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Lockdowns and Lags: Lessons from the effect of COVID-19 on the Perth transportation system

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Abstract

The COVID-19 pandemic has changed travel demand throughout the world as cities are locked down and new ways of working have been adopted to mitigate the effects of the pandemic. While Perth and Australia more generally have fared better than most places around the world, changes in mode choice and demand have been observed within Perth from traffic count and smartcard usage data. This has been especially notable during 'lockdown' periods where residents were required to stay home. More importantly, over the year since the pandemic has begun, the "between lockdown" periods offer unique insights into possible longer term effects which could be perpetuated into the future, with ongoing consequences for deferring or avoiding the need for transport system infrastructure. While previous studies have reported on overall changes in vehicle traffic and public transport volumes across cities as a whole, this study considers spatial trends for different parts of the city in order to differentiate changes in travel to and from the city centre from cross-city travel in inner and outer suburbs of differing types. This has been gleaned from various traffic counting sites throughout Perth alongside an analysis over time of the public transport smart card boardings and alightings between 'catchment areas' for various lines throughout Perth. Indications are that recovery is quicker for shorter lockdowns and to higher levels within inner-city areas with spatial differences suggesting changes in recovery depend also on socio-economic context.

1. Introduction

The COVID-19 pandemic has had a large impact on the way people move throughout the world; localised and wider-ranging mobility restrictions around the world have had an economic impact on far-away places such as Chile (Asahi et al. 2021) to here in Australia (Pham et al. 2021, Munawar et al. 2021, O'Sullivan, Rahamatbulla & Pawar, 2020). While the wider-ranging mobility restrictions such as those that stop international travel have had a devastating economic effect on international airlines (Pham et al. 2021), localised travel restrictions alongside anxieties surrounding the virus have caused changes in the way people use the transportation system, as evident in Sydney (Beck & Hensher 2020).

This paper aims to examine and quantify the effects of COVID-19 on the road and public transport network throughout Perth, Australia over the months since the pandemic began in March, 2020 (World Health Organization 2020) using quantitative data gathered from sensor systems throughout the city on the public transport and road networks. In particular, this paper examines 1) 'inter-lockdown' trends as proxies for longer term trend possibilities and 2) spatial differentiation of trends across the city. To achieve this, firstly similar existing work will be examined to determine gaps in knowledge alongside methodologies and data sources that can be adapted for this work. Next, the specific methodology utilized will be formulated and detailed before the results of applying the methodology are presented. These results are then discussed to determine the knowledge gained regarding the effect of COVID-19 on transport demand throughout Perth and how this demand changes over both space and time, before concluding remarks are presented.

2. Background

The effect of localised restrictions on the transport network has been studied in many cities throughout the world using a variety of methods; from online surveys containing behavioural questions and transport diaries asked throughout Australia (Beck & Hensher 2020) to the analysis of quantitative transport volumes by week and mode in Budapest, Hungary (De Vos 2020). In Columbia, congestion data has been gathered from government sources and analysed on a city level for various cities over time (Arellana, Márequez & Cantillo 2020) whereas smartcard data has been analysed over time in Santiago, Chile (Gramsch et al. 2020).

Another common set of sources used to enumerate the changes in travel demand have been the indexes published by Google and Apple that have compared throughout space the differences in requests made for transport information by mode within their mobile mapping applications (Falchetta & Noussan 2020). However, these sources are limited by their sample used for observation – in the case of Apple, this is of users of Apple Maps (hence users of Apple devices) who have made directions requests (Apple Inc. 2020) rather than the passive observation of travel patterns for all users. In the case of Google, data is aggregated from users of the 'Location History' feature (Google Inc. 2021a) which is an opt-in feature that can gather location data in the background on mobile devices (Google Inc. 2021b), however not much detail is made publicly available as to how this is undertaken, except that the data is anonymized.

