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# Urban traffic patterns through the pandemic: A four-year analysis of mobility disruptions and recovery in Western Australia (2019–2022)

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## Abstract

The COVID-19 pandemic brought a dramatic and sustained change in urban transport and mobility patterns globally and Perth, WA, provides a distinct context to investigate the effects of public health interventions and behavioural adaptions on traffic dynamics. This paper presents a four-year longitudinal analysis of urban traffic dynamics across Perth, WA from 2019 (pre-pandemic benchmark) through the peak of public health restrictions (2020-2021) and into the recovery phase (2022). Based on the aggregated traffic sensor data and government mobility reports, this paper highlights key disruptions and transitional phases in traffic volume across Perth, with a focus on temporal and spatial variations, peak travel behaviour and transport mode shifts.

Pre-pandemic 2019 data have been used to establish the baseline of normal traffic demand characterised by pronounced morning and evening peaks during the weekdays. In 2020, traffic volumes dropped drastically from March to April consequently from lockdown measures and working from home mandates. It is noticeable that slightly increase in midday traffic which reflects the shifts in daily routines and essential travel needs and unexpected surge in October 2020 due to short-term rebound from eased restrictions and local events. The year 2021 marked a phase of adaptive recovery with consistent weekday traffic patterns with below pre-pandemic levels. In 2022, traffic patterns stabilised, but still not public transport use, indicating a continued preference for private vehicles due to lingering health concerns. In terms of spatial distribution for traffic volumes, there was no significant changes during these four years in Perth, Western Australia.

This case study demonstrates how relatively low COVID-19 case numbers, strict border controls, and regional policy responses shaped local mobility trends differently from other global urban centres. This research contributes to the discourse on transport resilience, offering policy-relevant insights into how cities can better prepare for and adapt to systemic shocks.

## 1 Introduction

The COVID-19 pandemic severely disrupted urban transport and mobility systems around the world and reshaped transportation behaviours, road infrastructure use and travel demand. For public health concerns, governments implemented travel restrictions, lockdowns and working from home mandates. Therefore, all cities across the globe experienced an unprecedented decline in traffic volumes during the pandemic, followed by an uneven and complex recovery after pandemic. Perth, the Western Australia, is characterised by its unique geographic isolation and strict border controls and the pandemic's impact on its urban traffic patterns offers crucial insights into transport resilience and adaptation of its mobility systems.

This study investigates the urban traffic patterns in Perth, the Western Australia from Jan 2019 to Oct 2022, incorporating pre-pandemic baselines, the period of strict public health measures

like social distancing, and the subsequent phases of state border reopening and recovery. By analysing the vehicle count data, congestion trends and travel mode shifts, this study identifies significant variations in traffic volume and temporal and spatial patterns during and after COVID-19 pandemic. There was reduction in peak-hour traffic, increases in off-peak and weekend traffic demand as a result from notable shift from public transport to private transport, which reflects broader behavioural adaptations.

Referring to both traffic sensor data and public health policy timelines, this paper contributes to a growing body of research on transportation resilience and post-pandemic urban transport planning. It is important to understand how traffic systems responded to and recovered from the pandemic as it can inform future infrastructure decisions, particularly in the context of future public health crises, climate change adaptation and the transition towards more sustainable urban transport and mobility.

## 2 Literature review

In this literature review section, COVID-19 impact on traffic and mobility will be reviewed first and then findings on urban traffic patterns from some data analytics research projects will be discussed.

The OECD report from International Transport Forum (2021) projected three scenarios in future global transport trends up to 2050 by considering the effects from pandemics as

- Recovery scenario by continuing the current efforts without significant policy changes,
- Reshape scenario by implementing ambitious decarbonisation policies and
- Reshape+ scenario by leveraging COVID-19 induced changes to accelerate sustainable transport.

It is projected that passenger transport will be increased by 2.3 times and freight transport will be increased by 2.6 times by 2050. This report also emphasizes the need for implementation of policies which promote sustainable mobility by considering the pandemic's long-term impact on transportation systems. Recent report from the International Transport Forum (2023) also examines how urban mobility has changed during the pandemic, by predominantly focusing on the shifts in work arrangements. This report highlights that increasing in working from home arrangements has changed the peak travel times and reduced overall commuting or journey to work demand. It is recommended that cities should be encouraged to adapt to these changes by promoting sustainable and equitable transport options including active mobility and improved public transport.

Abu-Rayash and Dincer (2020) also document that globally, there is a shift in urban travel trends such as reduced public transport usage and increased reliance on private transport and/or active transportation as a result of lockdown measures and public health concerns. Shamshiripour et al. (2020) conducted the administered online survey over 1,200 adults in the Chicago area to examine how COVID-19 was reshaping activity-travel behaviour in the study area. Their study highlights the substantial increase in telecommuting during the pandemic, significant decrease in public transport usage and a rise in active transportation due to health concerns and lockdown measures.

In addition, Gao et al. (2020) examine the mobility pattern changes across US counties during the early stages of COVID-19 pandemic by using anonymised mobile phone data to visualise and analyse the spatial and temporal shifts in population movement and to gain better understanding on public compliance with lockdown restrictions. Their study finds the significant declines in mobility in early stages of COVID-19 pandemic, earlier in major urban counties than in rural counties. Moreover, De Haas, Faber, and Hamersma (2020) conducted

the study to examine how the Netherlands COVID-19 lockdowns influenced people's daily activities, work routines and travel behaviour based on the longitudinal panel data collected before and during the pandemic. Their findings highlight significant decrease in overall travel frequency, especially work, leisure and shopping purposes due to work from home arrangements like in other parts of the world.

Tirachini and Cats (2020) conducted a comprehensive review on the effects of COVID-19 on public transportation systems globally and concluded that there are significant drops in public transport ridership because of pandemic lockdowns, social distancing and public health concerns. They also highlight the needs for policy and equity considerations because public transport is a lifeline for essential and low-income workers and increased private transport has the risk for sustainability. Their findings are consistent with the findings from the global survey conducted by Zhang, Hayashi, and Frank (2021) in terms of massive reductions in public transport use and increases in working from home arrangements. They anticipate the rise in private transport will continue for longer periods with moderate optimism for sustainable growth in active transportation.

The traffic and mobility patterns changed after easing off from COVID-19 pandemic in 2021. Xu et al. (2022) conducted spatiotemporal analysis of urban road congestion during and post COVID-19 pandemic in Shanghai, China. They found out that traffic congestion in the central urban area during the commuting peak hours gradually reached to pre-pandemic levels in the resumption period. Their findings also highlight the significant changes in daily congestion patterns during and after pandemic compared to pre-pandemic times as a result of shift from public transportation to private transportation with proportion of private vehicles reached 32.6% in March 2020 which is an increase of 12.1% over March 2019. Additionally, Peng et al. (2024) examined traffic accident severity influenced by COVID-19 Pandemic in Illinois, USA and highlights the significant change in daily travel time and traffic variations in spatial segments.

In Australia, Currie, Jain and Aston (2021) conducted the study on the impacts of COVID-19 on public transport ridership in Melbourne metropolitan area. Their study highlights the severe decline in public transport ridership by over 90% and significant shift to private transport and work from home arrangement. These findings are confirmed by the COVID-19 community mobility report from Google (n.d) based on the community mobility data during the five week period 3 Jan-6 Feb 2020 as baseline and 15 Oct 2022 as reporting one, it states that mobility trends for public transport places such as underground, bus and train station have decreased to 21%, indicating the higher reliance on private transport or avoidance of public transport in WA. This decline in public transport usage is also confirmed by annual reports from public transport authority, Western Australia. Referring to the Public Transport Authority's annual reports (2021, 2022, 2023), SmartRider data indicates a significant decline in total train boardings, dropping from 61.54 million in 2018–2019 to 49.74 million in 2019–2020, followed by 42.998 million in 2020–2021, 42.78 million in 2021–2022, and further decrease to 33.55 million in 2022–2023. Correspondingly, SmartRider bus boardings decreased from 79.27 million in 2018–2019 to 66.26 million in 2019–2020, then to 58.70 million in 2020–2021, with a trivial increase to 58.89 million in 2021–2022 and a noteworthy recovery to 69.38 million in 2022–2023.

# 3 Research method

This study uses a quantitative longitudinal design to investigate urban traffic patterns in Western Australia over a four-year period spanning from 2019 to 2022, describing pre-pandemic, pandemic, and post-pandemic phases. The research adopts a spatiotemporal analytical approach to examine changes in traffic volumes and temporal distribution of vehicle flows in response to COVID-19-related disruptions and subsequent recovery.

### 3.1 Data collection

Monthly traffic data for key urban road segments in Perth, Western Australia were collected from government traffic monitoring systems and open data repositories. The dataset includes traffic counts and its speed, gathered via automated traffic counters and sensors which are installed across major roads and intersections. Supplementary data on mobility restrictions, lockdown periods, and public health policy timelines were retrieved from official state government sources to contextualize the analysis.

