"I saw a fox in Melbourne CBD": Urban travel behaviour changes during COVID-19 and beyond

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A B S T R A C T

An unexpected outcome of the COVID-19 pandemic were the dramatic travel behaviour changes experienced in cities worldwide, which, could result in more sustainable transport systems. Consequently, there is a need for longer-term post-pandemic travel behaviour change research. This study aimed to investigate city-level travel behaviour changes during and post-pandemic. To our knowledge, this is the first qualitative study exploring the permanency of COVID-19 travel behaviour changes. This study involved a literature review of 41 studies and in-depth interviews with 19 transport stakeholders in metropolitan Melbourne, Australia. Melbourne is a valuable study area, given that it was the most locked-down city globally. Overall, the results of this study suggest that post-pandemic travel behaviour will be different to pre-pandemic, with working from home (WFH) an integral influence on travel behaviour. In addition, several overarching travel behaviour changes were identified: WFH significantly increased during the pandemic and is anticipated to continue post-pandemic. Both public transport and private motor vehicle (PMV) trips decreased during lockdowns; while PMV rebounded quickly, public transport remained low, and a long recovery is expected. Active transport (cycling and walking) increased during the pandemic and appear likely to endure. Finally, while shared travel modes have received less attention, modal variance is expected in the future. This study has made several key contributions. It consolidated our understanding of the wide range of urban travel behaviour changes experienced during and anticipated post-COVID-19. Secondly, it synthesised current knowledge of recent post-COVID-19 travel behaviour change research. Thirdly, this study demonstrated that complementary qualitative studies strengthen transport research by unearthing new insight into the reasons underpinning travel behaviours, which could be vital for developing solutions. Furthermore, this study identified critical future research topics. Given that most countries are learning to live with the virus, it is an opportune time to investigate whether these intended travel behaviours have endured.

1. Introduction

"I saw a fox in Melbourne CBD a couple of days ago…We're in lockdown. There's no one in the streets. You find the wildlife coming back into the streets. It's amazing." (Private Sector#2).

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Road transport accounts for approximately 70 per cent of the transport sector's carbon dioxide emissions (aviation: 12%; shipping: 11%; rail: 1%) (Intergovernmental Panel on Climate Change, 2022). As such, encouraging more sustainable road travel behaviours may benefit the sustainability of the entire transport sector (Santos, de Abreu, de Assis, Ribeiro, & Ribeiro, 2021).

An unexpected outcome of the COVID-19 pandemic was the most radical transport disruption and travel behaviour changes observed in recent history (Delbosc, Currie, Jain, & Aston, 2022). This included decreased private motor vehicle (PMV) use, increased active travel and working from home (WFH). If these travel behaviour changes endure, more sustainable road transport systems could evolve (Büchel, Marra, & Corman, 2022; Zhang & Zhang, 2021). In particular, changes in travel behaviour observed during COVID-19 revealed the significant impact WFH could have on road transport systems by reducing commuter travel (Balbontin et al., 2021). A recent study noted that if WFH continues, the transport sector's greenhouse gas emissions could be significantly reduced, with transport savings outweighing residential energy costs (Navaratnam, Jayalath, & Aye, 2022).

Consequently, researchers predict that travel behaviours, especially work-related travel, will be different and potentially more sustainable post-COVID-19 (Currie, Jain, & Aston, 2021; Stefaniec, Brazil, Whitney, & Caulfield, 2022; Zhang & Zhang, 2021). If achieved, these changes will significantly impact transport and land-use planning (Stefaniec et al., 2022). However, there is still uncertainty about the nature and permanency of these changes. For example, there are rebound concerns that even less sustainable travel behaviours will be adopted post-COVID-19 (Beck, Hensher, & Wei, 2020). Consequently, the critical next step is longer-term post-COVID-19 travel behaviour change research so that the benefits of the disruption can be encouraged beyond the pandemic (Currie et al., 2021). This study aimed to contribute to this next phase of post-COVID-19 travel research.

Travel behaviour change interventions can be classified as either planned, enforced interventions or due to naturalistic events (e.g., events, natural disasters, and pandemics). Pre-COVID-19, research was dominated by enforced travel behaviour change interventions (Pawluk De-Toledo, O'Hern, & Koppel, 2022). However, several seminal studies have specifically explored the impact of naturalistic events on changing travel behaviour. For example, Professor Greg Marsden has been pivotal in the field with his studies exploring travel behaviour change associated with the 2012 London Olympics (Parkes, Jopson, & Marsden, 2016), environmental events (e.g., snow and ice, flooding events) (Marsden et al., 2020) and the COVID-19 pandemic (Anable, Brown, Docherty, & Marsden, 2022; Marsden & Docherty, 2021).