Spatio-temporal analysis of transport data is a mature field with various transport modes, metrics, methodologies and levels of spatial detail explored (Wang & Cheng 2001, Bischoff and Maciejewski 2016). Transport demand is often modelled at a zone-based level using geographically weighted modelling techniques, as seen in Sydney (Tsai, Mulley & Clifton 2012) and Beijing (Liu et al. 2021). However, these modelling exercises aim to quantify the effect of various endogenic factors with respect to observed transport demand over time and space.

Often informing modelling exercises, is an understanding of how observed transport demand changes over both space and time. As stated by Profillidis and Botzoris (2018, p. 90), transport demand models are only useful in a limited range of circumstances where the assumptions underlying them are valid. This has been seen in Sydney where the changes in transport demand are examined and then connected to the effects this has on the cost to consumers from the COVID-19 pandemic (Hensher et al. 2021).

To understand the effects of the COVID-19 pandemic on consumers, the temporal aspect must first be enumerated. 'Lockdowns' are periods of enforced heavy movement restrictions, promulgated by governments to minimise the spread of COVID-19 (Brodeur et al. 2020). As a result of the COVID-19 pandemic, as of the authoring of this paper the Perth metropolitan area has been subject to three lockdowns:

- the longer first lockdown lasting approximately two months between 22 March 2020 when many indoor venues first closed nationally (Worthington 2020) and their limited reopening (at least in Western Australia) on 18 May 2020 (Laschon, Hamlyn & Manfield 2020);

- the second lockdown lasting five days in the Perth metropolitan and Peel regions between 1 February 2021 and 5 February 2021 (Laschon 2021) and;
- the third lockdown lasting three days in the Perth metropolitan and Peel regions between 24 April 2021 (Piesse & Bourke 2021) and 26 April 2021 (Warriner 2021).

While this paper was being written, Perth entered a fourth lockdown, currently slated to be between the dates of 29 June 2021 and 2 July 2021 inclusive (Government of Western Australia 2021). Due to the close time of this lockdown to the submission date, the effect of the fourth lockdown will be explored at a future time.

3. Methods

A spatio-temporal analysis was chosen to be undertaken as this allows for differences in vehicular traffic and public transport boarding volumes over both time and space to be analysed and investigated. The temporal aspect is important due to the continued run of lockdowns identified above; depending on the length of the lockdown, the extent of the lockdown and the time between lockdowns, different behaviour may be observed both during the lockdown or afterwards. The spatial aspect is also important due to the fact any trends observed which differ over space may warrant further investigation to discern the reasons for this difference throughout space, such as socio-demographic or other reasons.

For the purposes of this analysis, open data sources were chosen for use. Reasons for this included the rapid availability of the data as well as the ability for replication of the research. As such, open data sources were identified that provided vehicular traffic volumes as well as public transport patronage throughout Perth. Within Western Australia, Main Roads WA maintains a network of vehicular detection infrastructure. While different systems of different technologies are in place, some temporary and some permanent, the system of Network Performance Sites (NPS) provide the most temporally consistent data of the few systems which are publicly accessible.

NPS sites provide continuous vehicular volume and speed data when in service at fifteen-minute intervals, when in service, as seen through the IRIS data interface provided by Main Roads WA (2021a) which aggregates the data from this and other vehicular detection systems. It is possible the NPS system directly can provide more fine-grained data, however this is not available to users of the open data interface. The Main Roads WA (2021b) ‘trafficmap’ details the locations of NPS sites which is provided in Figure 3.1 below.

This data interface also provides information regarding the quality of the data provided; only data that is deemed ‘high quality’ was utilised in the analysis, with other data discarded and the time period linearly interpolated over. It is still noted that no warranty is provided on the data.