### 3.2 Data preprocessing

All numerical traffic counts are aggregated and then organized by month and year, enabling direct comparison across different temporal phases of the pandemic over four years. The same data processing was conducted to organise by day and month for each of the study year.

### 3.3 Analytical approach

Descriptive statistics and visualizations (line graphs, heatmaps) were used to identify trends and disruptions in traffic patterns. Time-series analysis was conducted to assess changes in average daily traffic volumes, peak vs. off-peak variation, and weekday-weekend differences. Additionally, a 3D visualisation is adopted by incorporating time-of-day data, which allows for a more granular analysis of traffic pattern changes and peak periods across weekdays and weekends. This approach allows us to gain deeper insights into diurnal variations in traffic flow and how they progressed over time. Comparative analyses between pre-pandemic (2019), pandemic (2020–2021), and post-pandemic (2022) periods were performed. spatial distributions of these traffic volumes are also analysed to understand if there is any particular area or region where unusual traffic demand occurred. Policy interventions and public health measures were overlaid on traffic data visualizations to analyse the contextual findings between policy events and mobility shifts.

## 4 Findings

The COVID-19 pandemic brought unprecedented changes to daily life across the globe, and one of the most visible impacts was on urban mobility and traffic patterns. This analysis examines the daily traffic volume trends in Perth from January 2019 to October 2022, highlighting how the pandemic influenced travel behaviour over time. By comparing data across these four years, it is observed that the sharp decline in traffic during lockdowns, the gradual recovery as restrictions eased, and the eventual return to near pre-pandemic levels. Understanding these trends is essential for urban planners and policymakers to better prepare for future disruptions and to adapt transport infrastructure and mobility strategies in a post-pandemic world.

### 4.1 Yearly traffic volumes in Perth (2019-2022)

The monthly traffic volume data from 2019 to 2022 illustrates how traffic patterns in Perth were impacted by seasonal variations, public holidays, and the broader socio-economic disruptions because of the COVID-19 pandemic. These trends offer insights into how traffic flows responded to external incidents, particularly government restrictions, work-from-home transitions, and subsequent recovery phases. The following figure shows that COVID-19 had a clear and measurable impact on traffic patterns in Perth, especially in 2020. There is an evident that this disruption in traffic patterns was recovered in 2022 after adaptation to new travel and work arrangements. It is noticeable that seasonal trends remained consistent

across pre, during and post COVID 19 with predictable decrease in January and December as well as peaks in autumn and spring.

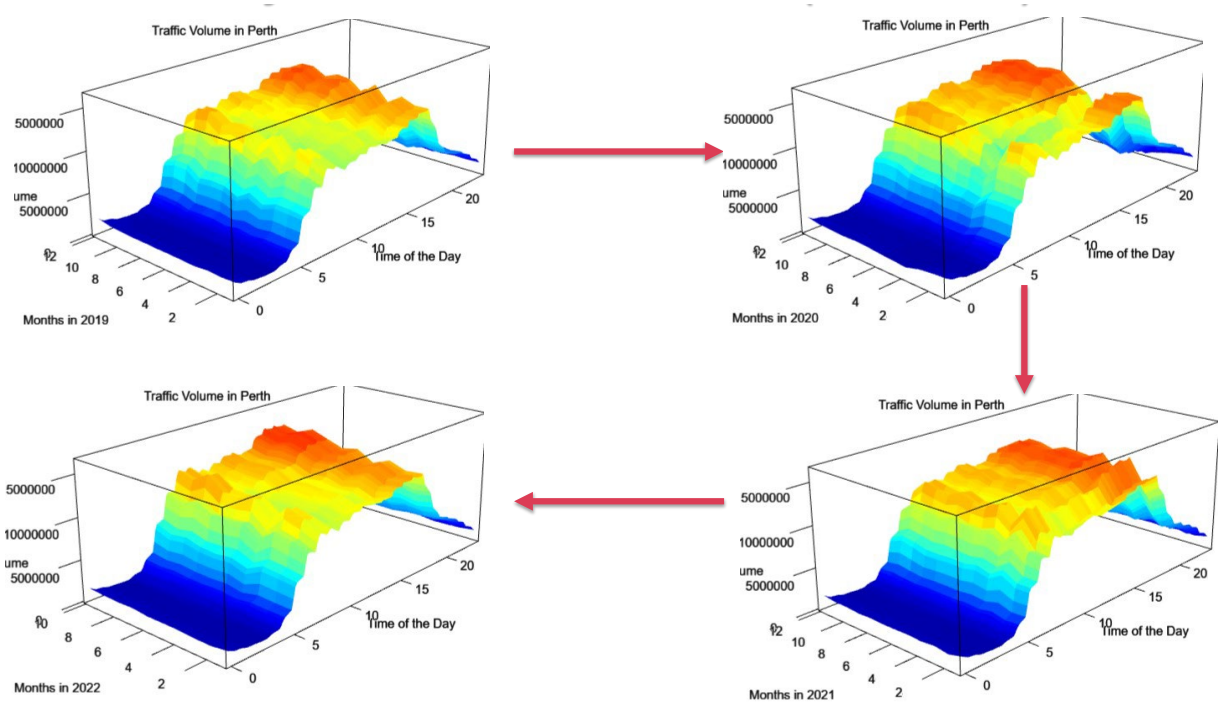


**Figure 1: Monthly Traffic Volumes (3D) in Perth (2019-2022)**

### 2019: Baseline pre-pandemic patterns

In this study, 2019 serves as a baseline year, indicating normal traffic behaviour before the pandemic. Normal traffic patterns were observed followed predictable seasonal cycles, such as noticeable lower volumes in January and December — coinciding with summer holidays and school holidays. School terms and standard working schedules reflected in the higher traffic from March to May and again from September to November. There were minimal monthly fluctuations indicating the stable travel demand and economic activities in Perth, Western Australia.

### 2020: Disruption due to COVID-19

There were national and state lockdowns from March to May 2020 and these public health measures such as implementation of working from home arrangements and school closures significantly result in the sharp and immediate decline in traffic. There was the lowest traffic volume in April 2020 across the four-year span, reflecting the peak of mobility restrictions in Perth, Western Australia. With state border lockdown and ease of mobility restrictions within local administrative boundaries, traffic began recovering from June 2020, but volumes remained below 2019 levels throughout the year. Due to continued caution, mobility restrictions, social distancing and reduced tourism, there was decline in traffic volumes in December 2020.

### 2021: Transition and adaptation with volatile recovery

Traffic volumes in early 2021 demonstrates the early recovery from the pandemic, but remained sensitive to the snap lockdowns, especially in February, April and June as well as continued working from home arrangement or hybrid work policies in many industry sectors. There was significant increase in traffic volumes in March and May, peaking in March at the highest single month volume across all four years with above 14.2 million. It is followed by slightly higher traffic patterns from July to November compared to 2019. Traffic volumes dropped slightly in December 2021, contrasting with previous stability in year-end months.

**2022: Recovery and realignment**

In 2022, traffic volumes began modestly in January and February, mirroring the patterns seen in 2019 and 2020. A strong upward trend followed from March to May, with particularly high volumes in May and July, both of which surpassed those of previous years. August marked the peak, recording the highest traffic volume of any month across all four years—approximately 14.4 million—indicating robust mobility and strong economic activity. This was followed by a slight decline in September and stable volumes in October.

**Figure 2: Monthly traffic volumes (line graph) in Perth (2019-2022)**

Figure 2 illustrates clear impacts of COVID-19 lockdowns, restrictions, and their easing on travel behaviour across 2019–2022. In 2019, both traffic volumes and public transport usage remained consistently high, reflecting stable pre-pandemic mobility patterns. In 2020, strict restrictions in March and April caused a sharp decline in traffic, with an even steeper drop in public transport use as people avoided shared spaces. While traffic volumes rebounded quickly from mid-2020 as restrictions eased and workplaces reopened, public transport recovery was slower, indicating a shift towards private vehicle use. In 2021, despite intermittent short lockdowns, traffic volumes remained high, with peaks following restriction easing, suggesting pent-up travel demand and continued reliance on cars. Public transport use increased but stayed well below pre-COVID levels, showing greater sensitivity to health concerns and restrictions. By 2022, traffic volumes had largely returned to or exceeded 2019 levels, driven by the widespread return to office work, school attendance, and social activities.

Public transport usage also rose steadily during 2022 but did not fully recover to pre-pandemic levels, indicating a lasting behavioural change influenced by hybrid work arrangements and a preference for private transport.

