weekends**
- **Highest** overall traffic is on **Friday evening rush hour**

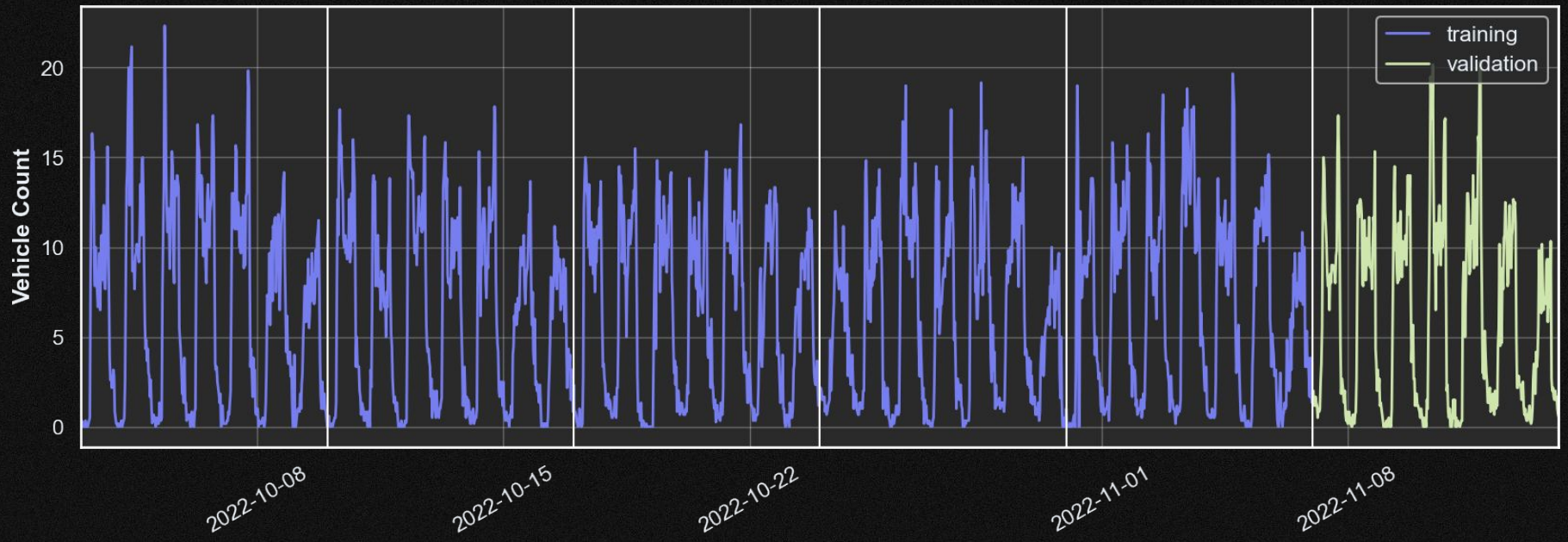
04

Forecasting

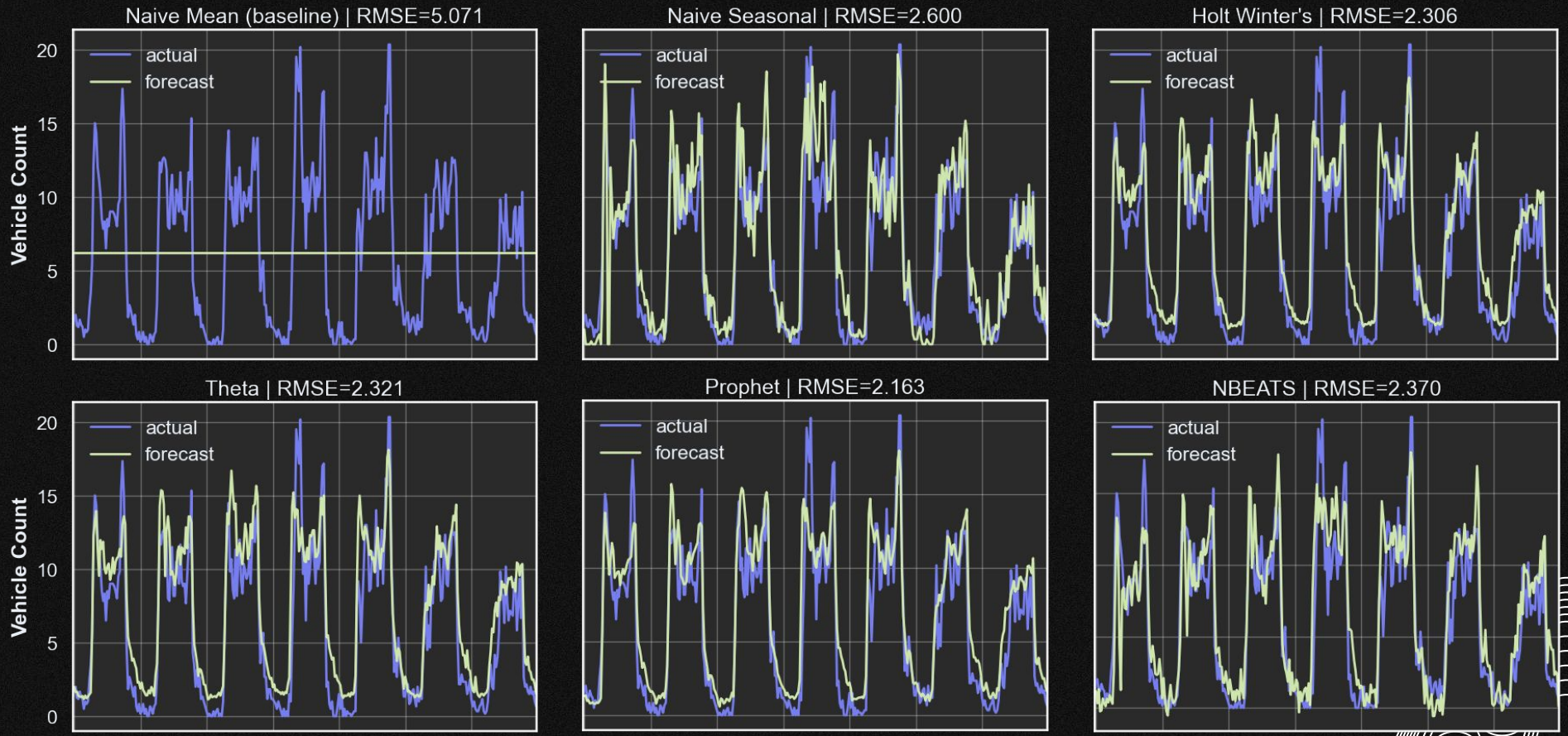
Time series modelling on vehicle count

Train-Test Split

- **Training set:** 5 weeks (W1 Oct → W1 Nov)
- **Testing set:** 1 week (W2 Nov)



Time Series Modelling

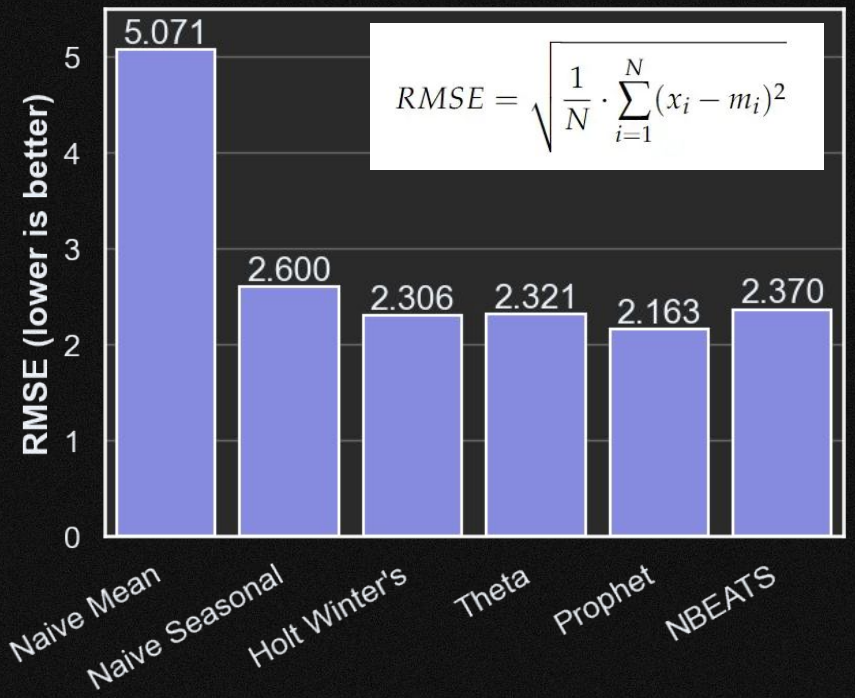


Model Metrics

- **Root Mean-Squared Error**
  - Not sensitive to zero values