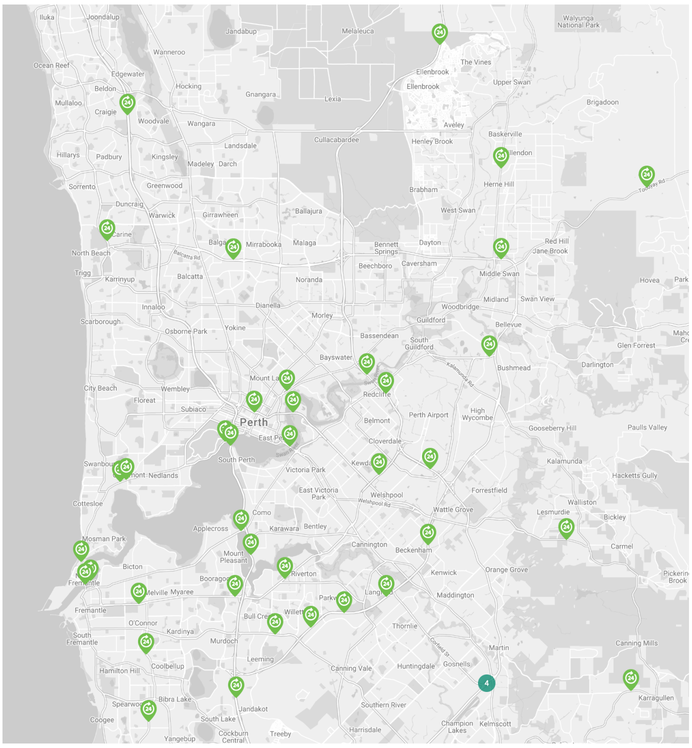

Figure 3.1 Location of Network Performance Sites (Main Roads WA 2021b)

As such, the quarter-hour measurements were retrieved for a selection of road links which were known to contain NPS sites, and the values summated for all-day, AM peak (7AM inclusive to 9AM exclusive) and PM peak (4:30PM inclusive to 6:30PM exclusive). Due to the time taken for the data interface to respond to a request, this was only completed for Wednesday each week as a representative day for the week. Wednesday was chosen to avoid the interference of public holidays at the ends of the week.

From this, graphs were generated showing the change in volume throughout time, with measurements starting from the first week of February in 2019 to compare a year before COVID with a year of COVID-influenced change. Two groups of NPS sites were analysed; as seen in Section 4 below which details the sites included there is a set of CBD ‘cordon’ sites surround the Perth CBD as well as a ‘suburban’ set of sites which shows a cross-section of the Perth suburbs, primarily within 30km of the CBD but covering all compass directions.

One non-NPS site was used for the Mitchell Freeway in the Perth CBD, however the data was still marked as ‘accurate’ and is assumed to be imputed from a wide range of nearby sensors, including NPS itself.

Data regarding the use of public transport was gathered from the Public Transport Authority (2021)’s web page named ‘Transport performance’, as this is the most up-to-date publicly accessible source of transport patronage for the Perth metropolitan area. This web page details total boardings for the entire Transperth system, each mode of travel (bus, train and ferry) alongside each of the five radial train lines (Armadale/Thornlie, Midland, Joondalup, Fremantle and Mandurah). This data consists of boardings via the SmartRider smart card ticket, alongside cash boardings which are modelled into the data due to their limitations.

While data was provided in a monthly level of aggregation, for comparison data was extracted from February 2019 onwards. This was graphed in a similar manner to the traffic data above for visual comparison. Two graphs were generated, based upon two groups: one with the total system boardings and modal boardings, the other with boardings for each train line.

Finally, an initial analysis of smartcard journeys (rather than boardings) was undertaken as a comparison from fifteen regions throughout Perth. These regions were generated on a postcode level, where a set of Voronoi polygons was drawn from each railway station over the Perth metropolitan area and aggregated per railway line. Next, the coverage of each postcode area by each of the railway line polygons was calculated, with the postcode allocated to the line with the highest coverage. The inner-city stations within and surrounding the CBD of Perth, McIver, Claisebrook and Elizabeth Quay were deemed their own line named ‘City Stations’. This is not ‘open data’ however was of interest for comparison so was also used.

