Public Transport Accessibility and Coverage in Melbourne Metropolitan: A Spatial Analysis of SA2 and SA4 Statistical Area.

Course: FIT5137

Assignment 3

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1. Introduction

The purpose of this report is to provide a detailed spatial analysis of public transportation accessibility and coverage within the Melbourne Metropolitan area, focusing on Statistical Area Level 2 (SA2) and Statistical Area Level 4 (SA4) regions. With Melbourne's rapid growth and evolving transportation needs, understanding the current distribution and accessibility of public transport options, such as trains, trams, and buses, is essential for informed planning and policy decisions.

This analysis investigates key questions around public transport accessibility within Melbourne Metropolitan: How effectively does the current PTV network serve the region, and are there significant gaps in transportation access across SA2 and SA4 areas? Additionally, it explores which regions offer the most comprehensive multi-modal options to identify both underserved areas and those with optimal coverage.

2. Methodology

Dataset Overview

This analysis uses two key datasets: the PTV/GTFS dataset and the Australian Boundary data.

PTV/GTFS Dataset:

The GTFS dataset, dated 17th March 2023, provides details on Melbourne's public transit system, covering stops, routes, and schedules for trains, trams, and buses. This standardized format allows us to analyse transit accessibility and identify multi-modal options. More details on Google GTFS documentation and the PTV-GTFS data source.

Australian Boundary Data (ASGS):

Provided by the Australian Bureau of Statistics, this dataset outlines statistical areas, with Mesh Blocks forming the smallest units. These boundaries allow us to aggregate data at the SA2 and SA4 levels, aiding in spatial analysis of transportation accessibility across Melbourne. More information is available in the ASGS overview.

Data Restoration and Preprocessing

The data restoration and preprocessing steps were conducted using PostgreSQL with PostGIS for spatial processing and DBeaver as the interface for executing SQL queries and initial data exploration.

Multiple tables relevant to PTV data were restored. Each table has been verified for completeness, and the number of rows was checked to confirm successful restoration. The following table displays each restored table and the corresponding number of rows, as shown in the Appendix.

1. **Data Import:**

   The PTV/GTFS data files were imported into PostgreSQL using SQL scripts and the \COPY command to load data from CSV files. The Australian Boundary data, provided as shapefiles, was imported using the ogr2ogr utility in GDAL to load spatial data directly into PostGIS, creating geometry-based tables for mesh blocks and statistical areas.

2. **Data Exploration:**

After importing, initial exploration was conducted in DBeaver. Basic queries were used to confirm data completeness, inspect row counts, and ensure accurate restoration. Key tables, such as stops, routes, and mesh blocks, were checked for integrity, with row counts validated against expected values.

Data Preprocessing for Melbourne Metropolitan area

- To focus on Melbourne Metropolitan, a new table mb2021_mel was created containing only mesh blocks within this region. We filtered by the gcc_name21 column, selecting rows labelled "Greater Melbourne." This streamlined approach ensures data relevance, optimizes spatial query efficiency, and improves data organization for Melbourne-specific analysis. The SQL script used is provided in the Appendix for reference.

- To define the Melbourne Metropolitan area, a boundary polygon was created by aggregating all mesh block geometries within the region. Using the ST_Union function, we combined these geometries into a single polygon representing the metropolitan boundary. This boundary serves as a reference for analysing transport accessibility within the specified area.

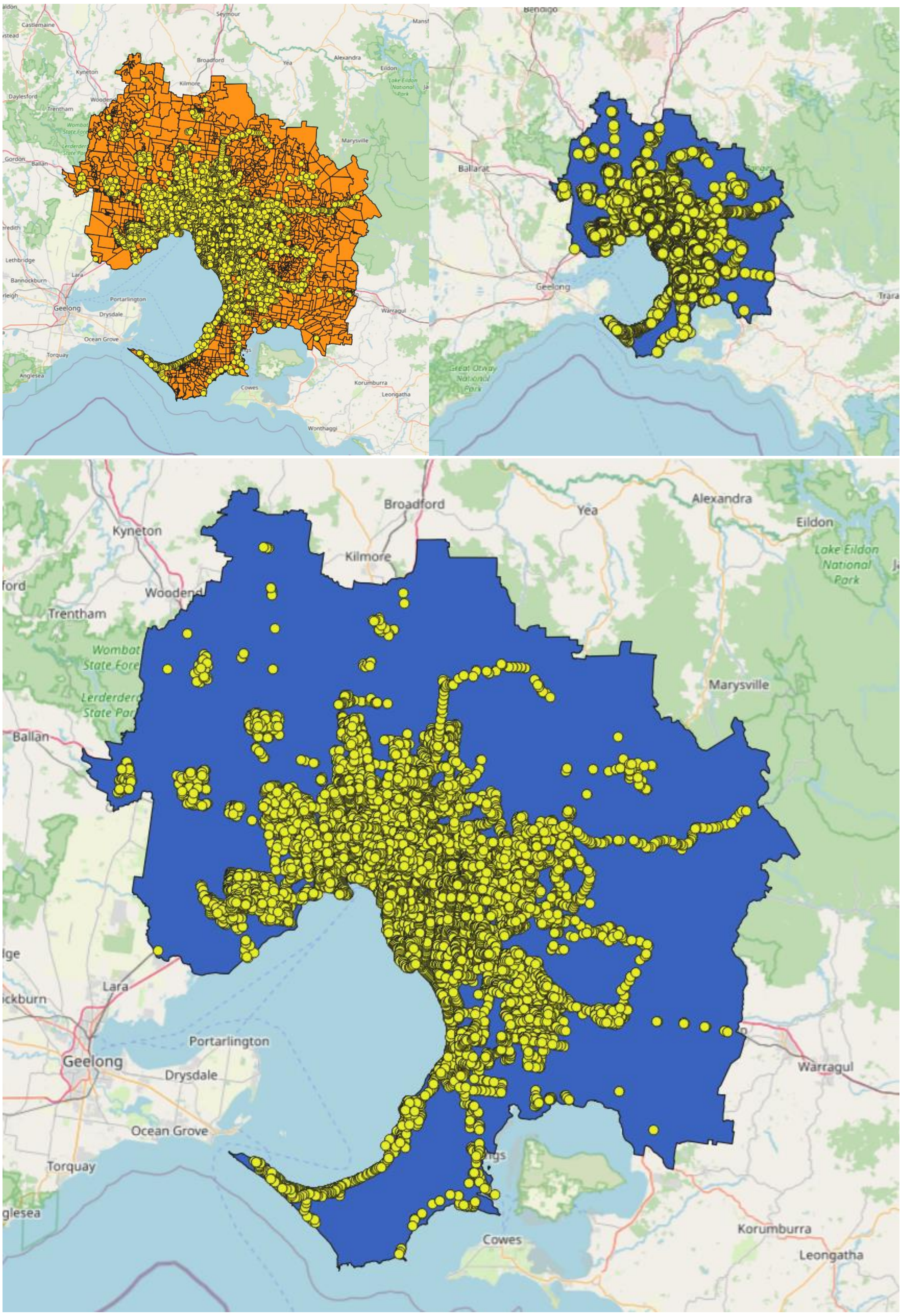
- To enable spatial analysis, a geometry column was added to the stops table by converting latitude and longitude coordinates into spatial points using the `ST_SetSRID` and `ST_MakePoint` functions. This transformation allows for efficient spatial queries, such as identifying stops within specific boundaries or calculating distances between stops.

- To streamline analysis, a consolidated table was created to combine stop data with vehicle type information (train, tram, or bus). By joining the `stops`, `routes`, `stop_times`, and `trips` tables, each stop was associated with its respective route and vehicle type. This unified table simplifies multi-modal transport analysis, allowing us to efficiently examine stop distribution and accessibility across different transport modes.

- To support regional analysis, separate tables were created for SA4 and SA2 boundaries by aggregating mesh blocks. SA4 boundaries offer a broad view, useful for summarizing transport coverage across larger Melbourne areas. In contrast, SA2 boundaries provide finer detail, allowing for in-depth analysis of public transportation accessibility at a more localized level. **(Australian Bureau of Statistics, 2021)**

Data Analysis and Visualization

The analysis begins with a spatial map of Melbourne Metropolitan, displaying all public transport stops (train, tram, and bus) across the area. This map provides an overview of stop density and distribution, highlighting areas with high accessibility and potential gaps for further investigation.