  - Penalizes large deviations
    (suitable for traffic predictions)

- **Interpretation:**
  Compare **RMSE** vs **Std.Dev**
  *(SD_{test_set} = **5.044**)*

- Best model: **Prophet Model**
  - 54% better than Naive Mean
  - 11% better than Naive Seasonal

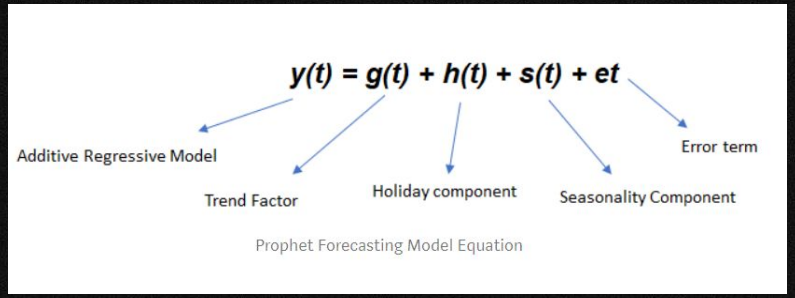


$$RMSE = \sqrt{\frac{1}{N} \cdot \sum_{i=1}^{N} (x_i - m_i)^2}$$

Prophet Model

- **Developed by Facebook**
- Works best with TS with **strong seasonal effects**