It is worthwhile to understand the difference between a boarding and a journey. In this case, boarding is simply when a person enters a vehicle, whereas a journey captures the origin and destination of a person on the public transport who connects through multiple journeys, in concert with the fare rules. In this case, multiple trips (a boarding and consequent alighting) are combined into a journey if they occur within two hours for a journey up to four zones and within three hours for a journey that covers more than four zones. Transperth fare zones surround the Perth CBD in 8-10km radial bands for nine zones numbered 1 to 9.

Next, the OpenRouteService (2020) system was used to calculate the road distance between the centroids of each suburb and the Perth CBD. Distances less than or equal to 15 kilometres were deemed ‘Inner’ postcodes, greater than 15 kilometres and less than 30 kilometres were deemed ‘Middle’ postcodes and distances greater than 30 kilometres were ‘Outer’ postcodes.

This yielded the following fifteen regions: Inner Armadale, Inner City Stations, Inner Fremantle, Inner Joondalup, Inner Mandurah, Inner Midland, Middle Armadale, Middle Fremantle, Middle Joondalup, Middle Mandurah, Middle Midland, Outer Armadale, Outer Joondalup, Outer Mandurah and Outer Midland. No postcode that was closer to the Fremantle Line than any other was over 30 kilometres from Perth, likely due to the short length of the Fremantle Line itself.

The transactional data was grouped and aggregated per origin and destination suburb, passenger type, time-of-day and day-of-week for each month. From this, data was selected for the whole of the day travelling towards the Inner City Stations and similarly graphed as above.

The Python programming language alongside a large group of frameworks was used for all of the above analysis, including the Matplotlib library to generate the graphs, Requests to fetch the data from the PTA website and Main Roads traffic data interface, Pandas and Geopandas for spatial and statistical analysis and related tasks as well as Geovoronoi to generate the Voronoi polygons. This is an open-source programming language alongside freely available and open-source frameworks. Each analysis was written as a script to ensure repeatability and to update the results as new data became available.

4. Results

After gathering and filtering the data for traffic volumes and public transport boardings using the above methodology, various graphs were produced to understand the trends over the period of 2019 onwards, to first provide an understanding of a full year and its seasonal effects before the COVID-19 pandemic as well as the effects during the pandemic in 2020 and 2021. The graphs below show a wide range of data on a single set of axes and hence require some thought before interpretation. However, interpretation will be undertaken in the fifth section of this article. In all cases, 100% relative volume is measured at the first measurement in February 2019. Grey areas show the approximate period of the first two lockdowns; only the first is shown on the monthly data due to the measurement frequency whereas the reason also why the third is not shown is due to the data not yet being available.

Figure 4.1 and 4.2 below show the relative traffic for each of the 'CBD cordon' NPS sites below for the AM Peak period and all-day period respectively. A relative scale has been used to examine the effect individually on each of the road segments. A ‘total' data series is also displayed that is determined by summating the volume of each of the segments first to provide a wider ranging understanding of the network functioning together as a whole.

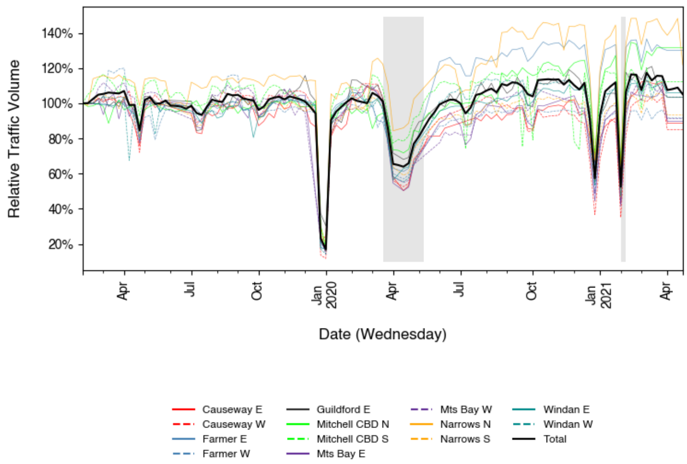

Figure 4.1 Relative traffic volumes at CBD cordon sites (AM Peak).