The findings from monthly traffic volumes analysis can be summarised as follows:

| Month | Key Insight |
|---|---|
| January | Steady across years, showing typical holiday slow-down. |
| February | Dip in 2021 stands out; otherwise, similar to January. |
| March | High volumes in 2021 and 2022 reflect reopening momentum. |
| April | 2020 crash clearly visible; 2021 dip interrupts the recovery trend. |
| May | 2021 and 2022 peak here, marking strong activity post-Q1. |
| June–July | Moderate dips and rises across years, with 2022 leading in July. |
| August | 2022 records the highest peak, showing clear recovery. |
| September | Frequently dips, suggesting seasonal slow-down or school holidays. |
| October–November | Strong, stable months across all years—suggesting full return to routine travel. |
| December | Always drops, but 2021's decline is most pronounced. |

**Table 1: Monthly traffic volumes in Perth (2019-2022)**

## 4.2 2019: Daily traffic volumes in Perth (Jan-Dec 2019)

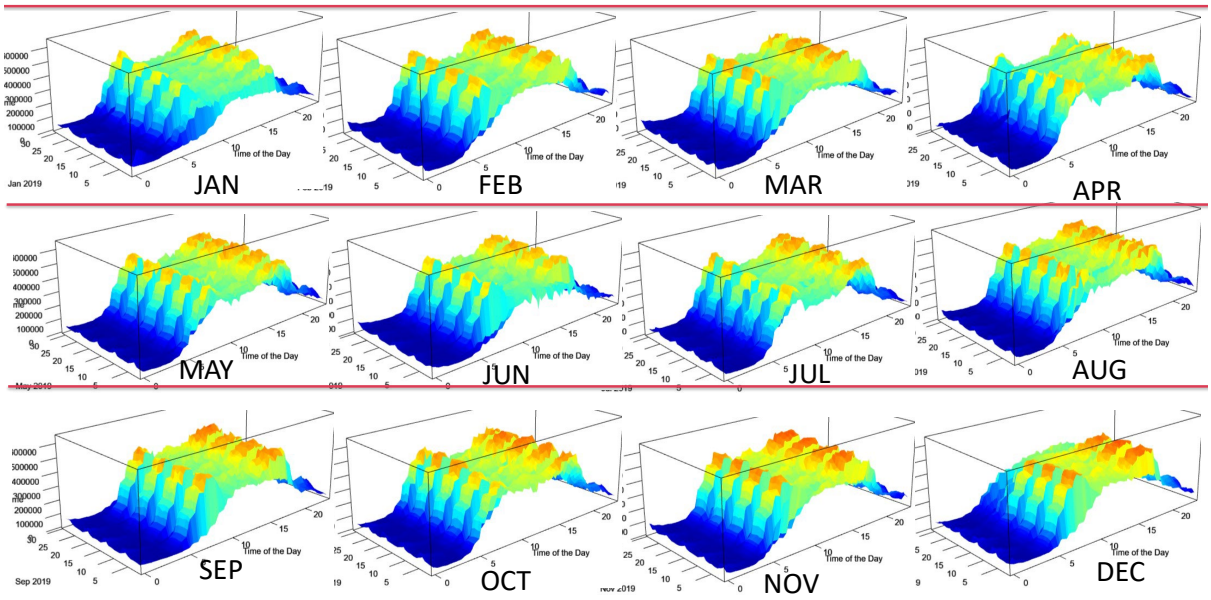


**Figure 3: Daily traffic volumes in Perth (Jan-Dec 2019)**

Figure 3 illustrates a comprehensive view of daily traffic volumes throughout the entire year of 2019, serving as a baseline reference for understanding normal, pre-pandemic traffic behaviour in Perth. The data highlights clear weekly and seasonal variations, which offer valuable insights into typical urban travel patterns in a non-disrupted year.

### Weekly patterns- clear weekend declines

One of the most prominent and consistent observations is the regular weekly cycle:

- Weekdays (Monday to Friday) consistently show higher traffic volumes, reflecting regular commuting patterns for work, school, and business.

- Saturdays show slightly lower traffic than weekdays, consistent with leisure and non-work-related travel.
- Sundays exhibit the lowest daily traffic volumes across the entire year, a consistent drop that reflects reduced travel demand and recreational or rest days.

This repeating pattern confirms the workweek-driven nature of traffic volumes in metropolitan Perth.

**Seasonal trends and school holidays**

Beyond weekly traffic patterns, Figure 3 also reveals seasonal shifts associated with school holidays and public holiday periods:

- January: Traffic volumes are lower throughout the month which reflects with summer holidays, when schools are closed and many families are on vacation. The lower weekday volumes especially reflect a drop in journey to work traffic.
- April: A noticeable dip in mid-April aligns with the Easter holidays and school break, resulting in reduced weekday traffic.
- July: Another decrease in traffic volume appears during mid-year school holidays, again reducing weekday travel volumes.
- October: A smaller decline is also visible around the October school holiday period.
- December: Starting from mid-to-late December, traffic volumes begin to drop again, consistent with the Christmas and New Year period when businesses slow down and schools are closed.

These seasonal patterns suggest that school calendars and public holidays significantly influence urban traffic volumes, especially on weekdays.

Traffic volumes are relatively stable throughout the workweeks across the year, with predictable peaks and troughs. There are no major anomalies or disruptions in the data, indicating that 2019 was a year of typical, uninterrupted traffic patterns. These patterns provide a valuable benchmark to compare against pandemic-affected years like 2020, 2021, and 2022.

## 4.3 2020: Daily traffic volumes in Perth (Jan-Dec 2020)

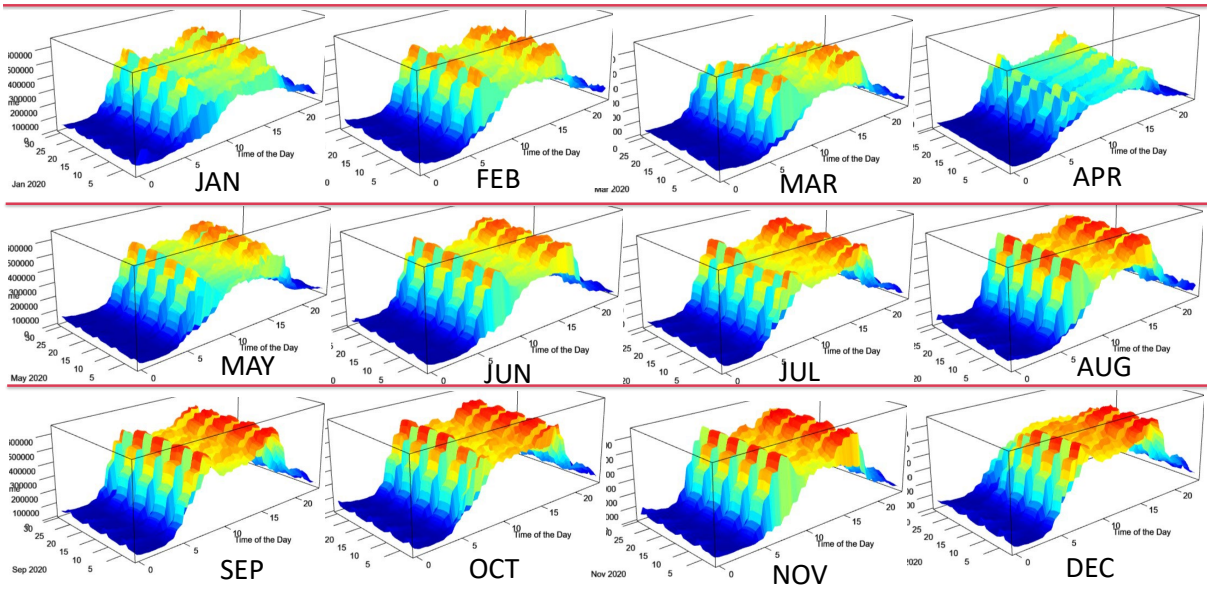


**Figure 4: Daily traffic volumes in Perth (Jan-Dec 2020)**

Figure 3 shows the significant disruptions and recovery trends in traffic volumes throughout the year 2020 — a year profoundly impacted by the COVID-19 pandemic. The data provides a complete contrast to 2019 with induced private transport demand from the pandemic, highlighting the effects of lockdowns, public health measures, and shifts in travel behaviour.

**Normal start in early 2020**

Starting from January to early March 2020, there are normal weekday and weekend patterns, similar to 2019:

- High volumes during weekdays as a result from work and school commutes.
- Low volumes on weekends, especially Sundays.
- There is no major disruption in the traffic pattern in these early months, suggesting that public life and commuting continued as usual until March.

**Sharp decline in March–April (first COVID lockdown)**

A sudden and significant decline in traffic volumes is observed beginning in late March, continuing through April 2020 which aligns with Western Australia's first COVID-19 lockdown and national restrictions such as schools and universities moved to online learning, offices transitioned to working from home and non-essential travel was restricted. The decline affects both weekdays and weekends, although weekday traffic reaches to the lowest point due to the disruption in work trips. April 2020 shows some of the lowest daily volumes of the entire year, reflecting the peak of travel restrictions.