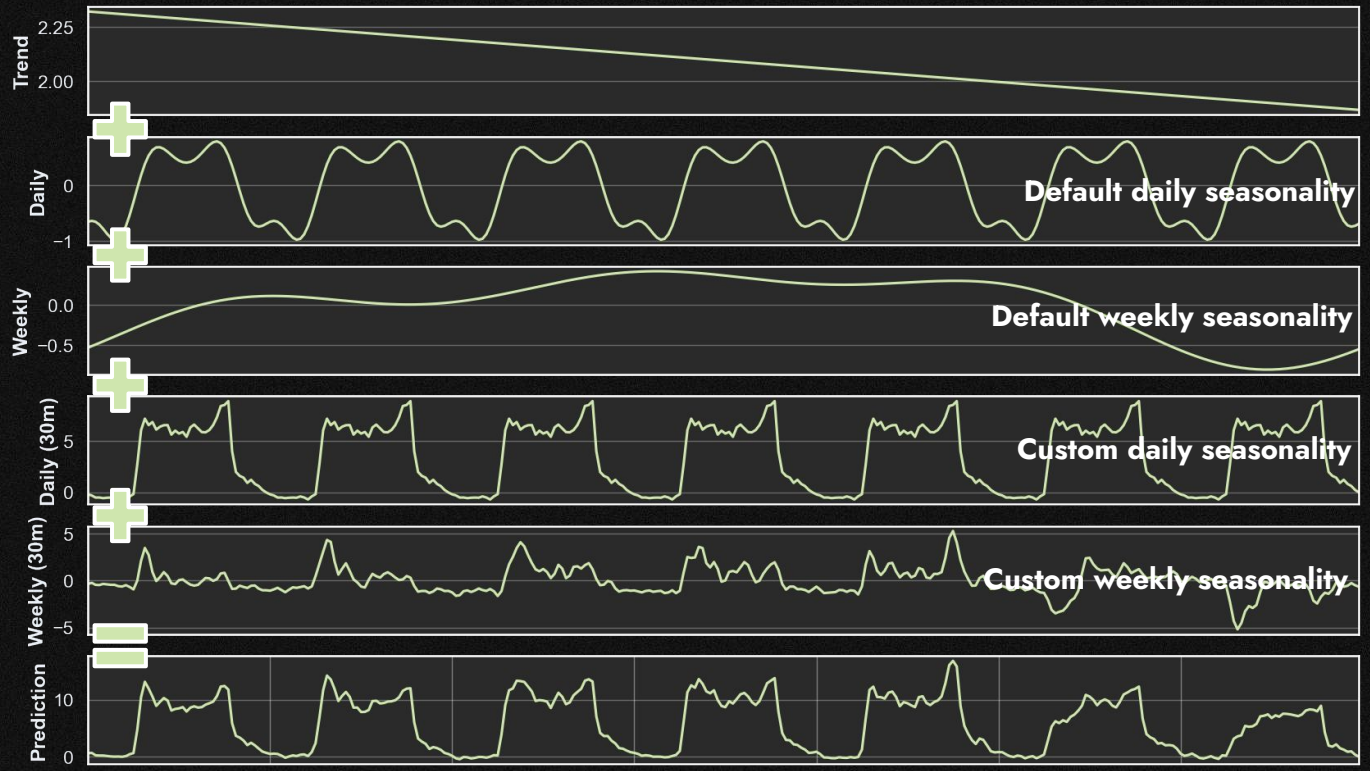
- Prophet infers the following from data:
  - Linear or non-linear **trends**
  - Yearly, weekly, and daily **seasonality**
    - *(Seasonality are fit using Fourier series)*



- Supports additional **custom seasonality**
  - (30 min-interval) Daily → **1*48 half hour intervals / day**
  - (30 min-interval) Weekly → **7*48 half hour intervals / week**

[5] https://research.facebook.com/blog/2017/2/prophet-forecasting-at-scale/

Prophet Model Interpretation



Breakdown of the **seasonal modes** in the Prophet Model

Most important factors: Custom daily & weekly seasonality

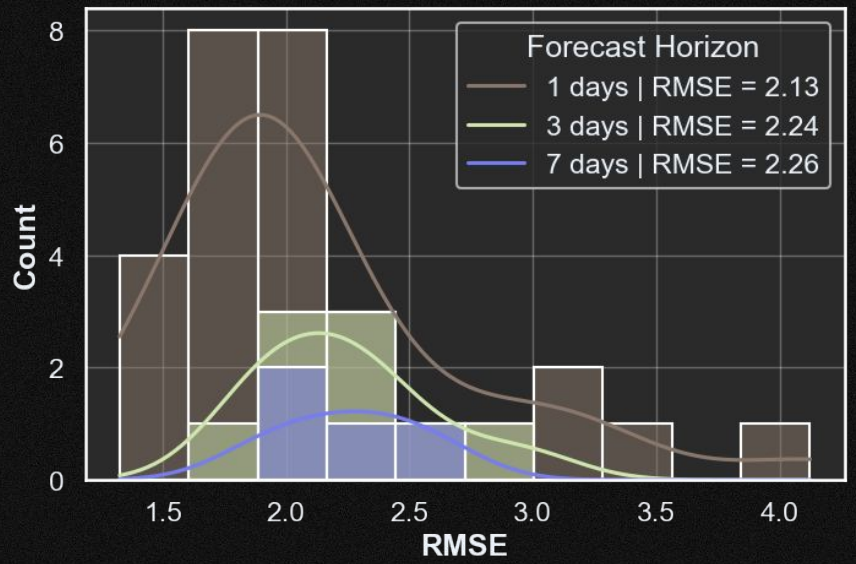
Forecasting Window

- During analysis, we a forecasting horizon of **7 days**
- Now we assess the **effect of forecast horizon** on the **accuracy** of the forecast