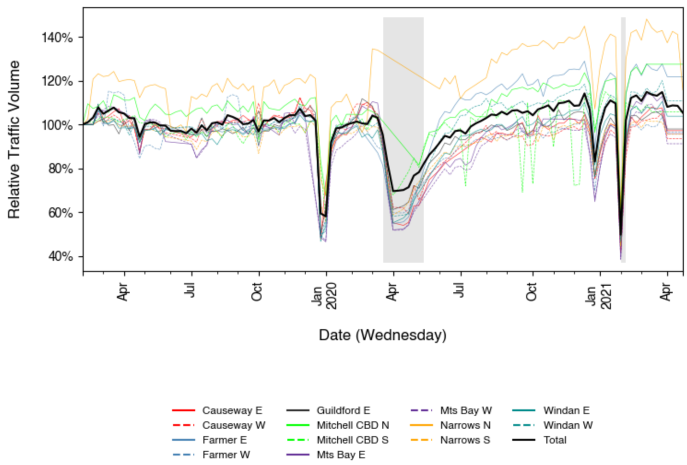

Figure 4.2 Relative traffic volumes at CBD cordon sites (All Day).

This can be compared with Figures 4.3 and 4.4 below, which show the relative traffic volumes at suburban traffic counting sites throughout Perth for the AM Peak period and all-day respectively. The same scaling has been applied and a ‘total' data series also generated.

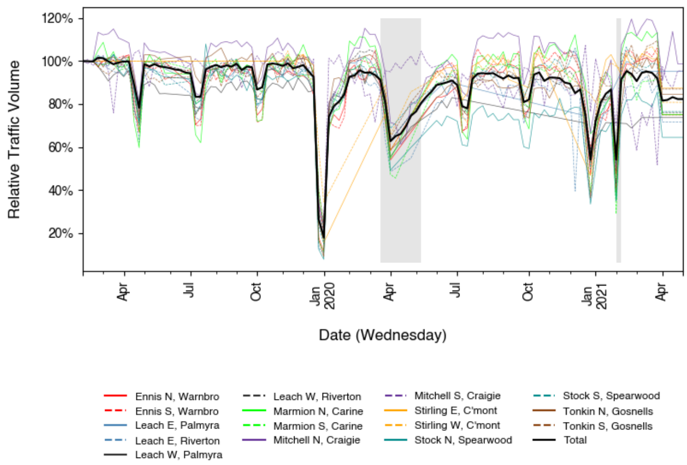

Figure 4.3 Relative traffic volumes at suburban sites (AM Peak).

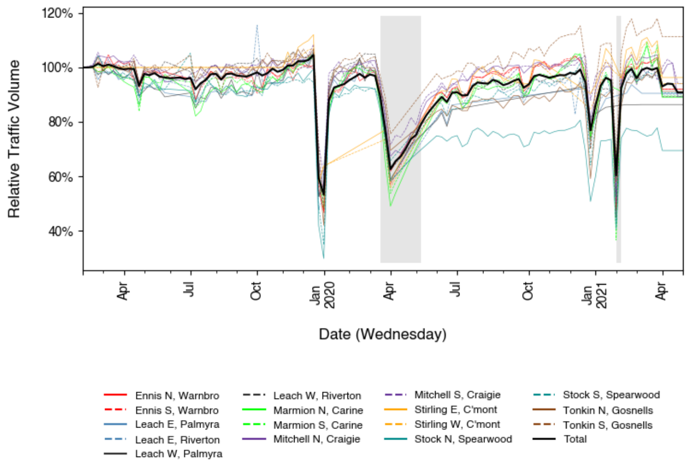

Figure 4.4 Relative traffic volumes at suburban sites (All Day).