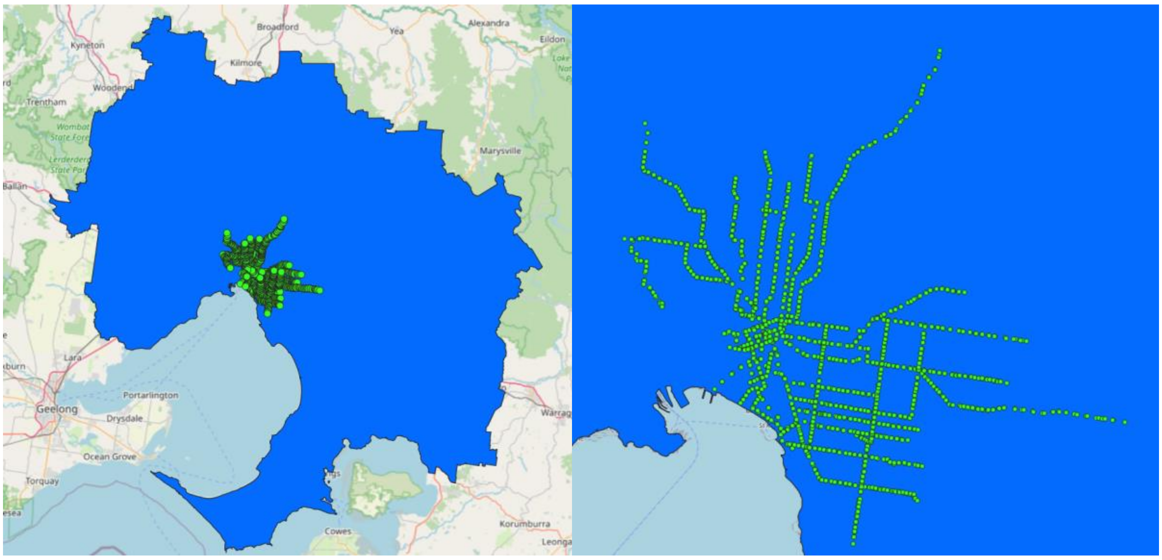
The primary focus of this analysis is to explore public transport accessibility within the Melbourne Metropolitan area, specifically examining the coverage and distribution of train, tram, and bus stops across SA2 and SA4 regions.

Analysis Conducted and Visualizations

The analysis included mapping stop density and distribution by transport mode, analysing coverage within each SA2 and SA4 area, and calculating the percentage of areas served by multiple transport modes. Visualizations used include:

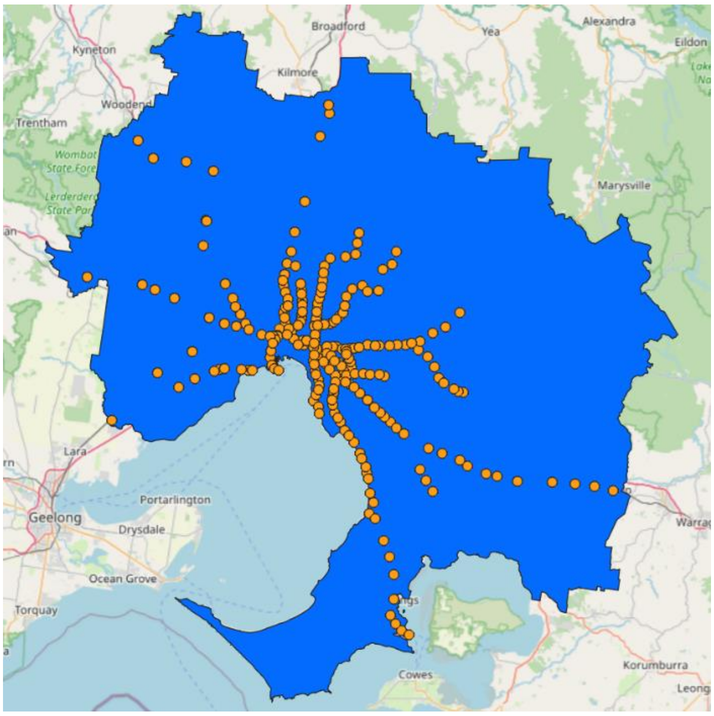
- **Spatial maps** showing stop locations and density, which provide an intuitive view of transport coverage.
- **Stacked bar charts** to compare stop counts by mode across top regions, highlighting areas with multi-modal accessibility.

Tram Stops



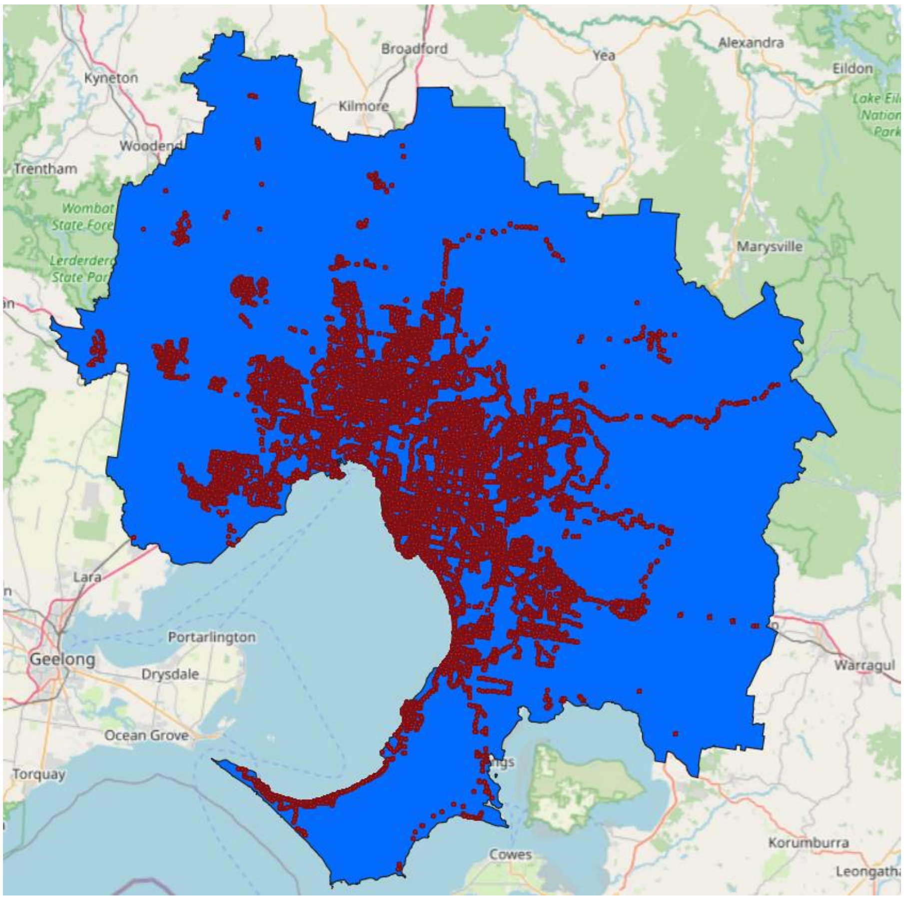
For an introductory visualization, displaying a map of Melbourne with tram stops provides an effective starting point to illustrate tram network coverage across the metropolitan area. From the visualization, it is evident that trams are primarily limited to areas concentrated around the Melbourne Central Business District (CBD), highlighting the network's urban-focused accessibility.

Train Stops



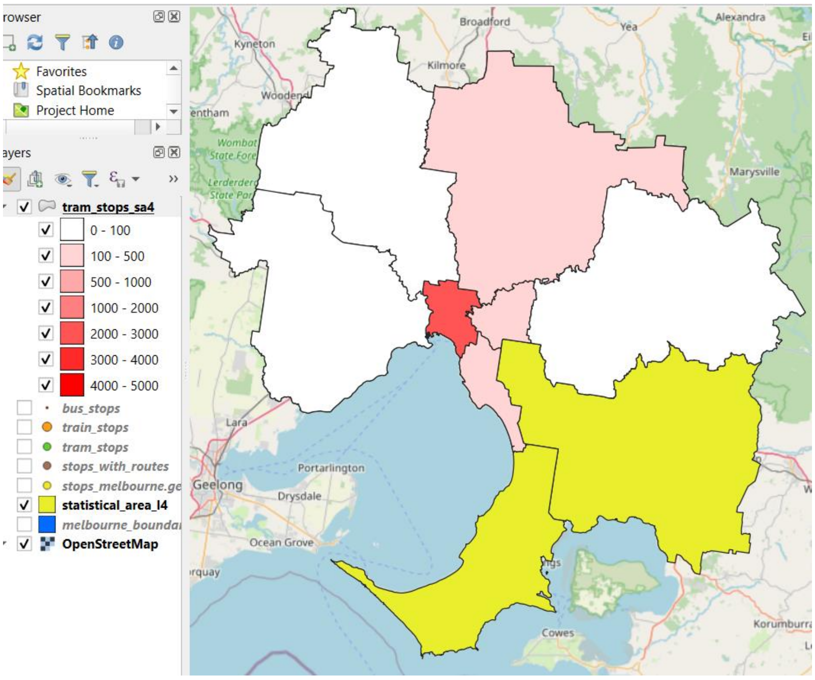
The map effectively illustrates the extensive reach of train services across Melbourne, with stops extending into suburban and outer areas. This visual highlights how train stops cover greater distances, with noticeably larger gaps between each stop, reflecting the network's design for longer-distance travel.

Bus stops



The map effectively demonstrates the high density and extensive coverage of bus stops across Melbourne. This visual shows how bus stops are numerous and widely distributed, reaching most areas and providing localized access.