- **Backtesting**
  - Using historical data to repeatedly train and test the model
  - **Study period:** 17/10 → 15/11

- Only about **6%** difference in avg RMSE

- We shall use a **forecasting horizon** of **7 days** for production

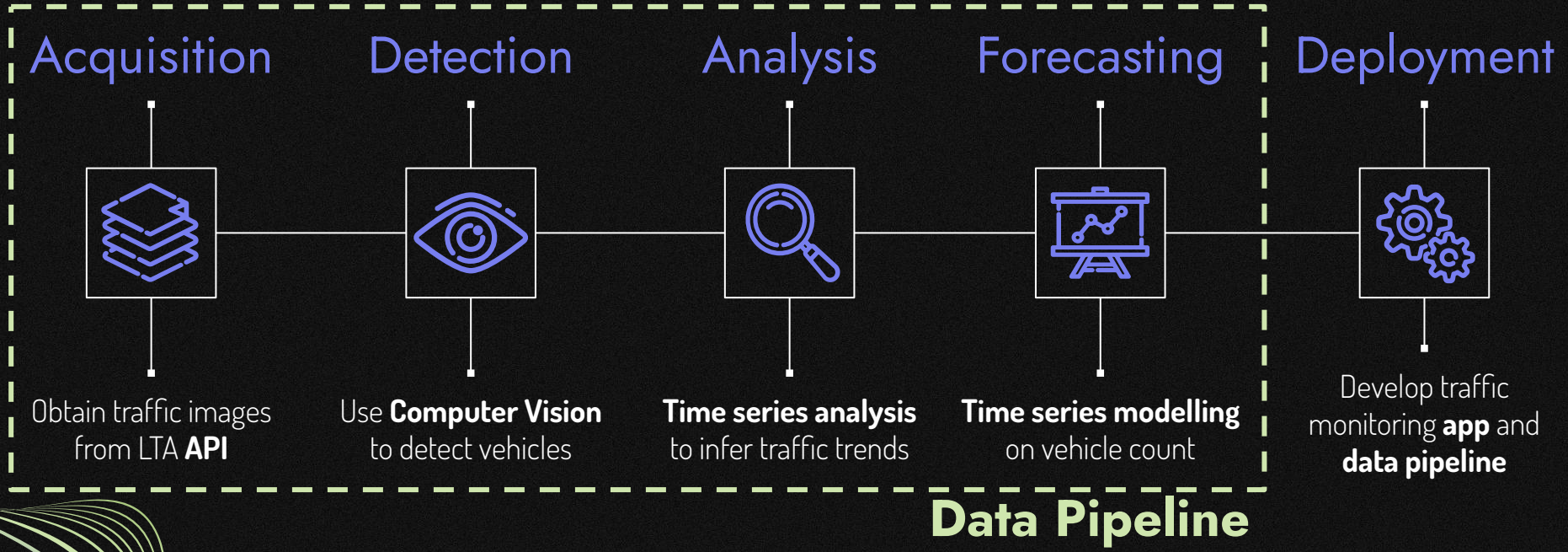


05

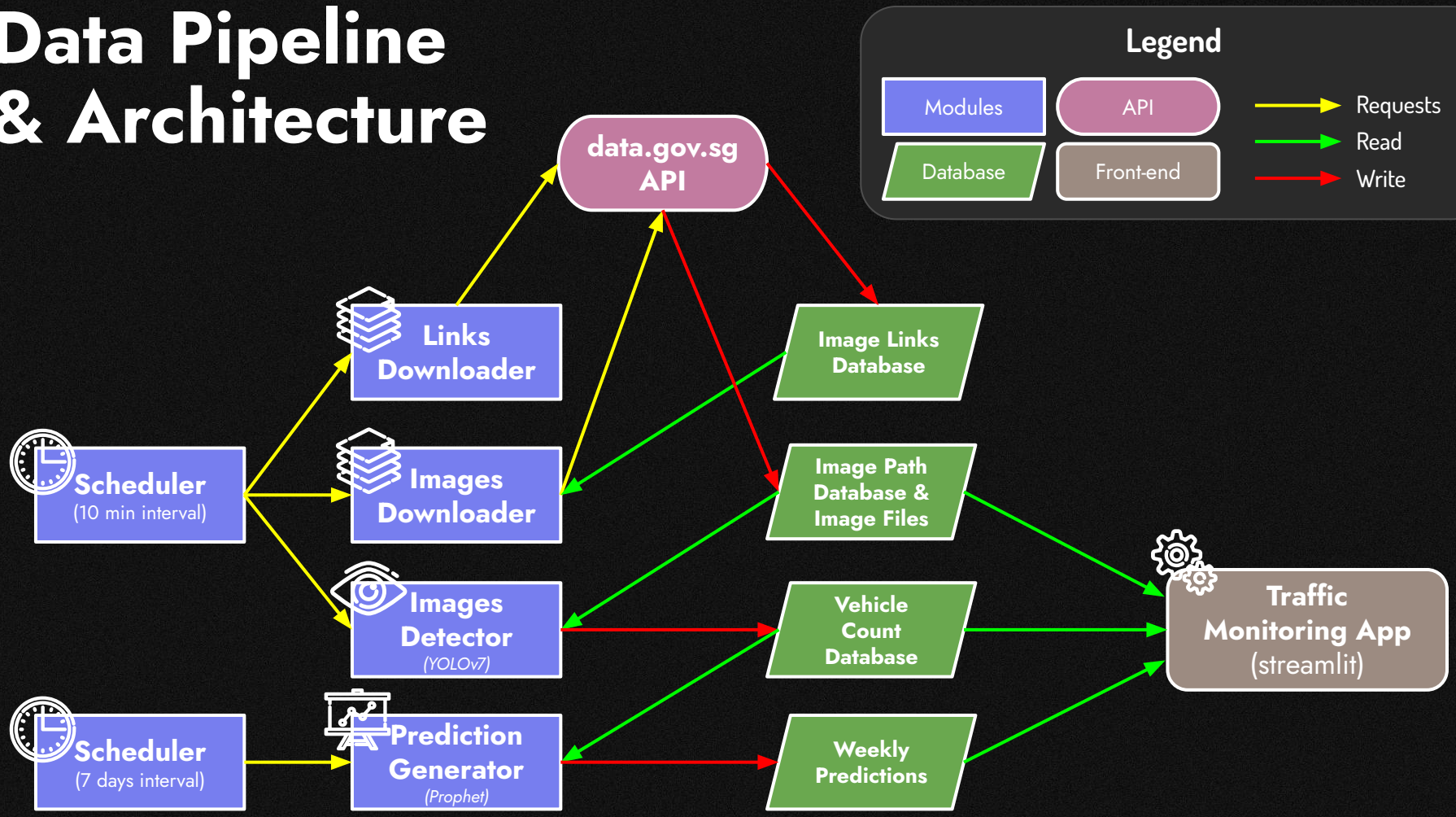
Deployment

Develop **traffic monitoring app** and **data pipeline**

Project Outline



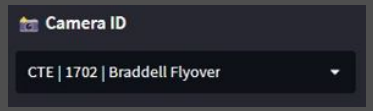
Data Pipeline & Architecture