**Gradual recovery from May to July**

Starting from May, traffic volumes begin to recover steadily, indicating the easing of lockdown measures, gradual return to schools and workplaces and also resumption of retail, leisure, and some inter-regional travel. By July, traffic volumes start approaching more typical patterns, even though still slightly below 2019 levels. It is noticeable that there was significant increase in induced traffic demand from the pandemic starting from June compared to the traffic demand in benchmarked year 2019.

**Stability and resilience from August to December**

From August to December, traffic patterns show a return to weekly consistency, with high weekday volumes and declines on weekends and noticeable reductions in school holiday periods (e.g., October and late December). It is also evidence that there is significant increase in traffic volumes in the mid-day from August to early December which is the unusual traffic volumes compared to other years. The resilience of traffic volume recovery in WA by the end of 2020 reflects the effective containment of COVID-19 compared to other regions and the public's gradual return to normal mobility behaviours.

Early 2020 traffic was normal, consistent with 2019 patterns even though it was followed by a steep decline occurred from late March to April 2020, driven by the first COVID-19 lockdown. Traffic volumes recovered gradually from May to July and stabilized through the second half of the year. Weekday vs weekend variations returned in the latter part of 2020, suggesting a resumption of routine commuting. The impact of COVID-19 on travel behaviour is clearly visible in the timeline, making 2020 a pivotal year in mobility trends.

## 4.4 2021: Daily traffic volumes in Perth (Jan-Dec 2021)

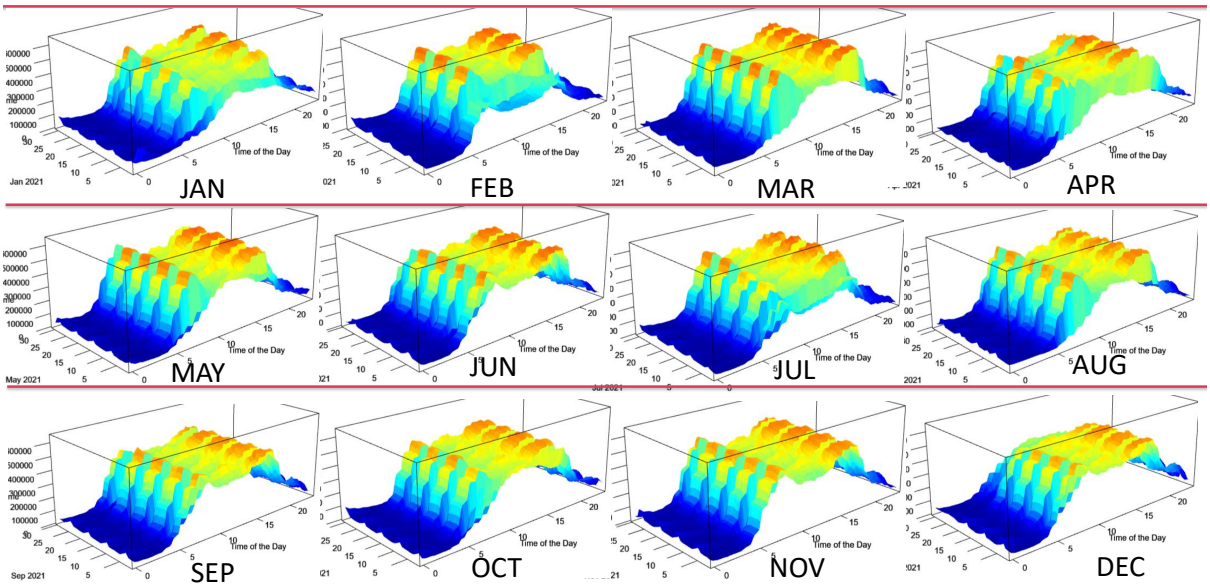


**Figure 5: Daily traffic volumes in Perth (Jan-Dec 2021)**

The traffic data for 2021 reveals a pattern of intermittent disruptions and recovery phases, reflecting a year where COVID-19 was still present but largely controlled in Western Australia (WA). The data illustrates how localized lockdowns, ongoing public health measures, and a gradual return to pre-pandemic routines shaped urban mobility throughout the year.

**Early 2021 – sharp drops due to snap lockdowns (January–March)**

Unlike the smooth early-year patterns of 2019 and 2020, January to March 2021 shows sudden drops in daily traffic, followed by quick recoveries. These drops correlate with WA's short "snap lockdowns", such as the five-day lockdown in early February and additional restrictions in April, impacting Easter travel. It reflects an adaptive mobility pattern, where traffic volumes dip sharply during lockdowns but bounce back quickly as restrictions ease.

**April to June – stable recovery**

From April through June, there is a return to more consistent weekday–weekend traffic patterns, similar to pre-pandemic norms. Traffic volumes stabilize, suggesting increased confidence in public health measures and resumption of commuting and business activities.

**July–August – mid-year snap lockdown effects**

A notable drop in July corresponds with another short-term lockdown due to emerging COVID cases in Perth and Peel regions. Additionally, the pattern shows a temporary decrease in traffic volume followed by quick normalization, reinforcing how 2021 was marked by episodic disruptions rather than sustained lockdowns.

**September to December – return to normality**

From September onwards, traffic patterns closely resemble 2019 levels where weekday peaks and weekend troughs are clear and regular. The October school holidays, and late December holiday period are reflected in minor dips in weekday volumes. These patterns indicate a nearly full resumption of pre-COVID travel behaviours, with minimal disruption during the final quarter of the year.

2021 was a year of mobility resilience, with people quickly resuming travel after each lockdown. Short-term, sharp traffic volume drops are aligned with WA's snap lockdown strategy. The ability to return to normal patterns quickly highlights both the public's adaptability and effective pandemic management in WA. By late 2021, daily traffic volumes largely mirrored pre-pandemic norms, suggesting a strong rebound in urban mobility.

## 4.5 2022: Daily traffic volumes in Perth (Jan-Oct 2022)

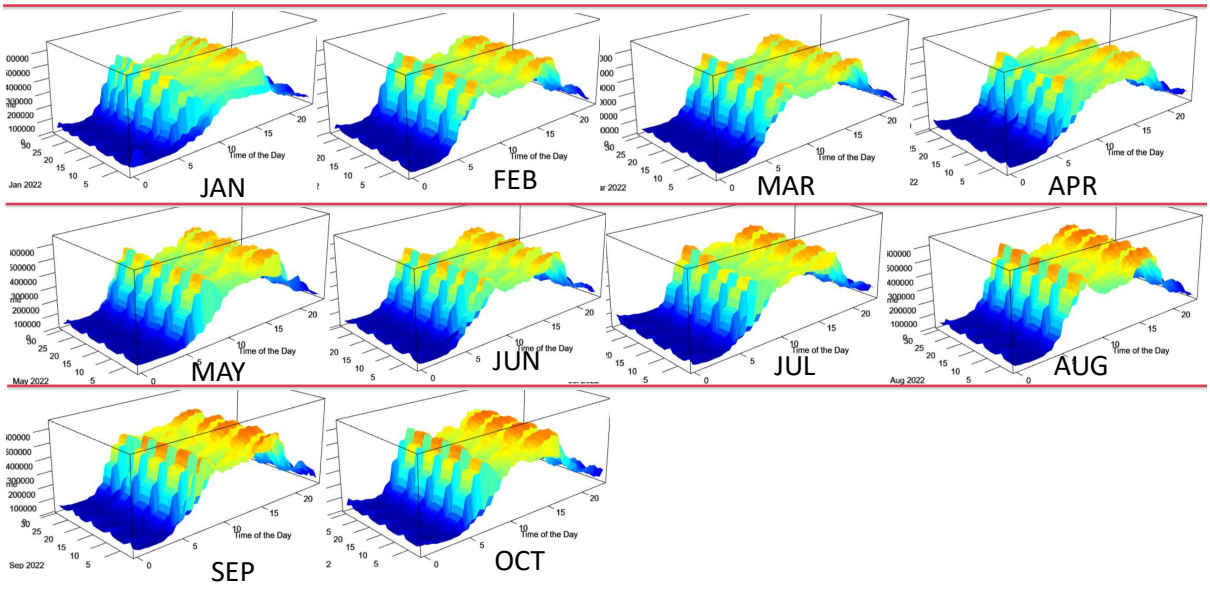


**Figure 6: Daily traffic volumes in Perth (Jan-Oct 2022)**

The traffic volume data for 2022 illustrates a transitional year, where travel behaviours begin to normalize after two years of pandemic-related disruptions. However, it also reflects the lingering effects of COVID-19 and changes in mobility patterns influenced by evolving work arrangements and public health trends.

### January to March – disruptions due to COVID-19 wave and restrictions

The year starts with notably lower traffic volumes, especially in late January and February. This decline aligns with the Omicron COVID-19 wave, which hit WA in early 2022. Although hard lockdowns were no longer enforced, there were self-isolation requirements, high case numbers, and caution among the public. Many people continued working from home, and schools saw lower attendance during peak infection weeks. These conditions led to reduced weekday travel and generally suppressed mobility in Q1.