Figures 4.5 and 4.6 provide a monthly view of public transport boardings (cash and smartcard) throughout the Transperth network of metropolitan Perth, with the first detailing the boardings by mode and the second by train line. This data is recorded for a full month rather than a sampled Wednesday but however is presented in relative form for comparison with the above traffic data, noting that a direct comparison is however not recommended due to the differences between the coverage and utilisation of the system, amongst other matters.

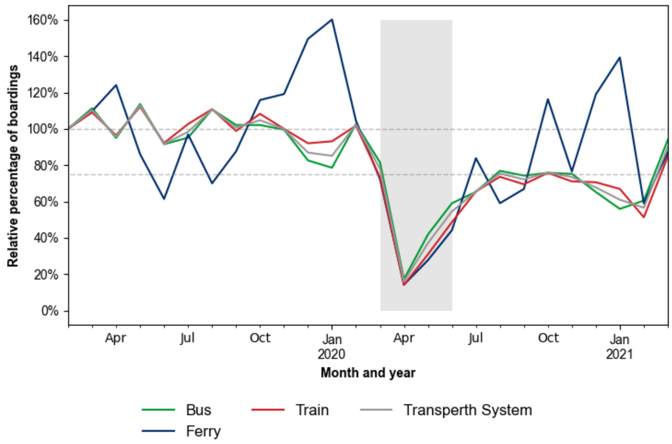

Figure 4.5 Relative public transport boardings by mode.

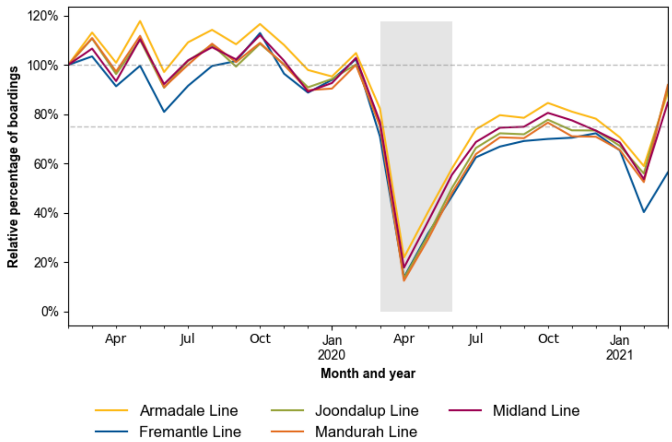

Figure 4.6 Relative public transport boardings by train line.

Finally, Figure 4.7 below delves deeper into what is seen in Figures 4.5 and 4.6 above, showing the journeys (rather than boardings) between the above described 'fifteen areas' and the Perth CBD area per month (during the whole day) over the same period, however only for the smartcard transactions.

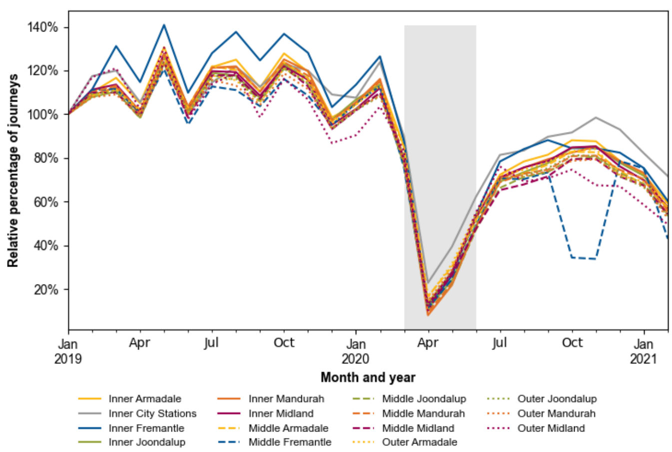

Figure 4.7 Relative public transport journeys to Perth CBD for the 'fifteen areas'.

The meaning and interpretation of the above graphs will be discussed in the section below.