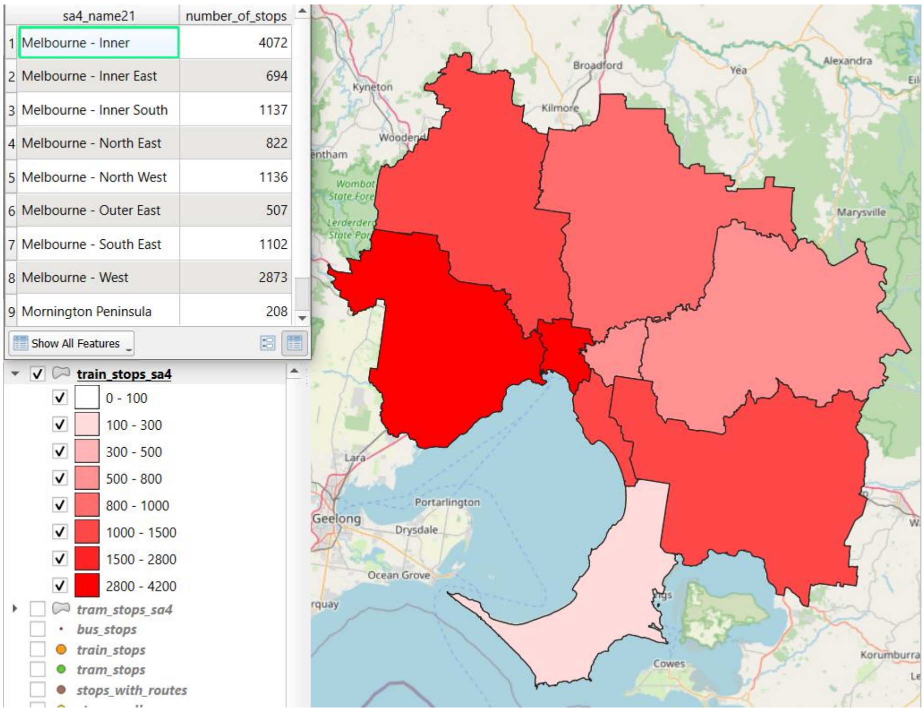
Tram SA4 Heat map



	sa4_name21	number_of_stops
1	Melbourne - Inner	2490
2	Melbourne - Inner East	500
3	Melbourne - Inner South	400
4	Melbourne - North East	108
5	Melbourne - North West	37
6	Melbourne - Outer East	10
7	Melbourne - West	58

The Tram SA4 Heat Map provides an effective representation of tram stop density across the Melbourne SA4 regions. By using colour gradients to indicate the number of trams stops, this visualization clearly highlights areas with high and low tram accessibility. The map reveals that the highest concentration of tram stops is in **Melbourne - Inner**, with 2,490 stops, emphasizing the focus of tram services around central Melbourne. In contrast, **Melbourne South East** and **Peninsula** regions, shown in yellow, have no tram stops at all.

TRAIN SA4 Heat Map

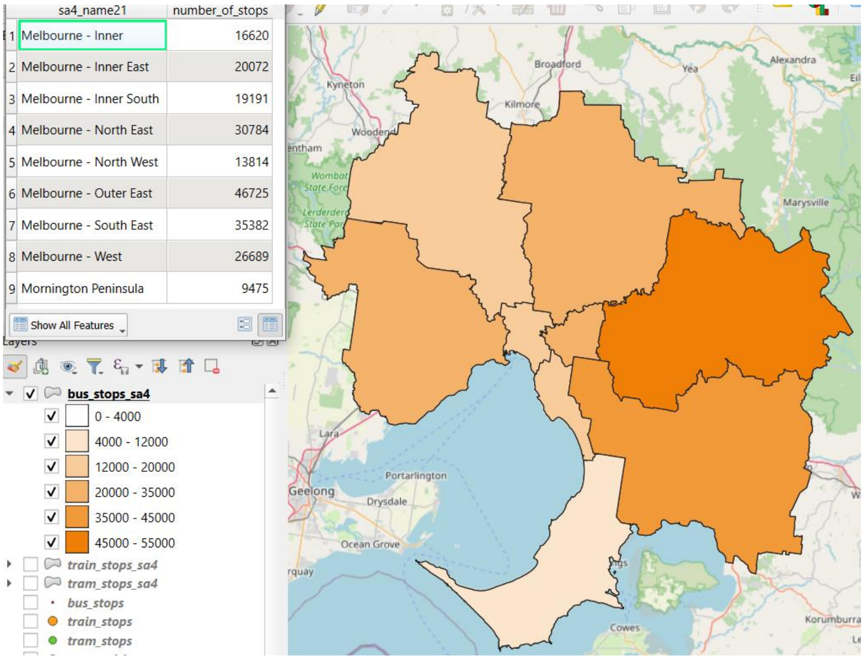


	sa4_name21	number_of_stops
1	Melbourne - Inner	4072
2	Melbourne - Inner East	694
3	Melbourne - Inner South	1137
4	Melbourne - North East	822
5	Melbourne - North West	1136
6	Melbourne - Outer East	507
7	Melbourne - South East	1102
8	Melbourne - West	2873
9	Mornington Peninsula	208

Map provides a clear view of train stop density across Melbourne's SA4 regions, with colour gradients indicating the concentration of stops. The **Melbourne - Inner area**, highlighted in dark red, has the highest concentration with **4,072 train stops**, reflecting the dense network around the city centre. Other areas, such as **Melbourne - West and Melbourne - South East**, also show substantial coverage, emphasizing the extended reach of train services.

In contrast, **Mornington Peninsula has limited train stops**, as represented by the lighter shade.

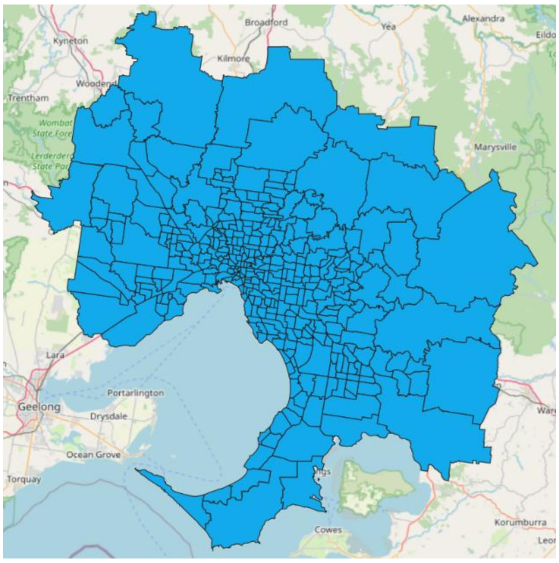
Bus SA4 Heat Map



	sa4_name21	number_of_stops
1	Melbourne - Inner	16620
2	Melbourne - Inner East	20072
3	Melbourne - Inner South	19191
4	Melbourne - North East	30784
5	Melbourne - North West	13814
6	Melbourne - Outer East	46725
7	Melbourne - South East	35382
8	Melbourne - West	26689
9	Mornington Peninsula	9475

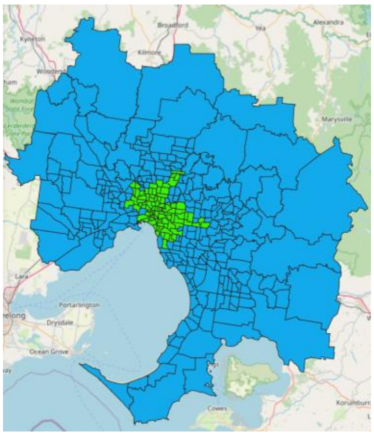
This shows extensive coverage of bus stops across Melbourne's SA4 regions. The gradient shades show a high density of bus stops in regions like **Melbourne - Outer East**, with more than 46,000 stops. These values highlight the comprehensive reach of bus services, especially in outer suburban areas.

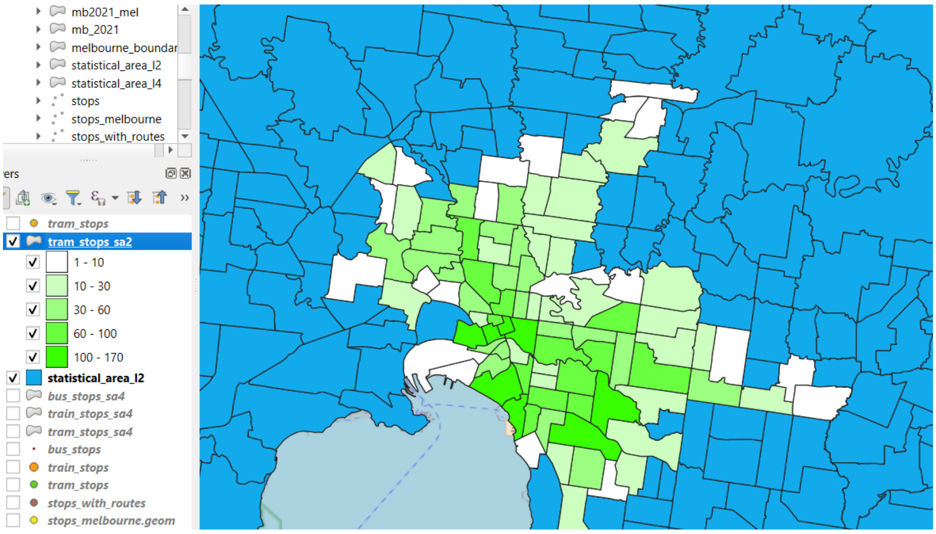
SA level 2



These SA2-level heat maps enable a granular analysis of public transport accessibility in Melbourne, allowing us to identify specific neighbourhoods with gaps in coverage.