While travel behaviour change during COVID-19 is a rapidly growing research field, there is limited research on the permanency of behaviour changes (Delbosc et al., 2022). Indeed, long-term behaviour change research in transport was limited even pre-COVID-19, with most post-intervention studies conducted within weeks of implementation (Pawluk De-Toledo et al., 2022). Consequently, this study aimed to contribute to the topic of longer-term behaviour change and the critical next phase of COVID-19 travel research by investigating the permanency of travel behaviour changes beyond the pandemic.

2. Aims

Given the reliance on quantitative data to study travel behaviour change due to COVID-19, the field could benefit from complementary qualitative research. Consequently, this study aimed to broaden the depth of understanding by adding a qualitative perspective. Specifically, this study aimed to investigate:

1. the main urban travel behaviour changes that occurred during the COVID-19 pandemic; and
2. the permanency of these travel behaviour changes.

3. Method

This study used a mixed-methods approach to address the research aims. Two complementary research methods were employed to strengthen knowledge: a thematic narrative literature review and in-depth interviews. The literature review aimed to synthesise learnings emerging in from the peer-reviewed literature. The in-depth interviews aimed to develop knowledge by focusing on the case study city of Melbourne, Australia. The research methods for both study components are detailed in the following sections.

3.1. Literature review

3.1.1. Data source
To identify the post-COVID-19 travel behaviour change studies, a search was conducted of the Web of Science (WoS) core collection academic database (Clarivate Analytics, 2020). The search query was adapted from Pawluk De-Toledo et al. (2022) to include only post-COVID-19 research. The Advanced Search function was used, with the Topic term (TS) and the WoS category (WC) Transportation as the search terms. The final search term was "(TS=("behavio* change" AND "post-COVID-19" OR "post-pandemic" OR "post COVID-19" OR "post pandemic")) AND WC=(Transportation)".

The search was conducted on 30 September 2022. The abstracts were screened for eligibility and were included if the study examined anticipated post-COVID-19 urban travel behaviours. A total of 41 peer-reviewed original studies were included in this study (Appendix 1). Primary bibliometric data was exported from WoS including: the author's name, article name, and journal title (see Appendix 1) and the full-texts were obtained for data analysis.

3.1.2. Data analysis
To address the research aims, a full-text thematic narrative review was conducted on each of the included journal articles. The first

step involved extracting study and behaviour related data and tabulating the results in a matrix including: date published online, behaviour studied, study location, study country, research method, and the date conducted (Appendices 1 and 2). The results data in each journal article was coded by timeframe (during COVID-19 or post-COVID-19) and by travel mode or behaviour. Then the data was thematically analysed (Braun & Clarke, 2006; Saldana, 2016), whereby results were coded into themes that inductively emerged. Finally, the themes within each travel mode and behaviour code were separately reviewed, and similar themes were synthesised, and themes were refined.

3.2. In-depth interviews

In-depth interviews were conducted to inductively develop new knowledge. The interview participants were transport stakeholders in metropolitan Melbourne, Australia. Melbourne is an important and novel study area for COVID-19-related research, given that it was the most locked-down city in the world (Boaz, 2021).

3.2.1. Interview participants

In line with previous transport stakeholder studies (Edge, Goodfield, & Dean, 2020; Moradi & Vagnoni, 2018; Steurer & Bonilla, 2016), diverse participants were sought (Ritchie & Lewis, 2003; Robson, 2011). Three stakeholder groups were developed: public, private, and civil society (Steurer & Bonilla, 2016). Purposive quota sampling was applied, aiming for six participants within each group (Robson, 2011). A quota of two women per group was also included, because previous studies have reported different gender-based experiences during the COVID-19 pandemic (Feng & Savani, 2020; Muric, Lerman, & Ferrara, 2021; Yaish, Mandel, & Kristal, 2021; Yavorsky, Qian, & Sargent, 2021). The research team's knowledge of the Melbourne transport system meant a diverse range of key transport organisations were represented. In total, 19 interviews were conducted (including seven with women), which is similar to previous transport stakeholder interview studies (Edge et al., 2020; Moradi & Vagnoni, 2018; Steurer & Bonilla, 2016). The final sample of participants by stakeholder groups included: Public sector (eight participants from the Victorian Public Service, local council and councillor); Private sector (five participants from large organisations, transport company and consultant); and Civil society (six participants from academia, union, NGO/association).