### Gradual recovery from April to July

From April onward, a steady increase in traffic volumes is visible. This rise corresponds with easing of border restrictions and quarantine rules. A return to on-site work, in-person schooling, and more regular social activities. Weekday traffic becomes more pronounced, while weekend volumes remain lower, suggesting a partial return to traditional commuting patterns.

### August to October – stabilization and resumption of routine patterns

Traffic volumes in August, September, and October show a re-establishment of consistent weekday–weekend patterns: Weekday peaks are clearly visible, reflecting commuting and school-related travel. Weekends remain lower, especially Sundays, consistent with long-

standing trends. This part of the year reflects a return to more normal levels of mobility, comparable to late 2021 or pre-pandemic times.

Early 2022 saw suppressed traffic due to Omicron-related impacts and a cautious approach to mobility. A gradual and sustained recovery began around April, with more consistent travel returning by mid-year. By August–October, the data shows reliable weekly cycles, indicating stabilization in urban mobility. Unlike 2020 or 2021, there are fewer sharp dips or spikes, suggesting fewer disruptions and greater public confidence in returning to routine travel.

### 4.6 2022: Spatial distribution of traffic volumes (2019-2022)

The Figure 7 illustrates the spatial distribution of traffic volumes across Perth which remains consistent across all four years (2019–2022), with recurring high- and low-traffic zones indicating stable commuting patterns and infrastructure use. The Kwinana and Mitchell Freeways is a prominent feature in this distribution, and they serve as the primary north-south arterial backbone, connecting key suburban areas from Yanchep in the north to Rockingham in the south. These corridors consistently carry the highest traffic volumes, emphasizing their critical role in supporting the mobility and linking major residential, commercial, and industrial zones.

It is worth noting that more traffic counters were installed in 2020, particularly in the eastern suburbs. Maps illustrating the spatial variation in traffic volumes across the six time periods; early morning (until 6 a.m.), morning peak (7–9 a.m.), late morning (10–11 a.m.), afternoon peak (12–2 p.m.), evening peak (3–6 p.m.), and late evening (until midnight) — are provided in the appendix. August and October were selected for the spatial variation analysis as these months typically exhibit minimal seasonal fluctuations in traffic flow.

Prior to COVID-19, continuous traffic flow was observed on the Kwinana Freeway and Mitchell Freeway which run from south to north through the Perth metropolitan area from the early morning until around 6 a.m. However, by August 2020, following the easing of gathering restrictions in July 2020, traffic along these freeway corridors became intermittent.
In August 2021, traffic volumes showed a substantial change compared with the same month in 2019 (pre-COVID). There was a significant increase in early-morning traffic volumes, as well as on major east–west arterial roads such as Morley Drive, Canning Highway, Leach Highway, and Roe Highway. This trend of higher early-morning travel in 2021 slowed considerably during the same period in 2022.

When observing traffic flows during the morning peak hours, there was little difference between August 2019 and August 2020. However, August 2021 recorded a significant increase in traffic flow, followed by a notable decline in 2022. Compared to the pre- and during-COVID periods (2019 and 2020), 2021 saw high traffic volumes along the West Coast Highway and Marmion Avenue on the western coastal corridor, as well as on inner arterial roads such as Wanneroo Road, which connects the northern suburbs to the city centre in the northern metropolitan area. In the southern metropolitan area, there was also a noticeable increase in traffic volumes along Rockingham Road on the southern coastal corridor, suggesting that traffic from the far southern suburbs was not solely reliant on the Kwinana Freeway; the main north–south backbone freeway linking the outermost northern and southern suburbs. Heavy traffic flow on Tonkin Highway was a notable feature of the morning peak in 2021, a pattern not observed in previous years, and it eased off in 2022.

From east to west, traffic volumes in the northern suburbs increased notably along Reid Highway, Alexander Drive, and Morley Drive. In the southern suburbs, Canning Highway, Leach Highway, and Roe Highway have also seen a significant rise in usage, serving as key routes connecting the southern coastal corridor to the airport, the Welshpool industrial zone,

and the eastern suburbs. The intermittent traffic flow on the backbone Kwinana Freeway decreased in 2021, with traffic patterns showing a more continuous flow compared to 2020.

Prior to and during COVID (2019 and 2020), traffic flow significantly eased during the late morning period between 10 a.m. and 11 a.m. In 2021, however, traffic during this time remained noticeably busy, before declining to relatively lower levels in 2022. It is unclear whether the higher traffic volumes in 2021 were a result of working-from-home arrangements, as most employees had returned to office-based work by 2022. In contrast, during other time periods, traffic flow on Tonkin Highway remained high in 2022 following the completion of the Tonkin Highway Gap road extension.

Prior to and during COVID (2019 and 2020), the afternoon peak between 12 noon and 2 p.m. showed a similar pattern to the morning peak, except that in 2020, traffic flows along the backbone Kwinana Freeway were not continuous, suggesting shorter-distance travel compared to the more continuous flows observed in 2019. In 2021, however, midday traffic volumes were significant across all metropolitan suburbs, with particularly heavy and continuous flows on the Kwinana Freeway, all major highways, and major roads along the west coastal corridor, as well as on key inner-suburban roads. These sustained traffic flows indicate a higher proportion of longer-distance travel. Interestingly, this midday traffic volume eased noticeably in 2022.

The evening travel peak in Perth occurs between 3 p.m. and 6 p.m., primarily driven by school pick-ups and homebound work trips. The traffic pattern during this period is similar to that of the morning peak. While traffic volumes were extremely high across the metropolitan area in 2021, they declined slightly in 2022. However, flows on the Kwinana Freeway remained high in both years, with only a slight decrease observed on its southern segment beyond Leach Highway.

It is noticeable that late-evening traffic in 2020, during COVID, was lower than in 2019 and showed very intermittent patterns, indicating shorter-distance travel. In 2021, however, volumes rose sharply, particularly on the Mitchell Freeway and Roe Highway in the north, the Kwinana Freeway and Reid Highway in the south, and Tonkin Highway in the east. Interestingly, this late-evening traffic pattern eased in 2022 for inter-suburban roads, while remaining slightly elevated on major freeways and highways.

The same spatial variation patterns are found in both August and October of studied years.

# 5 Conclusion

This paper provides a comprehensive spatiotemporal analysis of urban traffic patterns in Perth, Western Australia, across four critical years marked by the prior, onset, progression, and recovery phases of the COVID-19 pandemic. By analysing daily traffic volume data with 3D time-of-day visualizations, the analysis identifies both the magnitude and rhythm of mobility disruptions, as well as the gradual return to pre-pandemic norms.

The findings demonstrate that 2020 was a disrupted year from the pandemic, with sharp declines in traffic volumes during government-mandated lockdowns and health-related restrictions and unusual increase in traffic volumes when the restrictions are eased off. These disruptions significantly changed daily commuting behaviours in typical weekday peaks and increasing midday travel due to changes in work and lifestyle routines. In contrast, the years 2021 and 2022 demonstrate a resilient adaptation process. Journey to work traffic began to rebound with weekday–weekend distinctions re-emerged, and the diurnal peaks associated with work related or education related travel schedules were progressively restored—particularly evident in the strong morning and evening traffic surges observed in 2022.

Notably, the use of 3D visualization enriched the understanding of not just how much the traffic volumes changed but when and how those movements varied across different phases of the pandemic. It enables us to understand the dynamic insight on the importance of flexible, time-sensitive transportation planning that accommodates emerging travel behaviours, hybrid work models, and seasonal disruptions.

In conclusion, the Perth's traffic from 2019 to 2022 illustrates the profound impact of the COVID-19 pandemic on urban mobility in Perth and highlights the critical role of adaptive transport policies in building resilience for future disruptions. From the stability of 2019 to the sharp decline and unusual increase in 2020, the gradual recovery in 2021, and the near-normal levels in 2022, the trends suggest that while traffic volumes have rebounded, commuting behaviour and travel preferences may have undergone lasting changes. Urban planners and transport authorities may need to adapt strategies to this evolving landscape, which includes managing more flexible and less predictable travel demand. The lessons drawn from this analysis have broader implications for urban planners, policymakers, and transport authorities as they navigate the post-pandemic landscape and strive to design smarter, more responsive cities.