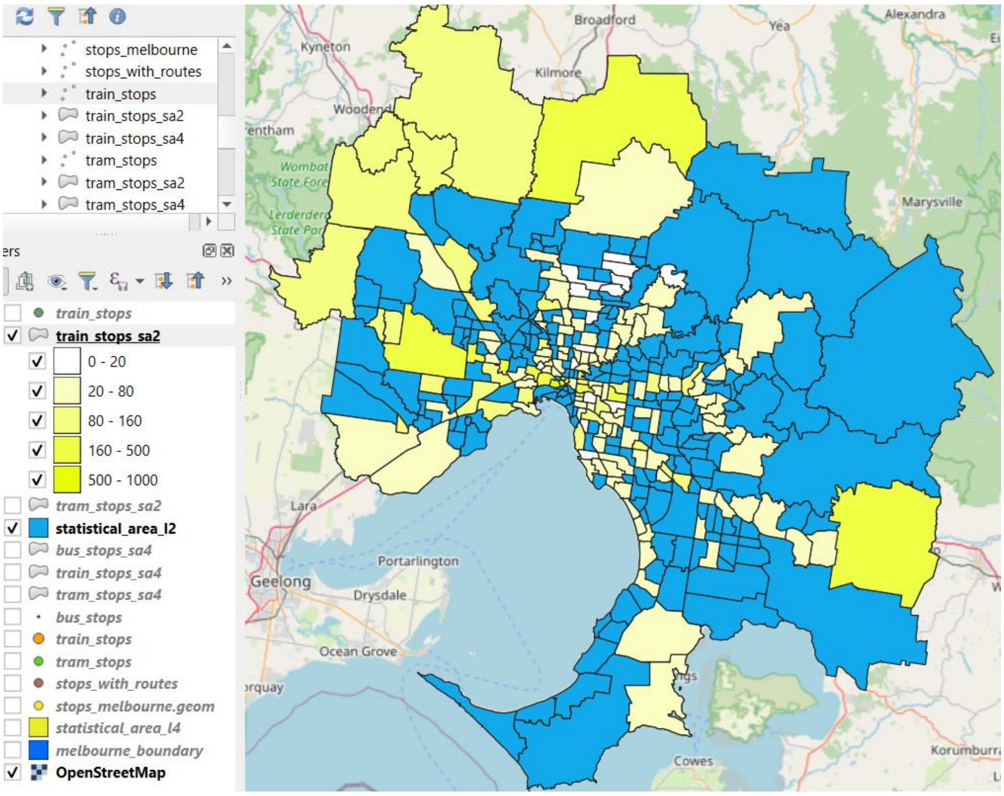
TRAM SA2 Heat map





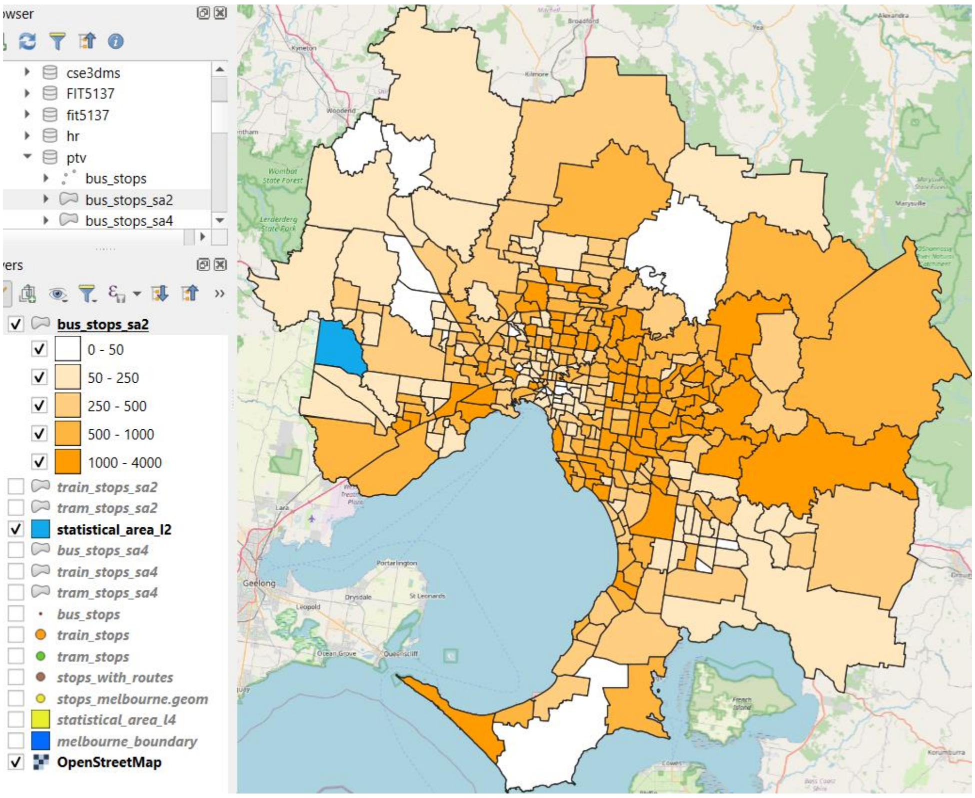
This visualization highlights the concentration of tram stops in the inner metropolitan areas, particularly around the Melbourne CBD, represented by shades of green. As shown, tram accessibility sharply declines in the outer suburban regions. And blue shows having no stops.

Train SA2 Heatmap



The colour gradient highlights areas with varying levels of train accessibility, with darker shades representing higher stop counts. Central areas around the Melbourne CBD, as well as some outer suburban regions, show moderate train stop density in yellow shades, indicating better train connectivity. And blue shows having no stops.

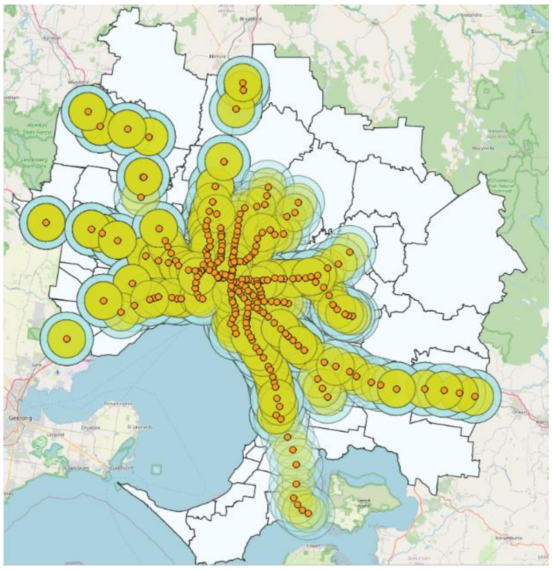
Bus SA2 Heat Map



This **map highlights the extensive reach of bus services throughout the metropolitan area**. The central and suburban areas are shaded in darker oranges, indicating higher numbers of bus stops, emphasizing the widespread accessibility provided by the bus network.

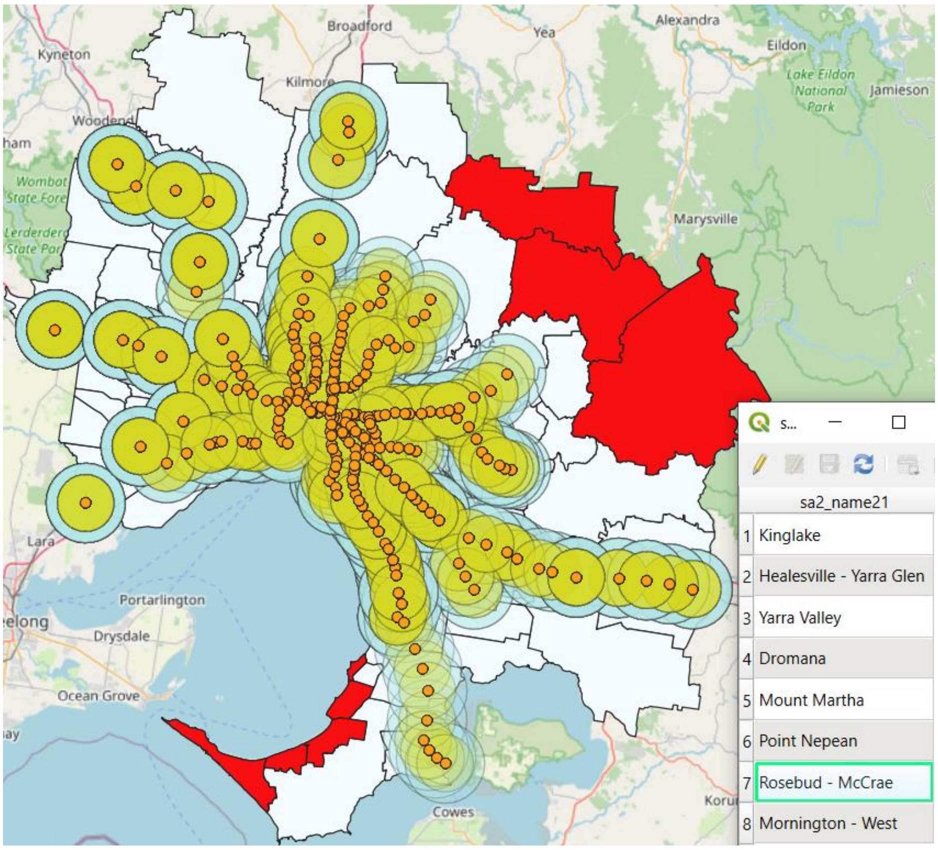
Compared to trams and trains, bus stops are more evenly distributed across both central and outer regions, filling in accessibility gaps left by other transport modes.