5. Discussion

Overall, the data from the CBD cordon sites during the AM peak shows that the demand stayed relatively constant around the 100% mark during the 2019 year, when looking at the 'Total', with small dips around the school holiday periods. There is a notable drop during the Christmas/New Year period of 2019 before gains above the 100% mark during the first quarter of 2020. Once the first lockdown starts, however, the relative volume decreases to around 70% of the relative volume, and appears to follow a log-like recovery (ignoring school holidays) for the period of time until Christmas/New Year in 2020. This drop is also to about the 70% level; however recovers quickly in the new year. It is expected the cause of lower traffic over the Christmas-New Year period is changes in travel patterns; it is noted by the Australian Transport Safety Bureau (2006) that road journeys in the Christmas holiday season are associated with greater passenger numbers, longer journey distances and greater involvement of rural environments, suggesting that journeys in this part of the year move from work-related journeys to those involving recreation or visiting friends and relatives.

The short lockdown in February also has a minimal effect; the total is slightly lower at 60%, however quickly recovers to above the 100% mark shortly thereafter. It is noted that some roads have recovered to a greater volume than 2019 whereas others fall slightly below the point. A similar pattern is noted for the all-day data; however the February lockdown is more pronounced, with a drop to approximately 45% of the reference level. This indicates that trips outside AM peak are more effected than those within it. In both the all-day and AM peak cases, the outperformance of the Narrows Bridge (northbound) is noted; the bridge is the major crossing between the northern and southern Perth. The Farmer Freeway also outperforms whereas the Causeway underperforms, both crossings serving the eastern side of the Perth CBD, indicating traffic may have moved from one to the other.

The traffic volumes throughout suburban Perth tell a similar but slightly different story. In the AM peak, ignoring the troughs of the school holidays, a slight decrease can be seen over the year. Total relative traffic drops to approximately 20% of the reference level over Christmas/New Year 2019, before a slow recovery in January and a larger recovery back to almost the reference level in February, assumed to be due to school trips. This already starts to fall before the first lockdown which bottoms out at 65% of the reference level, recovering to an almost steady state over the months until July in a somewhat linear fashion. From here, there is a slight rise and fall in traffic numbers (ignoring school holidays) over the year until Christmas/New Year 2020, staying relatively constant with peaks directly after the holidays. A drop to approximately 55% of the reference level is then seen over Christmas/New year, a recovery to the approximately 80% level over January before the lockdown in February sees a drop to the approximately 50% level before a recovery to the approximately 90% level thereafter. The effect of the third lockdown at the beginning of April can also be seen, dropping to the approximately 75% level. Sites such as the Mitchell Freeway northbound in the northern suburbs can be seen to outperform, however the corresponding southbound site underperforms. The Stock Road northbound site in the industrial area of Spearwood is also noted to underperform.

For the total, the all-day data shows a less pronounced dip over the Christmas/New Year 2019 period as well as a less severe dip in Christmas/New Year 2020. The recovery can be seen in two parts, although the first being a sharper linear increase than that of the second which is a slower linear increase. Similar patterns can then be seen thereafter. Notable patterns can be seen on the northbound and southbound counters of the Tonkin Highway in Gosnells over 2020 as well as the same marked decrease on Stock Road northbound.

Public transport tells a different story, with both bus and train modes staying relatively constant over 2019 (excluding the Christmas/New Year period) and then dipping to approximately 20% of usual boardings over the first lockdown and following an approximately log-shaped recovery until August 2020. This then starts to fall towards the Christmas/New Year period in 2020 before a rapid recovery in 2021. There seems to be no effect of the smaller lockdown over February due to its short length within the longer period of the month. A similar pattern is shown when investigating boardings per line; however the Armadale and Midland lines outperform the Joondalup, Fremantle and Mandurah lines, which indicates there may be a socio-economic factor at play as these areas are of a higher socio-economic index. It is noted major works were undertaken on the Fremantle Line in February 2021 which is likely to have impacted patronage.