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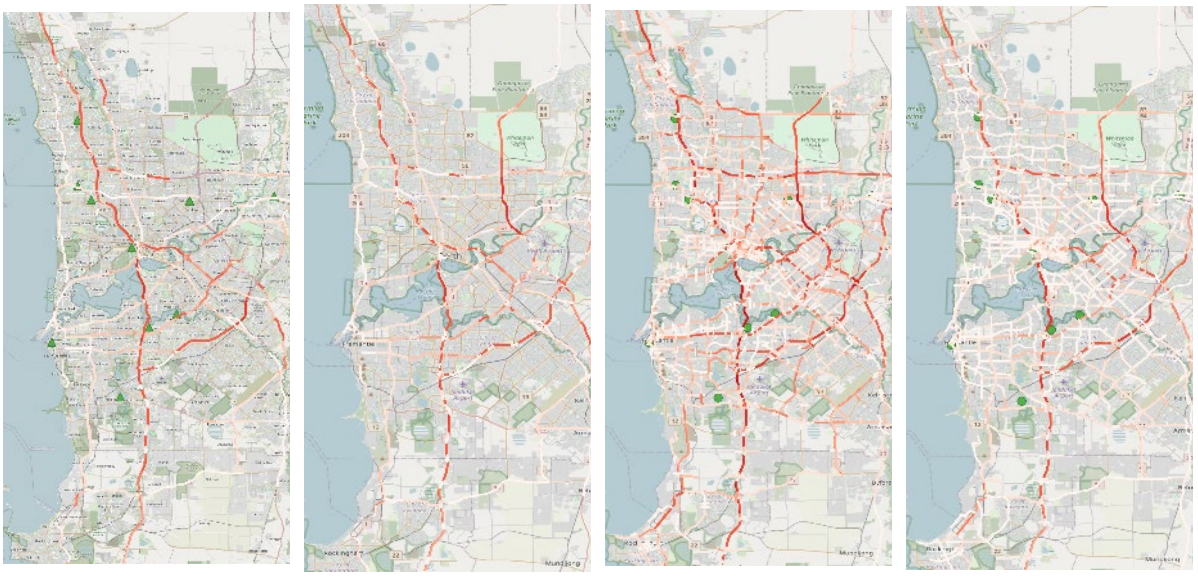
# 7 Appendix