In Depth analysis



The **5km and 7km Catchment Map** visualizes the reach of train stations within a 5km and 7km radius, represented by concentric circles around each station.

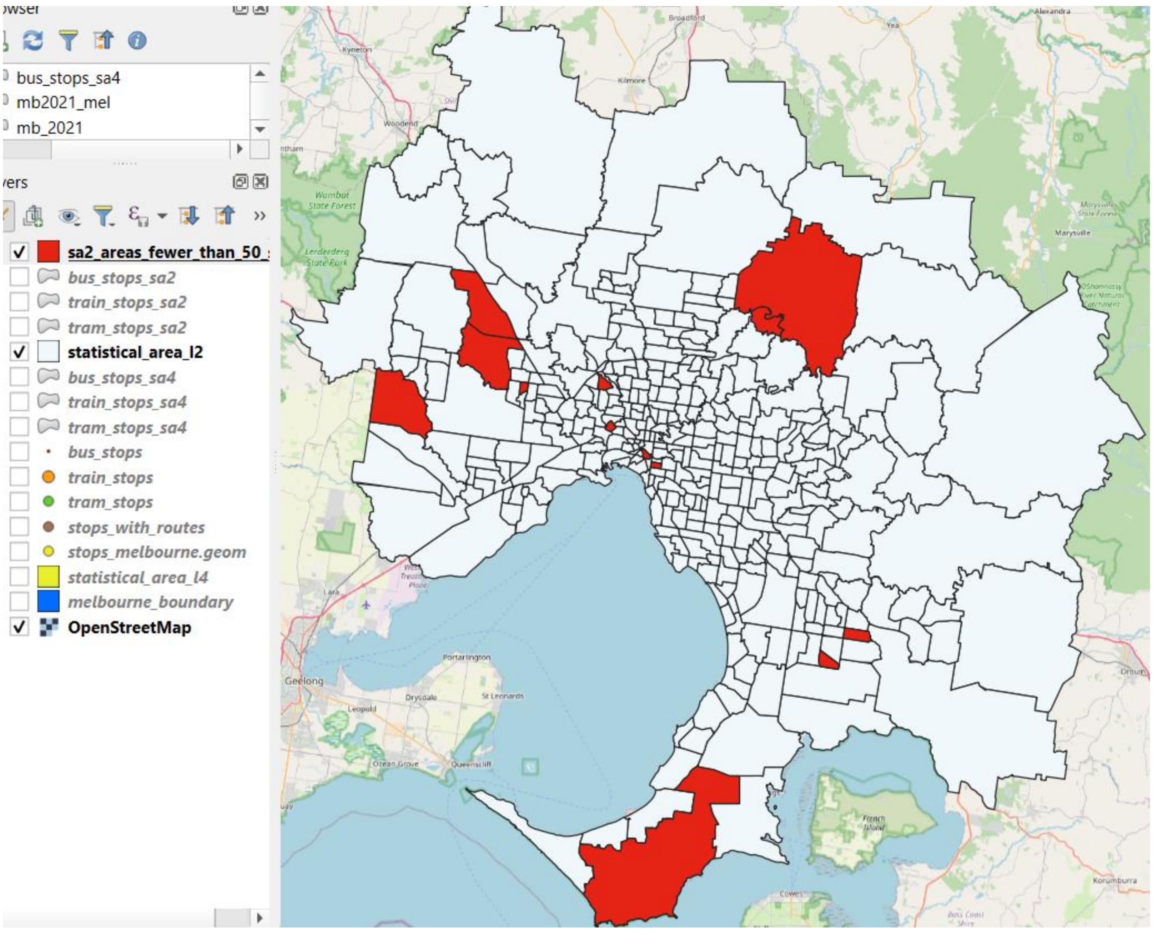
1) Identify SA2 Areas Not Covered by 7 km Catchment (Trains)



The SA2 Areas Not Covered by 7km Catchment Map **highlights regions in red that fall outside the 7km catchment zones of existing train stations**. These uncovered areas lack immediate access to train services, pointing to gaps in train transport accessibility.

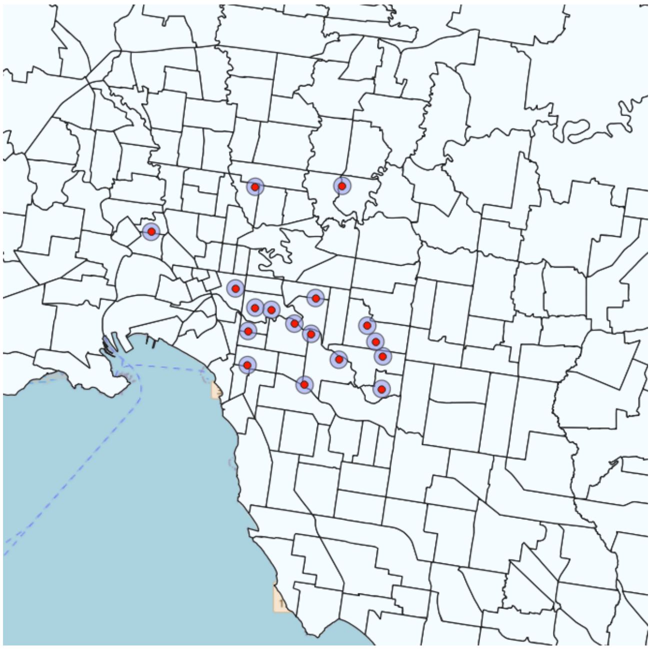
2) SA2 Areas with Fewer Than 50 Stops Across All Transport Modes

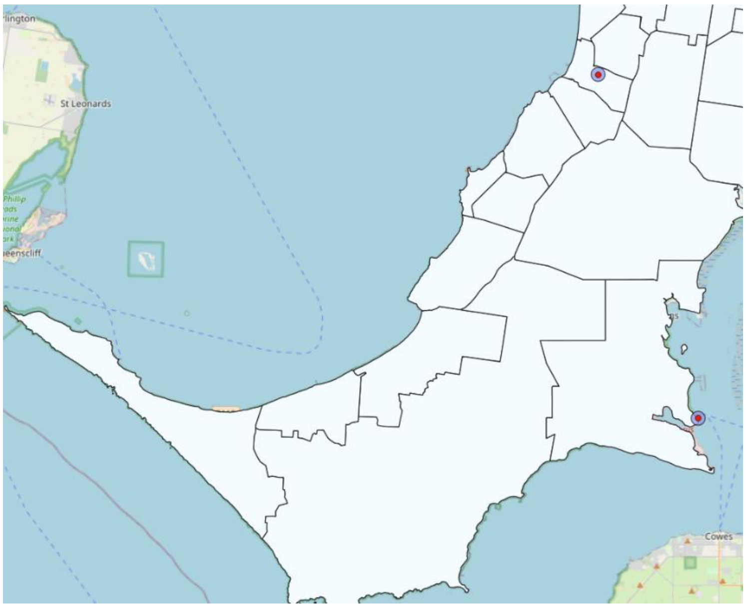
	sa2_name21	sa2_code21	tram_stops	train_stops	bus_stops
1	Burnside Heights	213041462	0	0	33
2	Clyde North - N...	212031555	0	0	44
3	Cranbourne Eas...	212031558	0	0	26
4	Diggers Rest	210041539	0	23	30
5	Essendon Airport	210011227	2	0	46
6	Eynesbury - Exf...	213041573	0	0	0
7	Flemington Rac...	206041120	3	2	12
8	Flinders	214021378	0	0	42
9	Fraser Rise - Plu...	213041574	0	0	42
10	Hurstbridge	209031210	0	19	18
11	Panton Hill - St ...	209031212	0	0	16
12	Royal Botanic G...	206041507	30	0	24
13	South Yarra - S...	206061516	18	25	42



This Map highlights specific regions in red that have limited public transport coverage, with fewer than 50 stops. Areas like Burnside Heights, Clyde North - North East, and Hurstbridge fall into this category**, indicating minimal access to public transportation services**.