Traffic Monitoring App

User Input

Select **camera** from dropdown



Select **date & time**

Process

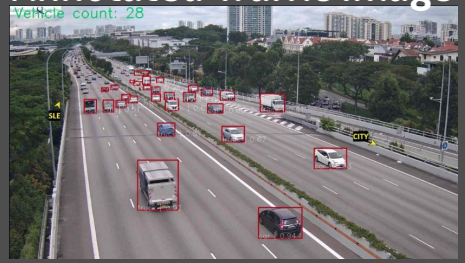
No inference done in Streamlit

Streamlit will call from the **database**

The database is **updated continuously** in the background

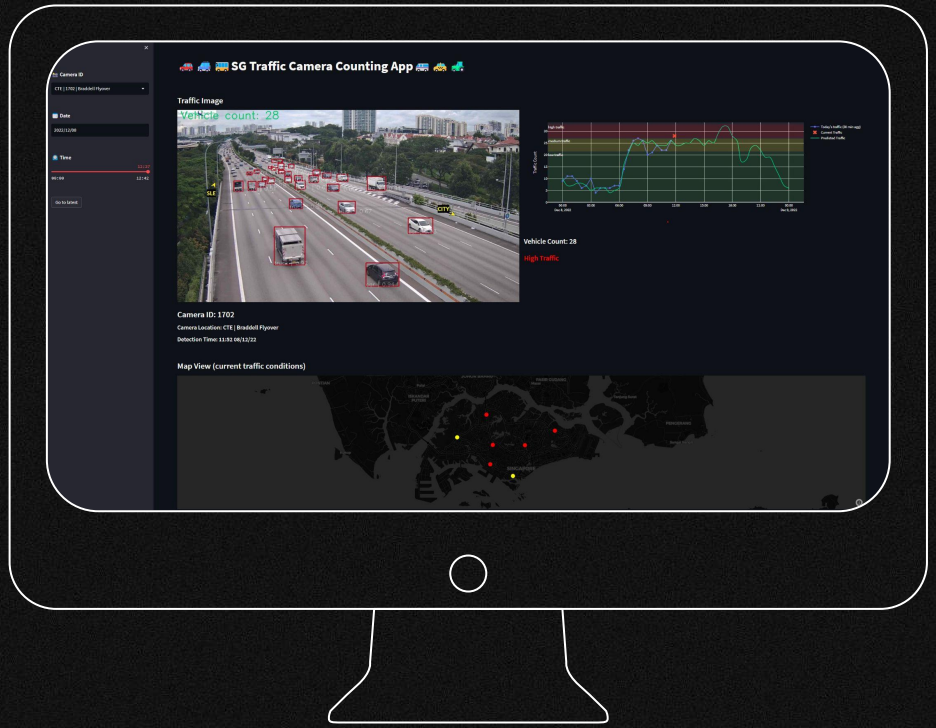
Output

Annotated Traffic Image



Map w/ Traffic Level

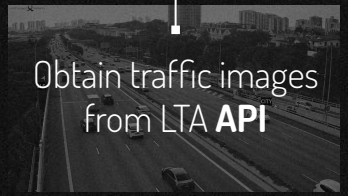
Traffic Count (Current, Historical, Forecast)