3.2.2. Interview procedure

The interviews were conducted between 14 May and 10 August 2021 via Zoom videoconference. The study was conducted while the city was open and during the early weeks of the city's longest lockdown (Boaz, 2021). The interviews ran for approximately one hour, with participants consenting to have their interview recorded and transcribed. Participants were not incentivised to participate in the interviews. The University Human Research Ethics Committee approved the study.

The interview involved a series of COVID-19, future travel behaviour and WFH questions focusing on metropolitan Melbourne, Australia. Participants were asked to provide their general thoughts on travel behaviour changes. Interview data from two specific interview questions were analysed to address the study aims:

Aim 1: Travel behaviour changes during COVID-19 was addressed by interview question 'What has been the biggest change in travel behaviour since the first lockdown in Melbourne in March 2020?'.

Aim 2: Permanency of travel behaviour changes was examined by interview question 'Do you think these travel behaviours will change in the next few years post-COVID-19? Why/Why not?'.

3.2.3. Interview data analysis

The transcribed interviews were coded with NVivo (version 1.3). The transcripts were coded by the first author and the process was based on the approach developed by Braun and Clarke (2006) and coding procedures by Saldana (2016):

1. All interview transcripts were coded by question.
2. Interview data for the two questions were extracted for analysis.
3. Data for each question was separately analysed line by line.
4. Data was classified into the overarching travel behaviour codes that emerged from the data.
5. Data in each travel behaviour code was thematically analysed by synthesising responses and inductively developing themes that emerged from the data.
6. Themes were labelled and refined by reviewing the themes in comparison to the overall analysis and other related themes.

4. Results

The results from the literature review and in-depth interviews will be presented separately in the following sections and compared in the discussion section.

4.1. Literature review

The results of the literature review are presented in two sections. Firstly, we describe the characteristics of the 41 included journal articles. Secondly, the travel behaviour change results during and post-COVID-19 are presented from the content analysis of the full-

text reviews.

A total of 41 peer-reviewed manuscripts were included in this study. The earliest studies to explore post-COVID-19 travel behaviour were published in August 2020, just five months after the pandemic was declared (Beck et al., 2020; Beck & Hensher, 2020) (see Appendix 1 for the complete list). Most studies investigating post-COVID-19 were published in 2021 (the number of peer-reviewed articles is represented by n: n = 23) and 2022 (n = 16 as of 30 September 2022) (see Appendix 2). All the studies were quantitative, mostly self-reported single-wave traveller surveys of the working-age population, distributed online, running between one week and six months, although most commonly one month. Convenience sampling was the primary recruitment technique using a range of online and social media channels. Most studies focused on the city (n = 16) or national level (n = 15), and Australia was the most studied country, followed by India. Nearly all the studies used stated preferences of future travel intentions, given the ongoing nature of the pandemic. However, two studies analysed periods between lockdowns as a proxy for post-pandemic behaviour (Khadem Sameni, Barzegar Tilenoie, & Dini, 2021; Luan, Yang, Jiang, Zhou, & Meng, 2022).

The main behaviours studied were WFH (n = 18) and public transit (n = 10). The studies focused on four main topics including:

1. During and post-COVID-19 travel behaviour changes.
2. Analysis of factors influencing the behaviour, including a wide range of socio-demographic characteristics (age, gender, employment, educational attainment, household or personal income, residential location, driver's license, PMV ownership and access, bicycle ownership, household size, number of children, marital status), travel behaviour, attitudinal and environmental concerns, and built environment characteristics.
3. Specific segments (e.g., university staff and students (Bagdatli & Ipek, 2022; Ceccato, Baldassa, Rossi, & Gastaldi, 2022; Tsavdari, Klimi, Georgiadis, Fountas, & Basbas, 2022), gender differences (Nguyen & Armoogum, 2021), people that WFH differing amounts (Mohammadi et al., 2022; Nguyen, 2021; Nguyen & Armoogum, 2021; Olde Kalter, Geurs, & Wismans, 2021); experts including transport agencies, government officials, university researchers, NGO practitioners and private consultants (Behrens & Newlands, 2022; Nelson & Caulfield, 2022; Zhang, Hayashi, & Frank, 2021)).
4. Developing future scenarios or models (Carrese et al., 2021; Zhang & Zhang, 2021).