3) Train stations – 0.5 km Catchment Areas with No Bus Stops





The 0.5 km Catchment Areas with No Bus Stops Map **highlights 19 train stops that lack nearby bus connections within a 0.5 km radius.** These isolated train stops, primarily in suburban and peripheral regions, indicate gaps in multi-modal connectivity that can impact commuters. Without nearby bus services, commuters using these train stations may face challenges in reaching their final destinations, especially in areas where walking distances to transit options are impractical.

```
select * from ptv.train_stops_half_km_no_bus_catchment;
```

train_stops_half_km_no_bus_catchment 1

select * from ptv.train_stops_half_km_no_bus_catchr | Enter a SQL expression to filter results (use Ctrl+Space)

	stop_id	stop_name	train_station_geom	catchment_half_km
1	19,827	Stony Point Railway Station (Crib Point)	POINT (145.221837462187 -38.3742345364979)	POLYGON ((145.22755885645554 -38.37432120
2	19,836	Leawarra Railway Station (Frankston)	POINT (145.139533963382 -38.1520339975268)	POLYGON ((145.14523769591818 -38.15212423
3	19,847	Alamein Railway Station (Ashburton)	POINT (145.079655668512 -37.8683203919916)	POLYGON ((145.08533726472166 -37.86841295
4	19,849	Burwood Railway Station (Glen Iris)	POINT (145.080511068965 -37.8515632823222)	POLYGON ((145.08619138183903 -37.85165576
5	19,850	Hartwell Railway Station (Camberwell)	POINT (145.075559591232 -37.8439845657224)	POLYGON ((145.0812393062772 -37.84407727
6	19,851	Willison Railway Station (Camberwell)	POINT (145.070297555358 -37.835715650541)	POLYGON ((145.0759766188035 -37.83580859
7	19,904	Glenferrie Railway Station (Hawthorn)	POINT (145.036438832309 -37.8214668222169)	POLYGON ((145.04211668969023 -37.82156137
8	19,906	Burnley Railway Station (Burnley)	POINT (145.007555147088 -37.8275602161722)	POLYGON ((145.01323337240532 -37.82765617
9	19,907	East Richmond Railway Station (Richmond)	POINT (144.997065693884 -37.8263999511211)	POLYGON ((145.00274379401222 -37.82649640
10	19,909	Heyington Railway Station (Toorak)	POINT (145.022635270015 -37.8346724432645)	POLYGON ((145.02831409225624 -37.83476768
11	19,910	Kooyong Railway Station (Kooyong)	POINT (145.033551606384 -37.8399289425958)	POLYGON ((145.0392308688958 -37.84002367
12	19,912	Gardiner Railway Station (Glen Iris)	POINT (145.051654659477 -37.8532790774277)	POLYGON ((145.05733500733874 -37.85337296
13	19,934	Eaglemont Railway Station (Eaglemont)	POINT (145.053942691014 -37.7635855335988)	POLYGON ((145.0596161799051 -37.76367911
14	19,944	Malvern Railway Station (Malvern)	POINT (145.029293938791 -37.8662532993132)	POLYGON ((145.0349752065487 -37.86634828
15	19,957	Windsor Railway Station (Windsor)	POINT (144.992035170295 -37.8560530797027)	POLYGON ((144.99771552672868 -37.85614984
16	19,959	South Yarra Railway Station (South Yarra)	POINT (144.992342213835 -37.838449349083)	POLYGON ((144.99802122109526 -37.83854606
17	19,979	Jolimont-MCG Railway Station (East Melbou	POINT (144.984098336822 -37.8165270224448)	POLYGON ((144.98977563553143 -37.81662408
18	20,015	Croxton Railway Station (Northcote)	POINT (144.997056186716 -37.7641010022257)	POLYGON ((145.00272952066018 -37.76419732
19	20,040	Newmarket Railway Station (Flemington)	POINT (144.928978466737 -37.7873276709024)	POLYGON ((144.93465333590763 -37.78742732

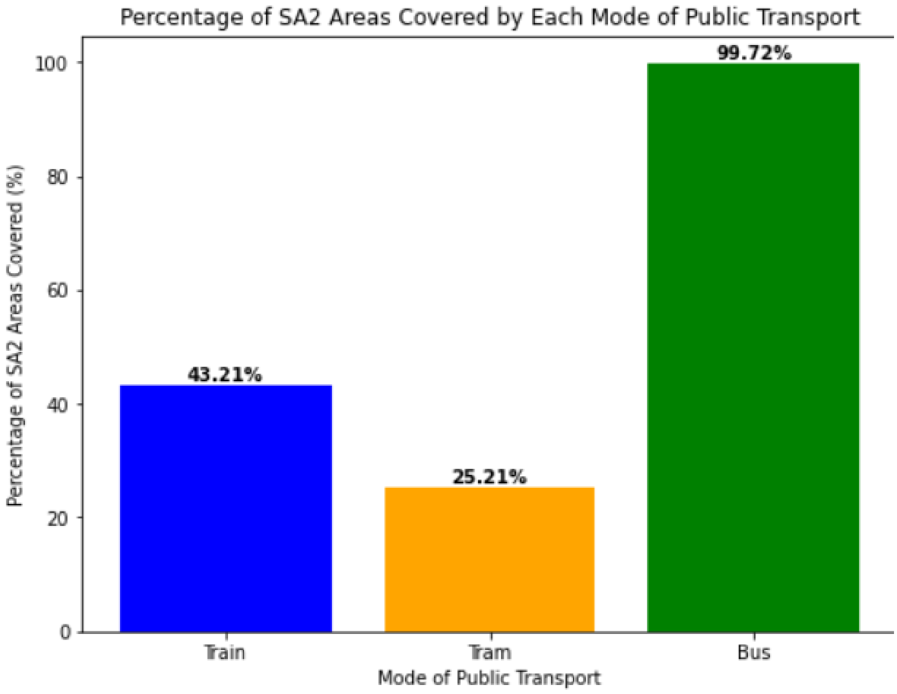
4) Calculate the Percentage of Train station Catchments with Nearby Bus Stops

bus_stop_availability	unique_catchment_count	percentage
Without Bus Stops	19	7.36
With Bus Stops	239	92.64

This analysis highlights that 92.64% of train station catchments have nearby bus stops within 0.5 km, indicating strong multi-modal connectivity across Melbourne's public transport network. However, **7.36% of train station catchments lack nearby bus stops within this range, which could hinder easy access for commuters needing to transfer between modes.**

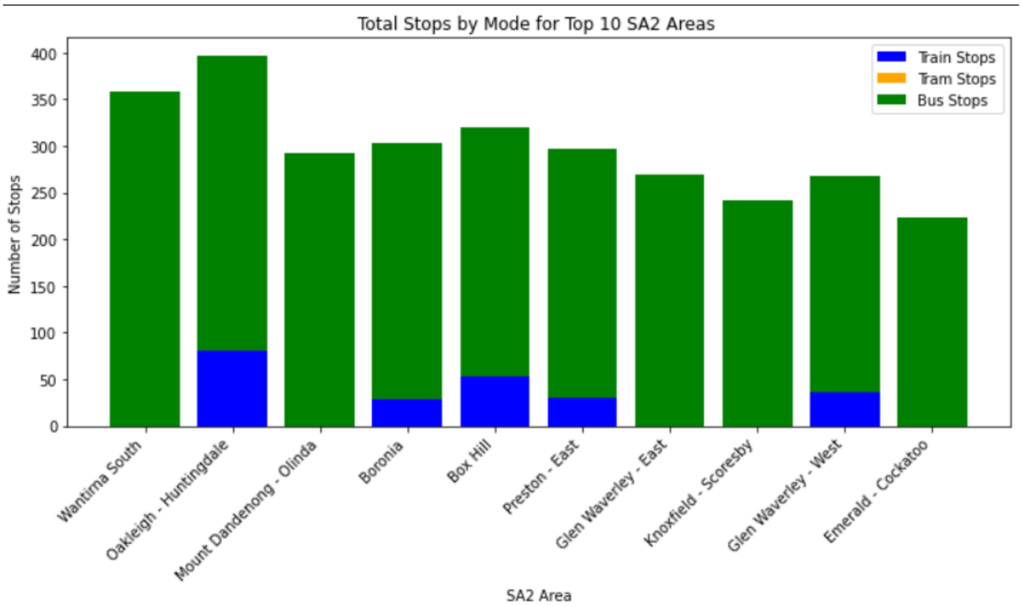
5) Calculate Percentage of SA2 Areas Covered by Each Type

stop_type	covered_sa2_areas	coverage_percentage
Train Stops	156	43.21
Tram Stops	91	25.21
Bus Stops	360	99.72



Bus Stops: Achieve the highest coverage with **99.72%** of SA2 areas, indicating that buses are the most widespread mode of transport across Melbourne.
Train Stops: Cover **43.21%** of SA2 areas, reflecting a more centralized reach, mostly connecting major suburban and urban hubs.
Tram Stops: Have the lowest coverage at **25.21%**.

6) Total Stops by Mode for Top 10 SA2 Areas based on stop count.



- Bus Stops (Green): Predominantly cover all top SA2 areas, highlighting the **extensive reach of the bus network.**
- Train Stops (Blue): Though fewer in number, these are strategically placed in certain areas like Oakleigh - Huntingdale and Box Hill, **serving as key commuter hubs.**

3. Results

Through spatial visualizations and calculations, we can address the primary questions set out at the beginning of this report.

1. **Overall Coverage:**

   Buses cover nearly all Melbourne SA2 areas (99.7%), ensuring widespread access. Trains serve 43% of areas, focusing on commuter routes, while trams cover only 25%, mainly in central, densely populated areas near the CBD and inner suburbs.

2. **Areas with Limited Accessibility:**

   Some outer Melbourne SA2 areas, notably in the south-east and Mornington Peninsula, have limited public transport access. A few train station lack nearby bus stops within 0.5 km, revealing gaps in intermodal connectivity for commuters.