SG Traffic Camera Counting App
Camera ID
CTE | 1702 | Braddell Flyover
Date
2022/12/08
Time
00:00
12:42
Go to latest
Traffic Image
Vehicle count: 28
SLE
CTE
Vehicle Count: 28
High Traffic
Camera ID: 1702
Camera Location: CTE | Braddell Flyover
Detection Time: 11:02 08/12/22
Map View (current traffic conditions)

App Demo

Conclusions

Acquisition



Obtain traffic images from LTA **API**

Detection

Use **Computer Vision** to detect vehicles

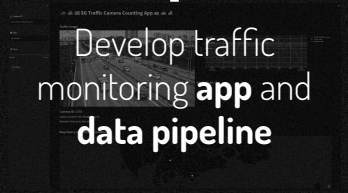
Analysis

Time series analysis to infer traffic trends

Forecasting

Time series modelling on vehicle count

Deployment



Develop traffic monitoring **app** and **data pipeline**

Thank you!

Do you have any questions?

gilbert.sebastiano@gmail.com
github.com/gilbertsg
linkedin.com/in/gilbertsg

CREDITS: This presentation template was created **by Slidesgo**,
including icons **by Flaticon** and infographics & images **by Freepik**

Guiding principles

Quality

Mercury is the smallest planet of them all

Efficiency

Venus is the second planet from the Sun

Resourcefulness

Earth is the third planet from the Sun

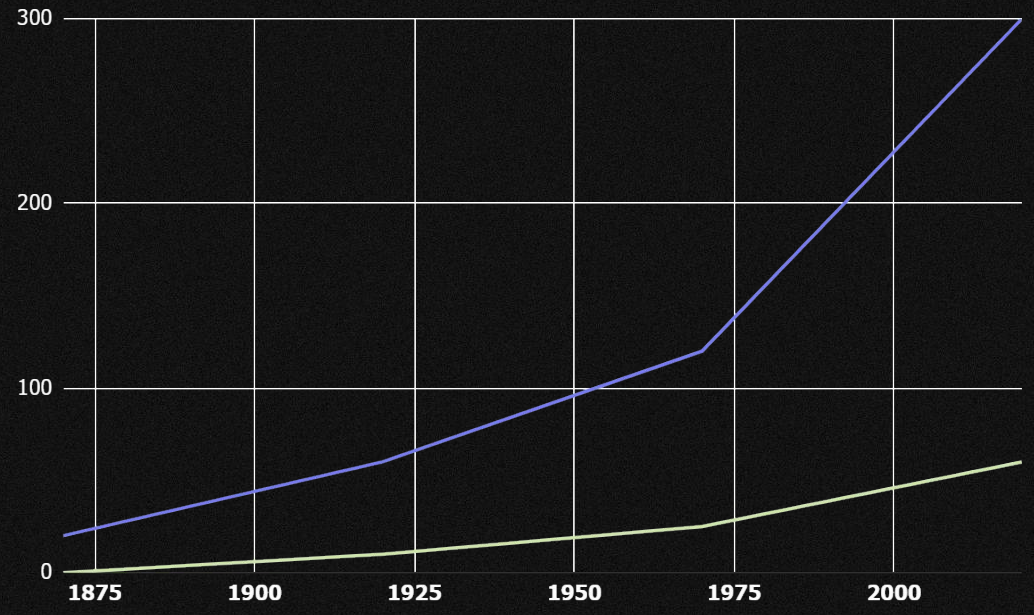
Success

Jupiter doesn't have a solid surface

“This is a quote, words full of wisdom that someone important said and can make the reader get inspired.”

—Someone Famous

Noise pollution evolution



Follow the link in the graph to modify its data and then paste the new one here. **For more info, click here**

Percentage of noise pollution

Venus is extremely hot, even more than Mercury

Actions to reduce noise pollution

Earth is the only planet known to harbor life

User persona profile

Biography

Age: 32 years old
Gender: Female
Location: Mexico
Income: $1900
Occupation: Lawyer
Education: University

Interests

Activism	10%
Environment	30%
Policy	60%

Motivations

Earth is the third planet from the Sun and the only one that harbors life in the Solar System. This is where we all live

Sales funnel

User journey

Invitations

Saturn is the second-largest planet in the Solar System

Meetings

Mercury is the closest planet to the Sun and the smallest of them all

Evaluation

Neptune is the fourth-largest planet in the Solar System

Types of noise pollution

Mercury

Mercury is the closest planet to the Sun

Venus

Venus is the second planet from the Sun

Mars

Mars is actually a very cold place

Jupiter

Jupiter is the biggest planet of them all

Saturn

Saturn is a gas giant with rings

Neptune

Neptune is the farthest planet from the Sun

SWOT Analysis

S

Strengths

Venus is the second planet from the Sun

W

Weaknesses

Mercury is the closest planet to the Sun

O

Opportunities

Earth is the third planet from the Sun

T

Threats

Saturn is a gas giant and has several rings

Goals

Short term

- Write your goal here
- Write your goal here
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- Write your goal here