Seven overriding urban travel behaviours emerged from the literature review and can be summarised as follows:

1. WFH increased and was anticipated to be sustained post-pandemic,
2. Travel patterns-changed, mainly there was less travel,
3. Public transport use decreased, and a long recovery was anticipated,
4. PMV use decreased and quickly rebounded, although there are conflicting views about PMVs post-pandemic,
5. Bicycling increased and is expected to be at higher levels post-pandemic compared to pre-pandemic,
6. Walking increased and is expected to be at higher levels post-pandemic, and
7. Varied mode share between shared modes is anticipated.

The seven overriding travel behaviours and their associated behaviour changes during and anticipated post-COVID-19 are presented in the following sub-sections.

4.1.1. WFH

During the pandemic, WFH significantly increased compared to pre-pandemic (Balbontin et al., 2021; Rahman Fatmi, Mehadil Orvin, & Elizabeth Thirkell, 2022). WFH increased during lockdowns and when WFH was no longer mandated (Ceccato et al., 2022; (Nayak & Pandit, 2021)). Greater levels of WFH resulted in overall trip reduction during the pandemic (Behrens & Newlands, 2022).

Post-COVID-19, workers have a strong desire to continue to WFH (Balbontin et al., 2021; Beck et al., 2020; Beck & Hensher, 2021; Ceccato et al., 2022; Kogus et al., 2022; Olde Kalter et al., 2021; Rahman Fatmi et al., 2022; Stefaniec et al., 2022; Zhang et al., 2021). Indeed, frequency of WFH post-pandemic is anticipated to be significantly more than pre-COVID-19 (Currie et al., 2021; Jain, Currie, & Aston, 2022). However, the amount of WFH post-COVID-19 is expected to be lower than during the pandemic (Beck & Hensher, 2020; Delbosc et al., 2022).

It is unclear what the frequency of WFH will be post-pandemic, although several days a week is most preferred (Balbontin et al., 2021; (Nayak & Pandit, 2021); Rahman Fatmi et al., 2022), especially Mondays and Fridays (Stefaniec et al., 2022). Also, socio-demographic (e.g., age, gender and income) WFH differences have been identified (Balbontin et al., 2021; Beck & Hensher, 2020, 2021; Hensher, Beck, & Wei, 2021; Mohammadi et al., 2022; Nguyen & Armoogum, 2021). Employers, available technology, length of exposure to WFH, and commute distance have all been identified as key influencing factors on WFH (Olde Kalter et al., 2021).

WFH, in combination with online shopping and greater bicycle mode share, is anticipated to reduce energy consumption and emissions, however the extent depends on the level of PMV mode share (Zhang & Zhang, 2021). Studies have found that WFH would result in a reduction in work-related (especially commuter) trips (Awad-Núñez, Julio, Gomez, Moya-Gómez, & González, 2021; Ceccato et al., 2022; Currie et al., 2021); nevertheless, a net increase in PMV trips is anticipated (Currie et al., 2021). Furthermore, WFH could also lead to an increase in PMV mode share compared to the pre-COVID-19 period (Ceccato et al., 2022). Alternatively, Hensher and colleagues (2021) found that if WFH decreases, commuter trips by PMV and public transport increase exponentially.

4.1.2. Travel patterns

During the pandemic, overall trips decreased due to lockdowns, restrictions, greater WFH, and less economic activity of lower

income groups (Behrens & Newlands, 2022). Post-pandemic, a decrease is expected in trip numbers and distance, especially for public transport trips (Christidis, Christodoulou, Navajas-Cawood, & Ciuffo, 2021). However, different trip frequencies are anticipated depending on trip purpose, for example fewer trips are expected for work commute and education (Awad-Núñez et al., 2021). Indeed, more intracity and intercity trips will transition to online (Zhang et al., 2021).

However, if the share of WFH decreases significantly, exponentially more trips could be made (Hensher et al., 2021). Furthermore, changes to trip distribution will depend on land use and transport changes (Behrens & Newlands, 2022). There is uncertainty about transport service viability, especially in peripheral areas, and challenges that economic downturns could pose (Behrens & Newlands, 2022; Christidis et al., 2021). Also, perceptions of risk could influence mode choices in the future (Christidis et al., 2021).