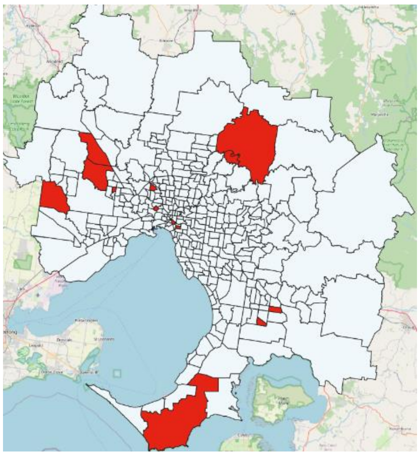
3. **Catchment Analysis:**

   The 5 km and 7 km train station catchment analysis show that most inner and middle-Melbourne suburbs are covered, while outlying areas face accessibility challenges. About 92% of these catchments have nearby bus stops, aiding seamless transfers.

4. **Top SA2 Areas for Public Transport:**

- The top 10 SA2 areas based on the total number of stops highlight the extensive bus network, with areas such as Wantirna South and Oakleigh - Huntingdale showing a particularly high concentration of bus stops. These areas cater to local accessibility and frequent connections to nearby hubs.

- **This Map highlights specific regions in red that have limited public transport coverage, with fewer than 50** tram, train, and bus stops.



This analysis confirms that Melbourne's public transport network prioritizes bus coverage for local accessibility. The findings indicate a need for improved integration in certain areas, particularly those lacking nearby bus stops within train station catchments, to enhance connectivity and streamline commuter transfers.

4. Discussion

- The analysis highlights key insights into Melbourne's public transport network.
- Buses offer the widest coverage, reaching 99.7% of SA2 regions and ensuring local accessibility.
- Train services, covering 43% of SA2 areas, focus on major commuter corridors and suburban connectivity, while trams, at 25% SA2 coverage, are primarily concentrated around central Melbourne.
- Certain train station catchments have limited nearby bus stops, pointing to potential improvements in multi-modal connections.
- Additionally, areas with fewer than 50 stops across all transport modes are highlighted.
- Key commuter hubs, such as Oakleigh - Huntingdale and Box Hill, have strategically placed train stops (blue), serving as important access points for suburban commuters.

5. Reference:

Australian Bureau of Statistics. (2021). ***Australian Statistical Geography Standard (ASGS): Volume 1 - Main Structure and Greater Capital City Statistical Areas, July 2021 - June 2026*****. Retrieved from** **https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026**

QGIS Development Team. (2023). ***QGIS Geographic Information System: Documentation*****. Open-Source Geospatial Foundation Project. Retrieved from** **https://www.qgis.org/resources/hub/**

Public Transport Victoria. (2023). ***PTV - GTFS data feed*****. Retrieved from** **https://transitfeeds.com/p/ptv/497**

6. Appendix

Task 1: Data Restoration

a) In this task, multiple tables relevant to PTV data were restored. Each table has been verified for completeness, and the number of rows was checked to confirm successful restoration. The following table displays each restored table and the corresponding number of rows, as shown in the accompanying screenshot.

ABC table_schema	ABC table_name	123 rows_n
ptv	agency	10
ptv	calendar	380
ptv	calendar_dates	15
ptv	lga_2021	368,286
ptv	mb_2021	368,286
ptv	routes	3,300
ptv	sal_2021	368,286
ptv	shape_metadata	15,016
ptv	shapes	9,757,418
ptv	stop_times	8,122,810
ptv	stops	27,821
ptv	trips	236,613

Task 2: Data Preprocessing for Melbourne Metropolitan area

b) SQL script for creating a table named "mb2021_mel" that contains ONLY the mesh blocks in Melbourne Metropolitan.

```
CREATE TABLE ptv.mb2021_mel AS
SELECT *
FROM ptv.mb_2021
WHERE gcc_name21 = 'Greater Melbourne';
```

c) Data Processing

1. Creating a Boundary Polygon for Melbourne Metropolitan

```sql
CREATE TABLE ptv.melbourne_boundary AS
SELECT ST_Union(wkb_geometry) AS boundary_geom
FROM ptv.mb2021_mel;
```

2. Adding Geometry to Stops

```sql
--2.Stops table does not have any geometry column. It might be useful to add a geometry
--column, using the latitude and longitude values available in the table. Make sure you use
--GDA2020 (SRID:7844) for this column.

ALTER TABLE ptv.stops
ADD COLUMN geom geometry(Point, 7844);



UPDATE ptv.stops
SET geom = ST_SetSRID(ST_MakePoint(stop_lon, stop_lat), 7844);
```

3. Creating a Consolidated Table for Stops with different vehicle types:

```sql
CREATE TABLE ptv.stops_with_routes AS
SELECT DISTINCT
    s.stop_id,
    s.stop_name,
    s.stop_lat,
    s.stop_lon,
    s.geom,
    r.route_id,
    r.route_short_name,
    r.route_long_name,
    r.route_type,
    CASE
        WHEN r.route_type = 0 THEN 'Tram'
        WHEN r.route_type = 2 THEN 'Train'
        WHEN r.route_type = 3 THEN 'Bus'
        ELSE 'Other'
    END AS vehicle_type,
    st.arrival_time,
    st.departure_time,
    st.stop_sequence
FROM
    ptv.stops_melbourne s
JOIN
    ptv.stop_times st ON s.stop_id = st.stop_id
JOIN
    ptv.trips t ON st.trip_id = t.trip_id
JOIN
    ptv.routes r ON t.route_id = r.route_id
ORDER BY
    s.stop_id;
```

4. Creating Statistical Area Level Tables (SA4 and SA2)

```
----------- Statistical Area Level 4  - sa4

CREATE TABLE ptv.Statistical_Area_L4 AS
select sa4_name21 , ST_Union(wkb_geometry) AS boundary_sa4_geom from  ptv.mb2021_mel
where mb_code21 in (
SELECT mb_code_2021 FROM ptv.lga_2021)
group by sa4_name21;


select * from ptv.Statistical_Area_L4;
```

```
---------- Statistical Area Level 2  - sa2

CREATE TABLE ptv.Statistical_Area_L2 AS
select sa2_code21,sa2_name21 , ST_Union(wkb_geometry) AS boundary_sa4_geom from  ptv.mb2021_mel
where mb_code21 in (
SELECT mb_code_2021 FROM ptv.lga_2021)
group by sa2_code21,sa2_name21;
```

SQL script for Data analysis and visualisation

- ## Tram stops

```
CREATE TABLE ptv.tram_stops AS
SELECT DISTINCT
    stop_id,
    route_id,
    stop_sequence,
    stop_name,
    stop_lat,
    stop_lon,
    geom
FROM
    ptv.stops_with_routes
WHERE
    vehicle_type = 'Tram'
ORDER BY
    stop_name;


drop table ptv.tram_stops;

select * from ptv.tram_stops ;
```

- ## Train stops

```
CREATE TABLE ptv.train_stops AS
SELECT DISTINCT
    stop_id,
    route_id,
    stop_sequence,
    stop_name,
    stop_lat,
    stop_lon,
    geom
FROM
    ptv.stops_with_routes
WHERE
    vehicle_type = 'Train'
ORDER BY
    stop_name;

select  * from ptv.train_stops;
```

- ## Bus stops

```sql
CREATE TABLE ptv.bus_stops AS
SELECT DISTINCT
    stop_id,
    route_id,
    stop_sequence,
    stop_name,
    stop_lat,
    stop_lon,
    geom
FROM
    ptv.stops_with_routes
WHERE
    vehicle_type = 'Bus'
ORDER BY
    stop_name;
```

- ## Tram SA4 heat map

```sql
CREATE TABLE ptv.tram_stops_sa4 AS
SELECT distinct
    sa.sa4_name21,
    sa.boundary_sa4_geom , -- Keep the statistical area's boundary geometry
    count(t.stop_id) as number_of_stops
FROM
    ptv.tram_stops t
join
ptv.Statistical_Area_L4 sa
on
ST_Within(t.geom, sa.boundary_sa4_geom)
group by sa.sa4_name21,sa.boundary_sa4_geom  ;
```

- ## Train SA4 heatmap

```sql
CREATE TABLE ptv.train_stops_sa4 AS
SELECT DISTINCT
    sa.sa4_name21,
    sa.boundary_sa4_geom, -- Keep the statistical area's boundary geometry
    COUNT(tr.stop_id) AS number_of_stops
FROM
    ptv.train_stops tr
JOIN
    ptv.Statistical_Area_L4 sa
ON
    ST_Within(tr.geom, sa.boundary_sa4_geom)
GROUP BY
    sa.sa4_name21, sa.boundary_sa4_geom;
```

- ## Bus SA4 heatmap

```sql
CREATE TABLE ptv.bus_stops_sa4 AS
SELECT DISTINCT
    sa.sa4_name21,
    sa.boundary_sa4_geom, -- Keep the statistical area's boundary geometry
    COUNT(b.stop_id) AS number_of_stops
FROM
    ptv.bus_stops b
JOIN
    ptv.Statistical_Area_L4 sa
ON
    ST_Within(b.geom, sa.boundary_sa4_geom)
GROUP BY
    sa.sa4_name21, sa.boundary_sa4_geom;
```

- ## Tram SA2 Heat map

```sql
CREATE TABLE ptv.tram_stops_sa2 AS
SELECT DISTINCT
    sa.sa2_name21,
    sa.boundary_sa4_geom AS boundary_sa2_geom,
    COUNT(t.stop_id) AS number_of_stops
FROM
    ptv.tram_stops t
JOIN
    ptv.Statistical_Area_L2 sa
ON
    ST_Within(t.geom, sa.boundary_sa4_geom)
GROUP BY
    sa.sa2_name21, sa.boundary_sa4_geom;
```