Long term

- Write your goal here
- Write your goal here
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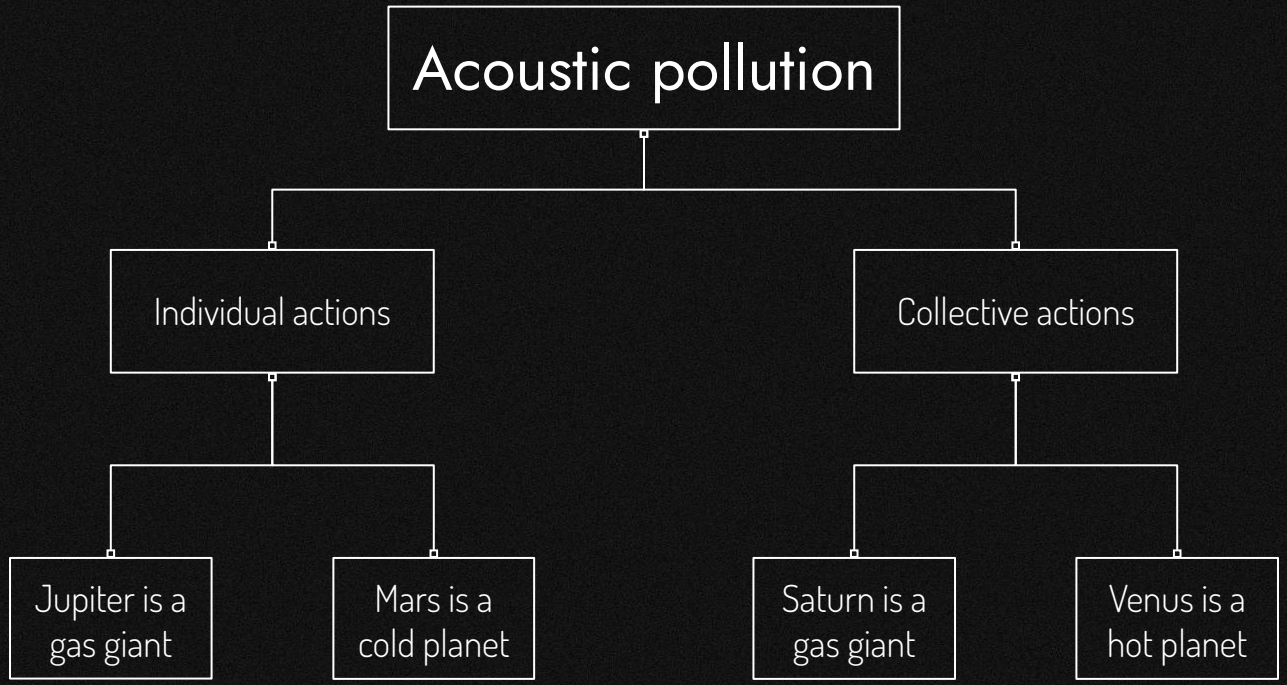
- Write your goal here

Strategy to eliminate noise pollution



Key action items

	First year	Second year	Third year
Key action 1	Mercury is the closest planet to the Sun	Venus is the second planet from the Sun	Ceres is located in the main asteroid belt
Key action 2	Jupiter is the biggest planet of them all	Saturn is composed of hydrogen and helium	Neptune is the farthest planet from the Sun
Key action 3	Earth is the third planet from the Sun	Pluto is now considered a dwarf planet	The Moon is Earth's only natural satellite

Steps to end noise pollution

1

Regulations

The Sun is the star at the center of the Solar System

2

Alternatives

Neptune is the farthest planet from the Sun

3

Sanctions

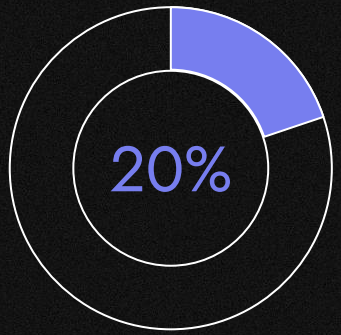
Ceres is located in the main asteroid belt