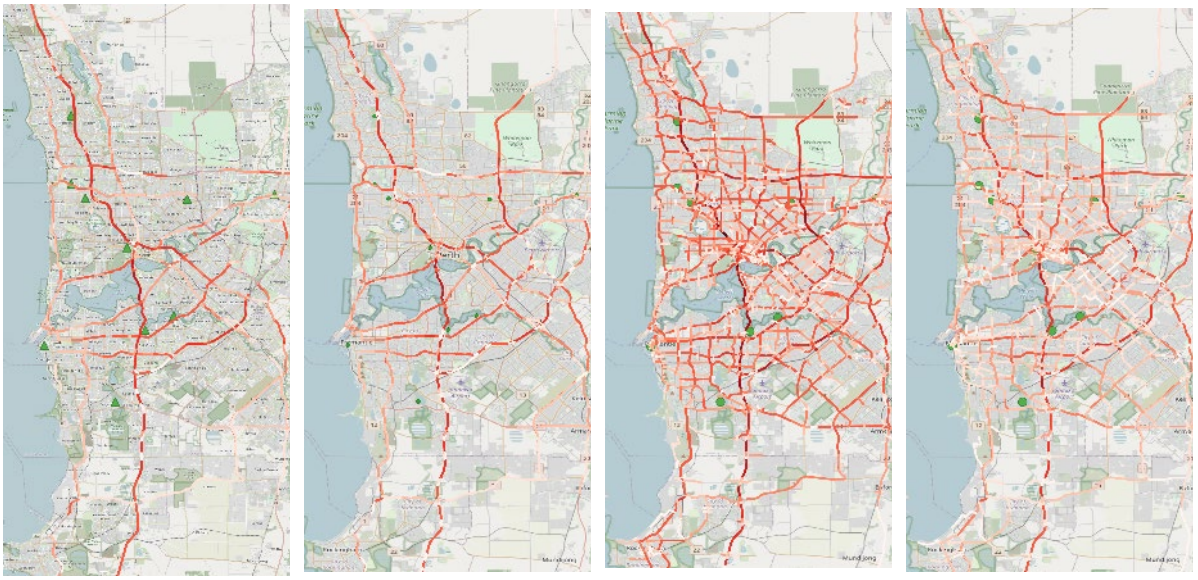
**0-6am (early morning) Aug**

2019 2020 2021 2022



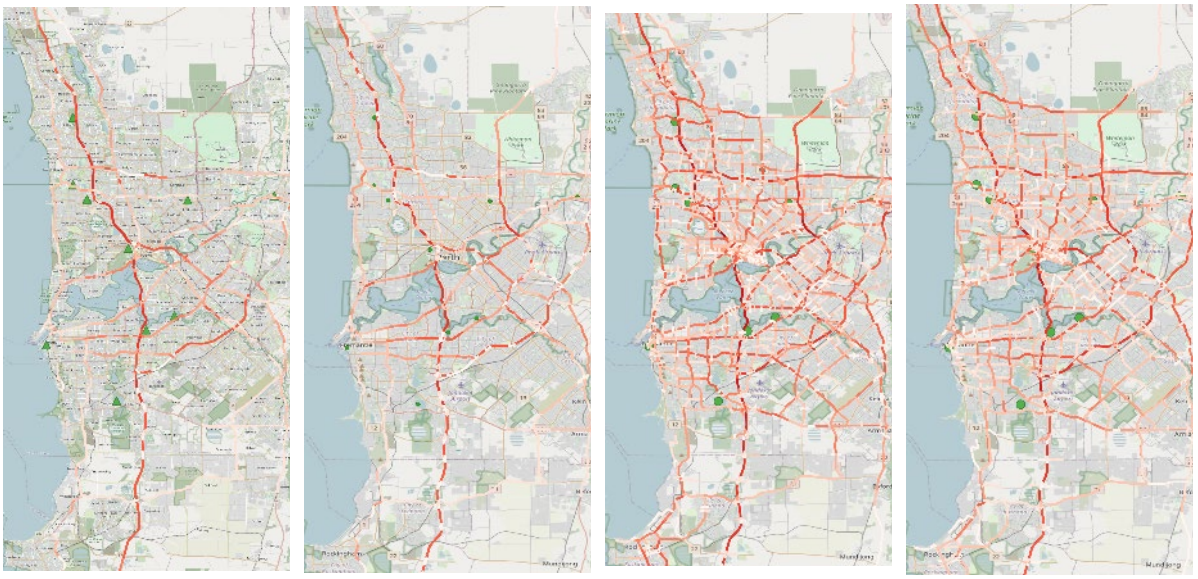
**7-9am (morning peak) Aug**

2019 2020 2021 2022



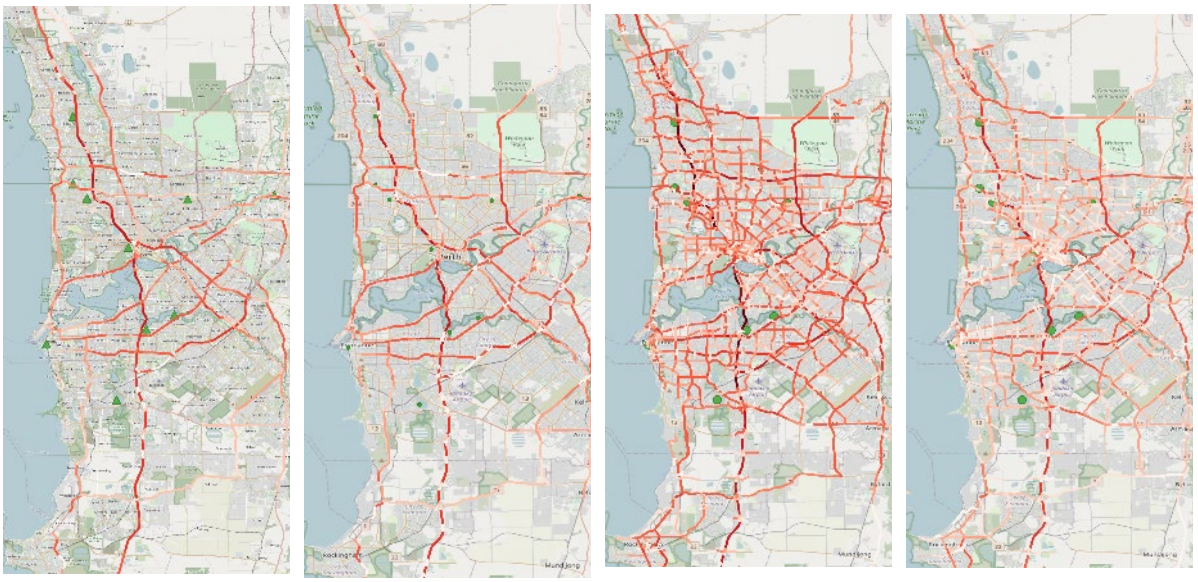
**10-11am (late morning) Aug**

2019 2020 2021 2022



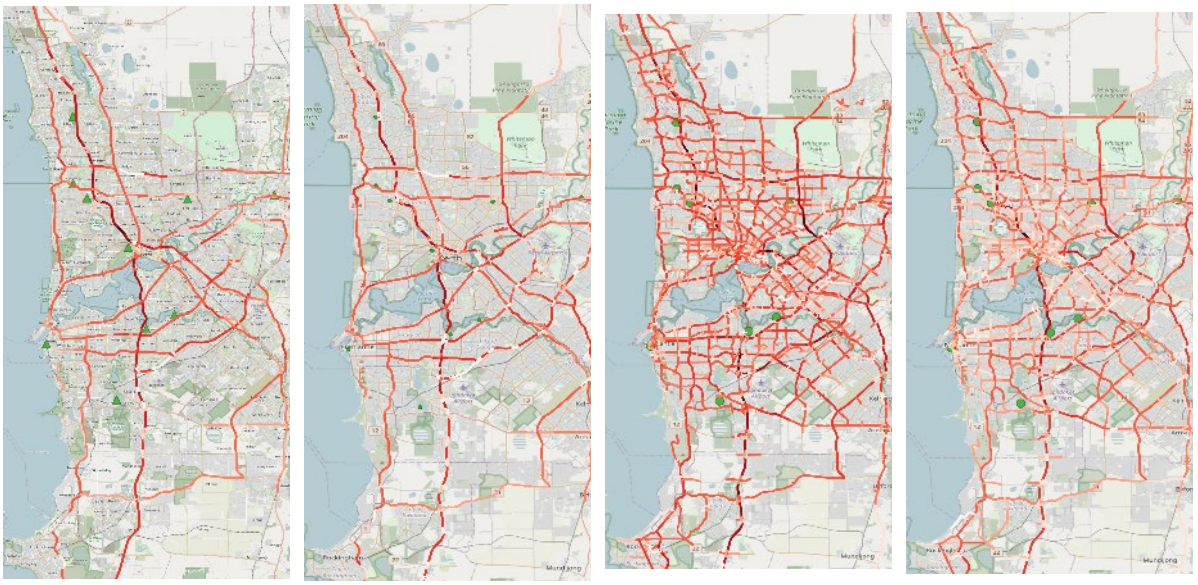
**12-2pm (afternoon peak) Aug**

2019 2020 2021 2022



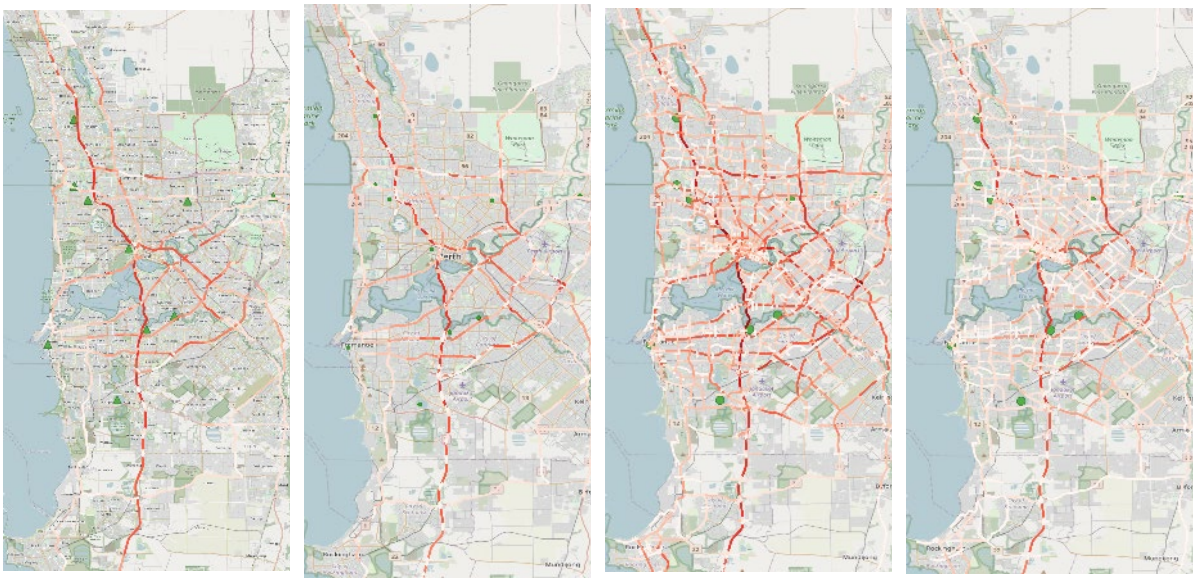
**3-6pm (evening peak) Aug**

2019 2020 2021 2022



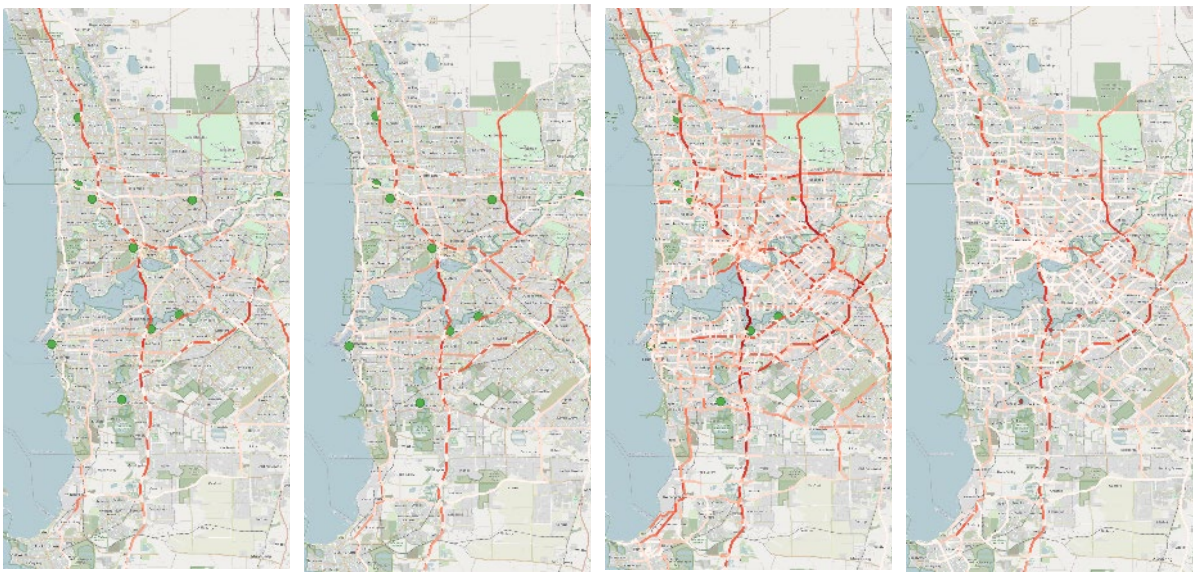