4.1.3. Public transport

Several studies identified that there was a significant decrease in the number of public transport trips throughout the pandemic (Carrese et al., 2021; Ceccato et al., 2022; Elias & Zatmeh-Kanj, 2021; Hsieh & Hsia, 2022; (Nayak & Pandit, 2021); Tsavdari et al., 2022). Furthermore, it is estimated that public transport will take as long as seven years to recover to pre-pandemic levels (Currie et al., 2021). Studies have reported that cities' major travel mode shift was away from public transport to PMV, followed by active travel modes (Das et al., 2021; Mashrur et al., 2022; Zhang et al., 2021). There were variations in recovery rates between the different public transport modes (Downey, Fonzone, Fountas, & Semple, 2022; Khadem Sameni et al., 2021). Also, a variance was found in mode shifts between countries (e.g., Europe: to active travel modes; South Korea and China: to PMV) (Zhang et al., 2021).

Post-pandemic, there is a strong reluctance to return to public transport (Tsavdari et al., 2022) due to the fear of infection (Downey et al., 2022). Ridership is expected to remain below pre-COVID-19 levels (Beck & Hensher, 2020; Currie et al., 2021), depending on the trip purpose (e.g., less likely to travel by public transport for work and study than for shopping and leisure) (Awad-Núñez et al., 2021). However, most users intend to return to public transport at some stage, especially with improved health measures (Awad-Núñez et al., 2021), such as more frequent cleaning (Downey et al., 2022). Some researchers found that the mass distribution of vaccines increased ridership (Awad-Núñez et al., 2021; Mashrur et al., 2022), however another study found that participants would reduce their use of public transport and increase PMV and active travel after large-scale vaccination (Downey et al., 2022).

Indeed, researchers found that further mode shift will occur from public transport post-COVID-19 to more PMV, active travel and WFH (Bagdatli & Ipek, 2022; Downey et al., 2022). Furthermore, Currie and colleagues (2021) caution that the mode shift from PT to PMV could result in peak traffic congestion post-pandemic. Whereby "reductions in commuting due to WFH do not offset mode shift from public transport to car driving resulting in a net increase in car use after the pandemic." (Currie et al., 2021, p.218).

Several studies found that as trip length increased, PMV mode share increased (Das et al., 2021; Thombre & Agarwal, 2021), whereas Ceccato and colleagues (2022) found potential shifts to car sharing and public transport for some trip distances.

4.1.4. PMV

During the pandemic, PMV use decreased during lockdowns and quickly rebounded (Ceccato et al., 2022; Khadem Sameni et al., 2021). The most significant mode shift was from public transport to PMV (Zhang et al., 2021). There are conflicting views about PMV post-COVID-19, whereby some researchers suggest that PMVs will be more dominant (Christidis et al., 2021; Currie et al., 2021; Thombre & Agarwal, 2021). Alternatively, there is a view that WFH will result in reduced PMV commutes (Olde Kalter et al., 2021), with country-level differences emerging (Zhang et al., 2021).

Furthermore, potentially PMV ownership will increase due to higher levels of WFH and risk avoidance attitudes, defined as the personal choice to avoid exposure to COVID-19 by refraining from social and business situations (e.g., crowds, face-to-face meetings, shared transport modes) (Christidis et al., 2021). Even when large vaccination programs are implemented, people anticipate using PMVs more (Downey et al., 2022). Consequently, there are concerns that greater PMV use will increase congestion levels and pollution (Nayak & Pandit, 2021).

4.1.5. Bicycling

More bicycling occurred during the pandemic than in pre-COVID-19 (Khadem Sameni et al., 2021; Olde Kalter et al., 2021). Furthermore, bicycling mode share is expected to increase post-COVID-19 (Awad-Núñez et al., 2021; Thombre & Agarwal, 2021), even after implementing mass vaccination programs (Downey et al., 2022). Bicycling increased during the pandemic, primarily due to a mode shift from public transport (Zhang et al., 2021). Travel mode preference tends to differ for different trip types; for example, bicycling will increase for work/study and leisure trips (Awad-Núñez et al., 2021). Also, bicycling will be part of the energy transition towards less energy-intensive travel modes (Zhang et al., 2021). In the long term, investment is needed to encourage adoption, including (1) developing bicycle infrastructure (e.g., bicycle highways, improving the safety of paths) and (2) overcoming negative attitudes by promoting it as an environmentally friendly, sustainable, and resilient form of transport (Thombre & Agarwal, 2021).