4

Prohibitions

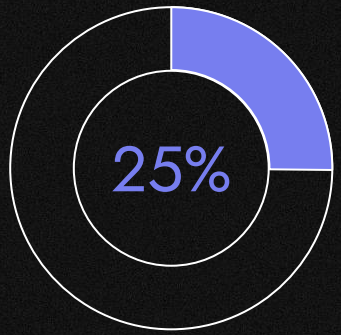
Venus is the second planet from the Sun

Budget



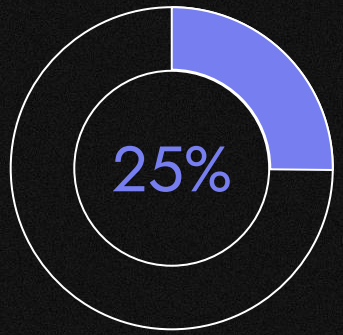
Earth

Earth is also known as the blue planet



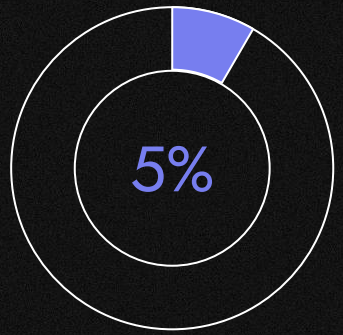
Mercury

Mercury is the smallest planet of them all



Venus

Venus has extremely high temperatures



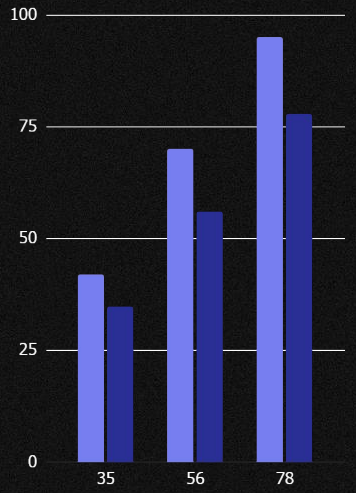
Jupiter

Jupiter was named after a Roman god

KPI overview

Compliance rate

Mars is a cold planet



Product 1

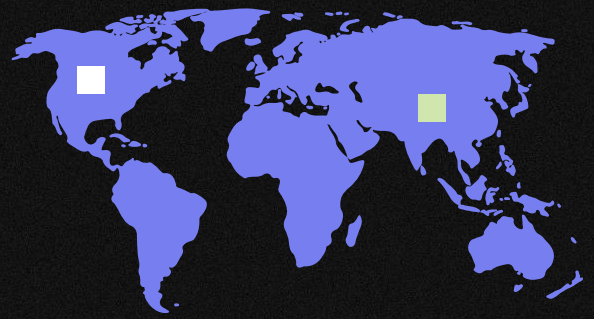
Jupiter is big

Product 2

Venus is hot

Outreach

Earth is also known as the blue planet



30%

Earth has life

20%

Mars is cold

Follow the link in the graph to modify its data and then paste the new one here. **For more info, click here**

Our team

Robert Doe

You can speak a bit about this person here

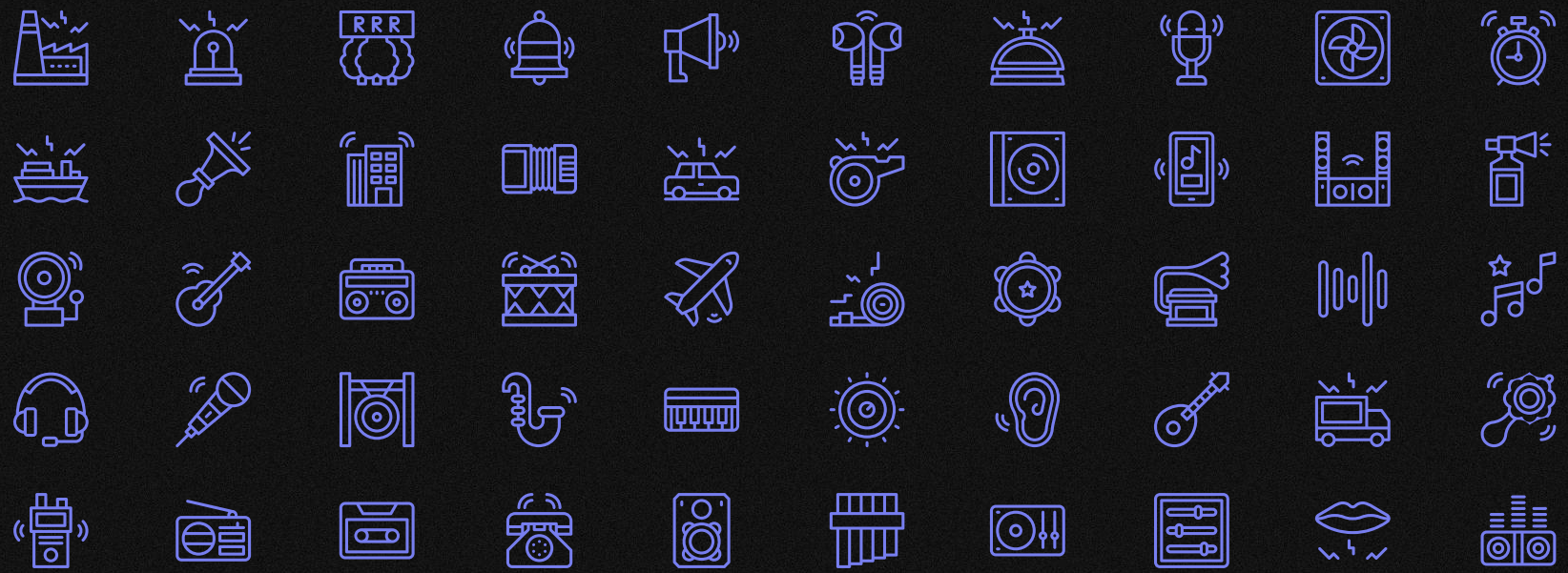
Timmy Jimmy

You can speak a bit about this person here

Jennifer Koi

You can speak a bit about this person here

Icon pack



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