**7-12pm (late evening) Aug**

2019 2020 2021 2022



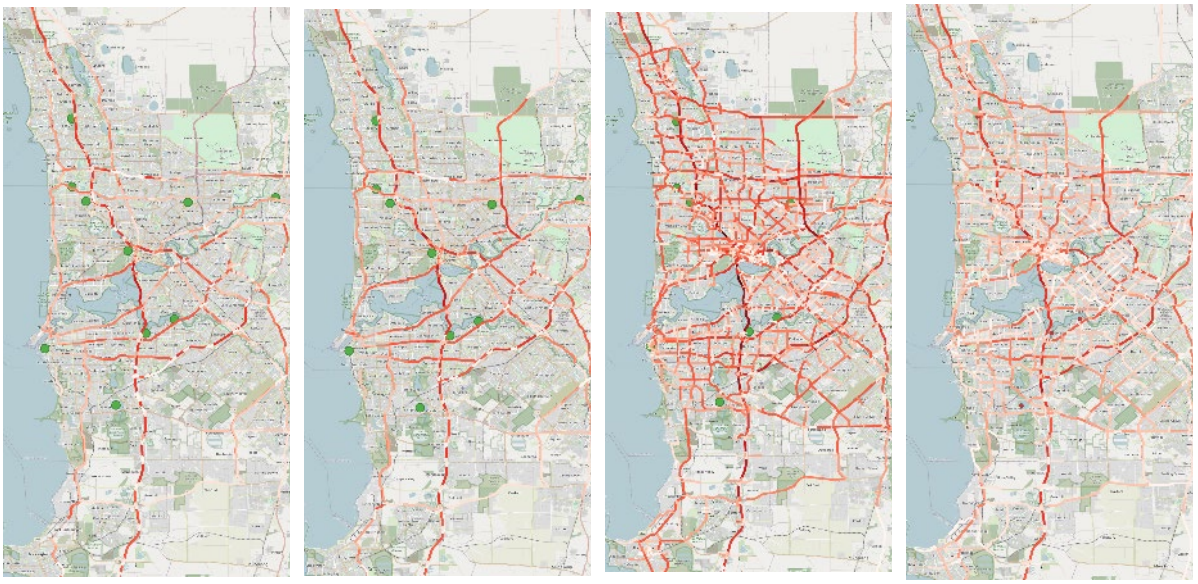
**0-6am (early morning) Oct**

2019 2020 2021 2022



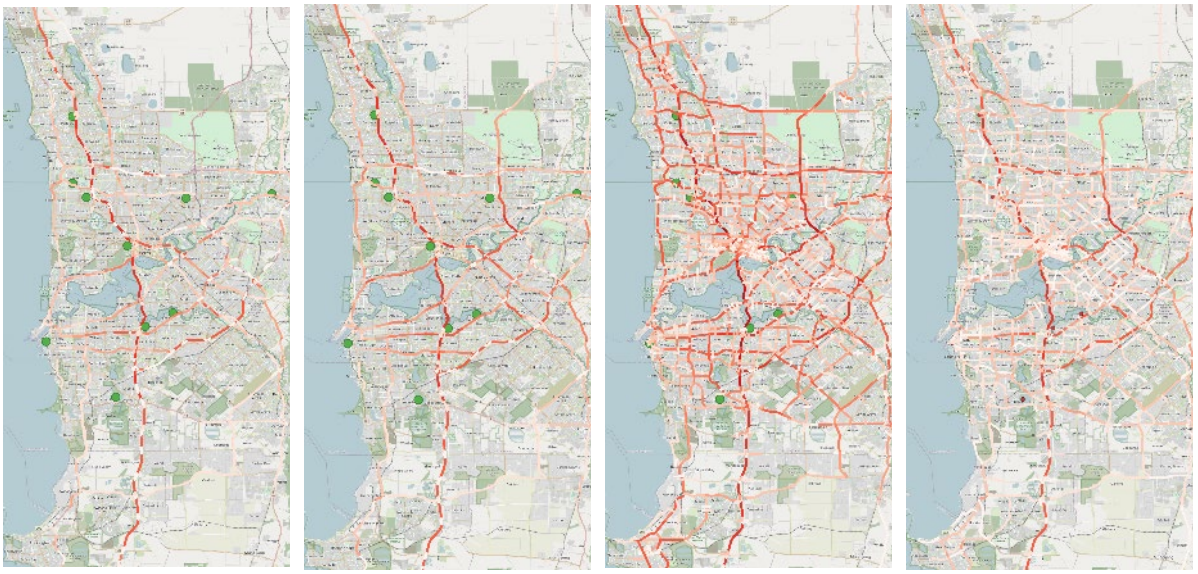
**7-9am (morning peak) Oct**

2019 2020 2021 2022



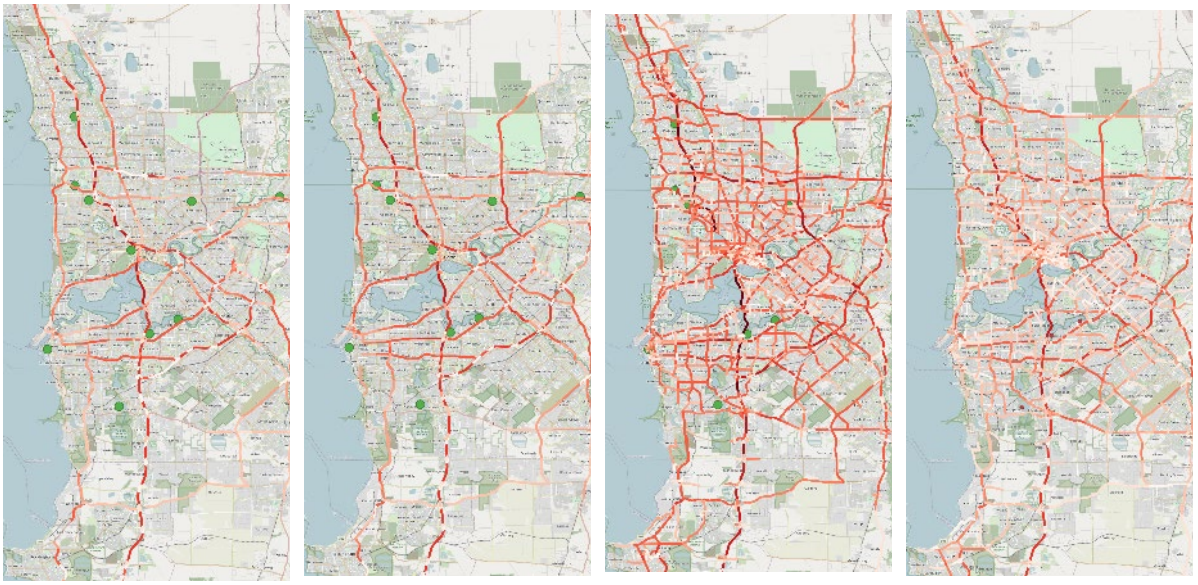
**10-11am (late morning) Oct**

2019 2020 2021 2022



**12-2pm (afternoon peak) Oct**

2019 2020 2021 2022



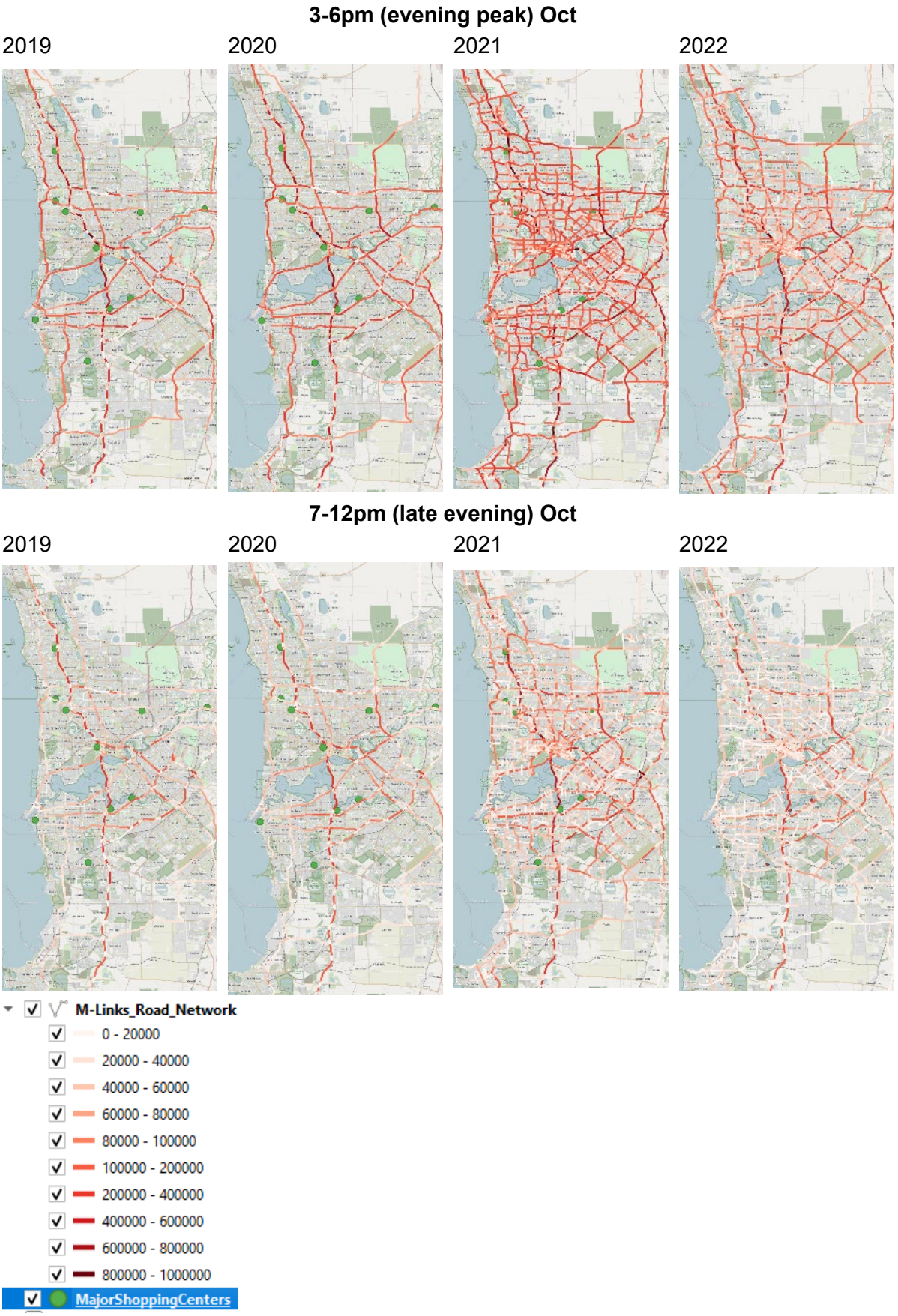



**Figure 7: Spatial variations traffic patterns in August and Octobers (2019,2020,2021,2022)**