When looking at the public transport network data from a journey-centric point of view and splitting out the network by distance from the CBD, a similar pattern occurs, however it is noted that generally inner sections are performing better than the middle and other sections, with the middle sections performing worst. Notably, the middle-Fremantle area is affected greatly in the later part of 2020 whereas the inner section is not. The effect of the works in February 2021 is also more pronounced in the middle rather than outer areas. As such, the recovery is more pronounced in inner areas rather than middle and outer areas.

As it can be seen, the trends for recovery differ between the different lockdowns, with the first longer lockdown taking longer for traffic and patronage to recover compared to the shorter lockdowns thereafter where the recovery was almost instant. Traffic differences spatially throughout the city are also observed, with higher recovery levels in inner-city areas, changes in traffic patterns (from one road to another) and roads commonly used for industrial uses continuing to be affected. Suburban areas are more affected within the AM peak period than outside said period. Similar effects are seen with public transport, where inner-city and higher socio-economic areas are recovering before others.

6. Conclusion

Like almost all cities throughout the world, the COVID-19 pandemic has had a great effect on many aspects of life within Perth. However, due to the comparative lack of lockdowns and restrictions compared to other cities worldwide, the recovery in traffic and patronage in Perth during between lockdown periods can be used as a case study to perhaps understand the future recovery of both public transport and private vehicle traffic in other cities throughout the world.

To satisfy the aims of understanding differences in traffic and public transport patronage between lockdowns and over space throughout Perth, analysis was undertaken of both road traffic volumes and public transport patronage to understand how these modes have fared during the COVID-19 pandemic and the issues that the scale of recovery of each may face in the future. Overall, it can be seen that in many cases (such as the CBD cordons) road traffic volumes have increased in the between-lockdown periods to between 5 and 10 percent over the historical norm of the previous year (2019), whereas public transport utilisation has only returned to approximately 75%. Indications are that recovery is quicker for shorter lockdowns with higher recovery levels occurring for inner-city areas. Spatial differences suggest changes in recovery depend also on socio-economic context.

Policy makers should take note that even in a relatively COVID-restriction free environment that there can still be big changes to demand and hence will need to plan accordingly to maximise the use of existing and future investment in transport infrastructure through enticing public transport usage while also ensuring a comparative level of comfort to road journeys as pre-COVID. The full effect of working-from-home in the long term from COVID is yet to be seen, however should also be considered within decision making.

The trends of reduced public transport patronage and increased private vehicle utilisation can cause issue with the utilisation of existing infrastructure, leading to congested roads and under-utilised public transport. While research earlier in the pandemic has suggested that the 'fear factor' of COVID may have driven people away from the public transport network (Reed & Biermann 2020), it is possible that changed working patterns ('working from home') and newly formed habits of utilising private vehicles are responsible for these changes. At least within the Perth context, these have been shown to have somewhat 'stuck'. As such, authorities must continue to encourage commuters to use public transport modes over private vehicles to entice passengers back (where travel has moved to private vehicle) as well as new passengers to these modes. This may be, as suggested by the Victoria Transport Policy Institute (2018) through tweaks to services to make them better meet demand more efficiently, new methods and techniques of ticketing (e.g. greater discounts for more journeys taken in a week or month), disincentives for other modes (such as reallocating road space to public transport) or other techniques not mentioned here. This will not only improve the experience for road-based transport users but will also improve the utilisation of existing and forthcoming physical infrastructure, the development of which has been accelerated as part of COVID recovery.

The authors are continuing to analyse and gather data regarding public transport and road traffic demand throughout Perth as the COVID pandemic ideally moves towards an end or steady-state to further understand the dynamics that the COVID pandemic has had and may continue to have afterwards. This includes current work being undertaken by the authors and others to understand the effects of working from home on the transport system throughout Perth on a finer scale with additional factors considered as part of modelling exercises.

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