4.1.6. Walking

Significantly more walking occurred during COVID-19 compared to the pre-pandemic period (Ceccato et al., 2022; Khadem Sameni et al., 2021), mainly due to the mode shift from public transport (Zhang et al., 2021). Post-COVID-19, the walking mode share is expected to grow (Awad-Núñez et al., 2021) due to changing work patterns and risk avoidance of public transport modes (Christidis et al., 2021). Indeed, people have indicated they would walk more even once mass vaccination programs had been rolled out (Downey et al., 2022).

However, the walking mode preference will differ depending on trip purpose. Greater walking is anticipated, especially for leisure (Awad-Núñez et al., 2021), and work/education trips (Thombre & Agarwal, 2021). Despite anticipated increases, the mode share in terms of kilometres travelled will not increase significantly due to the average short trip distances (Christidis et al., 2021).

4.1.7. Shared mobility

Shared mobility was only the key focus in two studies (Awad-Núñez et al., 2021; Shokouhyar, Shokoohyar, Sobhani, & Gorizi, 2021). Differential health measures are needed to encourage the use of different shared modes, including more frequent services and disinfecting for public transport, handlebar covers for shared bicycles and steering wheel covers for shared PMVs (Awad-Núñez et al., 2021). Post-COVID-19, the willingness to use different shared travel modes will vary, with users most willing to use public transport modes (Awad-Núñez et al., 2021).

4.1.8. Summary of key themes from the literature review

For most travel behaviour changes, there was consensus that these changes would endure post-COVID-19. Indeed, three strong themes emerged relating to public transport, WFH and PMV individually and collectively. Firstly, the mode shift from public transport to PMV and active modes was a key and ongoing change. There was concern that public transport modes would take years to recover to pre-pandemic levels and potentially experience a further shift away even after mass vaccination. Secondly, the unprecedented level of WFH is key to encouraging trip avoidance and an opportunity for establishing new travel patterns.

Overall, the future is unclear, dependent on whether WFH has a spillover effect and results in greater PMV ownership and use. This raises a third interconnected theme: the threat of greater PMV dominance post-pandemic. There were conflicting views around whether PMV would be more dominant in the future despite greater WFH, which could result in worsening traffic congestion and emissions.

4.2. Interview results

This section presents the results from the in-depth interviews with transport stakeholders from Melbourne, Australia. Firstly, the results related to travel behaviour changes during COVID-19 will be outlined. Then the results related to the anticipated longer-term post-COVID-19 travel behaviour changes will be presented.

4.2.1. Travel behaviour changes during COVID-19

Based on the participants' responses, WFH was the main behaviour change discussed, followed by changing overall travel patterns and increased cycling. Changed travel patterns were an overriding theme that emerged, directly and indirectly, due to other changed behaviours. In addition, WFH was a pivotal behaviour change that influenced other travel behaviour changes. Table 1 presents each

Table 1

Overview of the overarching and specific travel behaviour changes due to COVID-19.

Overarching travel behaviour changes	Specific travel behaviour changes
Increased WFH	● Reduction in overall work-related trips ● Changed and divergent travel patterns depending on location in the city ● Reduced long commutes ● Greater daily travel behaviour variance
Changed travel patterns	● During lockdowns- overall reduction on the road and public transport networks; reduced distances when travel restrictions (e.g. limited 5 km radius from home) ● During reopenings but WFH mandated- reduction in trips to the CBD ● Increased suburban trips and traffic congestion ● Shift in peak times due to school drop-off and pick-up times
Increased bicycling	● Greater bicycle purchases ● Commuter bicycle trips ceased ● Recreational bike trips increased ● Pop-up bike lanes installed in patchy roll-out across the city ● Resistance to road space reallocation is already returning
Decreased & rebounded PMV	● Dramatic decrease during lockdowns ● Quick rebound to nearly pre-COVID-19 levels ● PMV increase due to health risks associated with public transport and shared modes ● Mode shift from public transport users to PMV ● Increased single occupancy vehicles ● Increased drop-offs and pick-ups (e.g. to higher education or schools) ● More local suburb traffic congestion
Decreased public transport	● Dramatic decrease during lockdowns ● Mode shift to PMV ● Continued low patronage during openings due to infection fear and WFH (trip avoidance & altered network demand)
Increased walking	● Increased walking for local trips to shops and recreation ● Location variance (e.g. inner city versus out suburbs)
Decreased and changed rideshare	● Dramatic decrease during lockdowns ● Recovered faster than public transport ● Commuter trips more resilient than social & airport trips ● Social trips rebounded quickly after reopenings ● Social trip destinations changed (pre-COVID high streets & restaurants; after lockdown to parks and homes ● Outer suburb trips increased ● Peaks times changed ● New late-night summer trips in seaside areas

travel behaviour change in descending frequency of discussions, which are discussed individually in the following sections.