- ## Train SA2 Heat map

```sql
----- Train   sa2

CREATE TABLE ptv.train_stops_sa2 AS
SELECT DISTINCT
    sa.sa2_name21,
    sa.boundary_sa4_geom AS boundary_sa2_geom,
    COUNT(tr.stop_id) AS number_of_stops
FROM
    ptv.train_stops tr
JOIN
    ptv.Statistical_Area_L2 sa
ON
    ST_Within(tr.geom, sa.boundary_sa4_geom)
GROUP BY
    sa.sa2_name21, sa.boundary_sa4_geom;

select * from ptv.train_stops_sa2;
```

- ## Bus SA2 Heat map

```sql
CREATE TABLE ptv.bus_stops_sa2 AS
SELECT DISTINCT
    sa.sa2_name21,
    sa.boundary_sa4_geom AS boundary_sa2_geom,
    COUNT(b.stop_id) AS number_of_stops
FROM
    ptv.bus_stops b
JOIN
    ptv.Statistical_Area_L2 sa
ON
    ST_Within(b.geom, sa.boundary_sa4_geom)
GROUP BY
    sa.sa2_name21, sa.boundary_sa4_geom;
```

- ## The 5km and 7km Catchment Map visualizes the reach of train stations

```sql
CREATE TABLE ptv.train_stations_5km_catchment as
SELECT
    stop_id,
    stop_name,
    geom AS train_station_geom,
    ST_Buffer(geom::geography, 5000)::geometry AS catchment_5km -- 5 km buffer
FROM
    ptv.train_stops;


  ---7km

CREATE TABLE ptv.train_stations_7km_catchment AS
SELECT
    stop_id,
    stop_name,
    geom AS train_station_geom,
    ST_Buffer(geom::geography, 7000)::geometry AS catchment_7km -- 7 km buffer
FROM
    ptv.train_stops;
```

- ## Sa2 area not in 7 km catchment area

```sql
CREATE TABLE ptv.sa2_areas_not_in_7km_catchment AS
SELECT
    sa.sa2_name21,
    sa.sa2_code21,
    sa.boundary_sa4_geom AS sa2_geom
FROM
    ptv.Statistical_Area_L2 sa
LEFT JOIN
    ptv.train_stations_7km_catchment c
ON
    ST_Intersects(sa.boundary_sa4_geom, c.catchment_7km)
WHERE
    c.stop_id IS NULL;  -- Only select SA2 areas with no intersection
```

- ## SA2 Areas with Fewer Than 50 Stops Across All Transport Modes

```sql
CREATE TABLE ptv.sa2_areas_fewer_than_50_stops as
SELECT
    sa.sa2_name21,
    sa.sa2_code21,
    sa.boundary_sa4_geom AS boundary_sa2_geom, -- The geometry
    COALESCE(t.number_of_stops, 0) AS tram_stops,
    COALESCE(tr.number_of_stops, 0) AS train_stops,
    COALESCE(b.number_of_stops, 0) AS bus_stops
FROM
    ptv.Statistical_Area_L2 sa
LEFT JOIN
    ptv.tram_stops_sa2 t ON sa.sa2_name21 = t.sa2_name21
LEFT JOIN
    ptv.train_stops_sa2 tr ON sa.sa2_name21 = tr.sa2_name21
LEFT JOIN
    ptv.bus_stops_sa2 b ON sa.sa2_name21 = b.sa2_name21
WHERE
    COALESCE(t.number_of_stops, 0) < 50
    AND COALESCE(tr.number_of_stops, 0) < 50
    AND COALESCE(b.number_of_stops, 0) < 50
ORDER BY
    sa.sa2_name21;
```

- ## The 0.5 km Catchment Areas with No Bus Stops Map

```sql
CREATE TABLE ptv.train_stops_half_km_catchment AS
SELECT
    stop_id,
    stop_name,
    geom AS train_station_geom,
    ST_Buffer(geom::geography, 500)::geometry AS catchment_half_km -- 0.5 km buffer
FROM
    ptv.train_stops;

drop table  ptv.train_stops_half_km_catchment;

CREATE TABLE ptv.train_stops_half_km_no_bus_catchment AS
SELECT distinct
    t.stop_id,
    t.stop_name,
    t.train_station_geom,
    t.catchment_half_km
FROM
    ptv.train_stops_half_km_catchment t
LEFT JOIN
    ptv.bus_stops b
ON
    ST_Within(b.geom, t.catchment_half_km)
WHERE
    b.stop_id IS NULL; -- Only select catchment areas with no bus stops

drop table  ptv.train_stops_half_km_no_bus_catchment;
```

- **Percentage of train stations with / without bus tops nearby**

```sql
---Query to Calculate the Percentage of Train Catchments with Nearby Bus Stops
SELECT
    CASE
        WHEN has_bus_stop = true THEN 'With Bus Stops'
        ELSE 'Without Bus Stops'
    END AS bus_stop_availability,
    COUNT(DISTINCT stop_id) AS unique_catchment_count,
    ROUND((COUNT(DISTINCT stop_id) * 100.0 / SUM(COUNT(DISTINCT stop_id)) OVER ()), 2) AS percentage
FROM (
    SELECT
        t.stop_id,
        EXISTS (
            SELECT 1
            FROM ptv.bus_stops b
            WHERE ST_Within(b.geom, ST_Buffer(t.geom::geography, 500)::geometry)
        ) AS has_bus_stop
    FROM
        ptv.train_stops t
) AS train_catchments
GROUP BY
    has_bus_stop;
```

- **Calculate Percentage of SA2 Areas Covered by Each Type**

```sql
--- SQL Query to Calculate Percentage of SA2 Areas Covered by Each Type

WITH sa2_total AS (
    -- Total distinct SA2 areas
    SELECT COUNT(DISTINCT sa2_name21) AS total_sa2_areas
    FROM ptv.Statistical_Area_L2
),
sa2_coverage AS (
    -- Count of SA2 areas with each stop type
    SELECT
        'Train Stops' AS stop_type,
        COUNT(DISTINCT sa2_name21) AS covered_sa2_areas
    FROM ptv.train_stops_sa2
    UNION ALL
    SELECT
        'Tram Stops' AS stop_type,
        COUNT(DISTINCT sa2_name21) AS covered_sa2_areas
    FROM ptv.tram_stops_sa2
    UNION ALL
    SELECT
        'Bus Stops' AS stop_type,
        COUNT(DISTINCT sa2_name21) AS covered_sa2_areas
    FROM ptv.bus_stops_sa2
)
-- Calculate percentage coverage
SELECT
    c.stop_type,
    c.covered_sa2_areas,
    ROUND((c.covered_sa2_areas * 100.0 / t.total_sa2_areas), 2) AS coverage_percentage
FROM
    sa2_coverage c, sa2_total t;
```

- **distribution of public transportation stops across Train, Tram, and Bus modes in the top 10 SA2 areas**

```sql
SELECT
    sa.sa2_name21,
    COALESCE(train_stops.number_of_stops, 0) AS train_stops,
    COALESCE(tram_stops.number_of_stops, 0) AS tram_stops,
    COALESCE(bus_stops.number_of_stops, 0) AS bus_stops,
    COALESCE(train_stops.number_of_stops, 0) + COALESCE(tram_stops.number_of_stops, 0) + COALESCE(bus_stops.number_of_stops, 0) AS total_stops,
    CASE
        WHEN COALESCE(train_stops.number_of_stops, 0) > 0
             AND COALESCE(tram_stops.number_of_stops, 0) > 0
             AND COALESCE(bus_stops.number_of_stops, 0) > 0 THEN 'Train, Tram, Bus'
        WHEN COALESCE(train_stops.number_of_stops, 0) > 0
             AND COALESCE(tram_stops.number_of_stops, 0) > 0 THEN 'Train, Tram'
        WHEN COALESCE(train_stops.number_of_stops, 0) > 0
             AND COALESCE(bus_stops.number_of_stops, 0) > 0 THEN 'Train, Bus'
        WHEN COALESCE(tram_stops.number_of_stops, 0) > 0
             AND COALESCE(bus_stops.number_of_stops, 0) > 0 THEN 'Tram, Bus'
        WHEN COALESCE(train_stops.number_of_stops, 0) > 0 THEN 'Train'
        WHEN COALESCE(tram_stops.number_of_stops, 0) > 0 THEN 'Tram'
        WHEN COALESCE(bus_stops.number_of_stops, 0) > 0 THEN 'Bus'
        ELSE 'No Coverage'
    END AS modes_available
FROM
    ptv.Statistical_Area_L2 sa
LEFT JOIN
    ptv.train_stops_sa2 train_stops ON sa.sa2_name21 = train_stops.sa2_name21
LEFT JOIN
    ptv.tram_stops_sa2 tram_stops ON sa.sa2_name21 = tram_stops.sa2_name21
LEFT JOIN
    ptv.bus_stops_sa2 bus_stops ON sa.sa2_name21 = bus_stops.sa2_name21
ORDER BY
    total_stops DESC, modes_available DESC;
```