4.2.2. WFH

There was consensus that the most extensive travel behaviour change due to COVID-19 was the mandated WFH, which led to significantly more flexible working patterns than pre-COVID-19. Participants reflected that workers and employers were initially reluctant to WFH, but then they discovered the benefits, and over time there had been a mindset change. Participants believe a five-day office-based workweek no longer exists (see Work-related travel Section). However, they were sceptical about whether that means the death of the office that was speculated in 2020. There was consensus that the range of travel behaviour changes resulting from WFH would ultimately alter the demands of road and public transport networks in the city.

There would be greater variance in daily commuter travel behaviour, for example *"today, I'm going to go into the city, or I'm going to drive, or I'm going to public transport, or I'm going to WFH. So flexibility, I think, is going to be a real feature. An impact of COVID is that people will want flexibility."*(Private Sector#3).

"I think what's happened is people maybe go out and get a coffee. So they drop off their kids then, get a coffee, then come back home, and they've got to start a meeting…a friend of mine who worked in the city…He said, "It's great I can take my kids to school now." I said, "So, do you walk?" And he goes, "No, I don't walk because I don't have time. I've got to be back home in a meeting. So I only really have time to drive there, get out of the car, say a quick hello to some parents, drop my kids and then come back home. But I don't have time to walk.""(Public Service#7).

4.2.3. Changed travel patterns

One of the main travel behaviour changes was changes in travel patterns. In particular, two distinct phases emerged, dependent on the stage of the pandemic. Firstly, overall travel was reduced when locked-down, and secondly, as the city reopened, travel patterns changed again due to continued WFH.

Participants observed that when the city first locked-down, the reduction in travel was seen dramatically across the road and public transport networks. Initially, there was no travel, and then as lockdowns eased, but travel distance restrictions were in place (e.g., only travelling 5 km from home), this affected travel distances. Then as the city reopened, but WFH was still mandated, divergent travel patterns emerged across the city. The central business district (CBD) was empty (as illustrated by the opening quotation), whereas suburban road travel and activity increased. Also, there was a shift in peak times for road traffic and new localised suburb congestion. Participants perceived that both changes arose particularly due to people now doing school drop-offs and pick-ups by PMV (see WFH section).

"So, there's a lot of people saying, well, this isn't good for the CBD…But the level of activity out in the middle and outer suburbs is much greater than it ever was. So those local patterns of movement seem to have increased. My barber said, he's had a 25% increase in clientele. And he said, it's all come from businesses that were in the CBD. So you look at that, and you go, gee whiz, that changes things a fair bit."(Public Sector#1).

4.2.4. Bicycling

There was consensus that bicycling and bicycle purchases had increased since the first lockdown in March 2020. However, bicycling numbers had fallen during city reopenings. Also, participants reflected that there had been a change in trip purpose for bicycling. Pre-COVID-19, there had been an increasing number of bicyclists commuting to the CBD, which stopped entirely during COVID-19. The bicycling increases during COVID-19 were for recreational purposes and to local shops. Although, participants were optimistic that with more experience and confidence, recreational riders would continue bicycling and ideally switch to other trip types they might have once done by PMV.

Participants remarked on the opportunity the pandemic had provided to trial new infrastructure. However, they acknowledged that the pop-up bicycle lanes were installed at a slow rate and varied implementation depending on the local council. Furthermore, despite prolonged exposure to changed travel behaviours and road space reallocation, one participant noted resistance to bicycle lanes already returning.

"We only got about 20 or 25% of them (pop-up bike lanes) in. But the resistance to change is already coming through, and people are pushing to get rid of them already. Because they're taking up parking space or car lanes."(Public sector#1).

4.2.5. PMV

There was a consensus that PMV trips had drastically decreased during lockdowns but quickly rebounded after lockdowns eased to nearly pre-COVID-19 levels. PMV increase was mainly attributed to avoiding close contact on public transport and shared travel modes. Indeed, participants reflected that PMV trips increased partly due to mode shifts by former public transport users. Participants also observed other changes in PMV behaviour:

● Local suburb congestion at school drop-off and pick-up times (see Changed travel patterns section).

● Increased single occupancy.
● Increased number of PMV drop-offs (e.g. to schools and higher education).

"Mum and dad or friend was driving them. So that's where you're travelling with the known person, within the family group. And again, that was the messaging of COVID- decrease your interactions with other people."(Private Sector#3).

4.2.6. Public transport

Although Metropolitan Melbourne has three public transport modes (train, tram and bus), participants spoke in general terms about public transport behaviour changes. Participants saw a mode shift away from public transport during the COVID-19 pandemic, especially to PMV (see PMV section). There was consensus that overall public transport travel significantly reduced during lockdowns and remained low even when lockdowns eased due to a fear of infection and reluctance to travel on public transport.

Participants also observed that WFH impacted public transport trips in two ways: 1. trip avoidance by reducing the total number of trips and 2. reshaping network demand. They perceived that these changes should result in a change in transport policy.

"So I think we will see post-COVID a real shift to people working from home. And that'll change all the demands on the public transport network. And we already know the massive CBD-centric design of the current network. And it doesn't really allow people to travel and move freely, I suppose, from around their area."(Public Sector#8).

4.2.7. Walking

Participants noted that walking had increased for local shopping and recreation trips. However, participants recognised different walking experiences depending on whether people live in the inner city versus the outer suburbs.

"Those (urban fringe) growth areas have been designed to have more local trips and everything. But the reality is often very different. In terms of how those areas play out, they inevitably end up car-dependent areas."(Public Sector#1).

4.2.8. Rideshare

Participants noted that during the first lockdown, rideshare trips plummeted. However, they recovered faster than public transport after restrictions eased, although not back to pre-COVID levels. A range of changes to rideshare travel behaviours was observed:

● Commuter trips were more resilient than social and airport trips, with social trips bouncing back faster after lockdowns eased.
● The destination of social trips changed; pre-COVID-19 trips were to high streets and restaurants, but after the first lockdown, trips were to parks and people's homes (suburb-to-suburb trips).
● Restaurant reopening on 1 June 2020 saw a doubling of trips to restaurant strips but still fewer trips than in outer suburb trips.
● Peaks shifted (e.g. weekends shifted from 10 to 11 am to 3–4 pm).
● More late-night trips on Thursday nights are attributed to WFH and having Fridays off.
● A new summer peak travel time was observed during a reopened stage in January 2021, between 11 pm and 1am at the seaside areas of the Mornington Peninsula and Geelong region.

4.3. Permanency of COVID-19 travel behaviour changes

Four themes emerged about the permanency of COVID-19 travel behaviour changes (see Table 2). The results suggest that of all the urban travel behaviour changes experienced during COVID-19, only work-related travel changes would endure (see Work-related travel section). Nevertheless, participants expressed a strong desire for the reliance on PMVs to stop and simultaneously increase bicycling, public transport and WFH. However, participants saw safety as a barrier to bicycling (e.g., more separated bike lanes) and public transport (e.g., cleaning standards).

Table 2

Overview of the post-COVID-19 travel behaviour changes and anticipated changes.

Overarching travel behaviour changes	Anticipated travel behaviour changes
Travel mode shift	● Reversion to pre-COVID-19 travel modes
Work-related travel (a hybrid of home & office work)	● Trip avoidance that will reduce overall work-related trips
	● Time shift with peak spreading due to greater flexibility in travel times
	● Greater daily flexibility & WFH will create new travel patterns & transport demand
	● Less domestic and international business travel
	● End of long daily commutes
Public transport and PMV	● Public transport users will continue to make PMV trips in the short-term
	● Longer-term before public transport recovers to pre-pandemic levels
Bicycling	● Diversification of cyclist typologies and trip types is desired
	● Bicycling will become a genuine travel mode is desired

4.3.1. Travel mode shift

Participants perceived that the travel mode shift experienced during COVID-19 would cease (e.g., increased active travel). Nevertheless, participants held diverse views regarding the long-term impact of COVID-19 on travel modes. One participant expressed that COVID-19 impeded sustainable shifts in travel behaviour that had been occurring in recent years (e.g. pre-COVID-19 there were an increased number of commuter trips by bicycle and public transport). Other participants thought that travel behaviour changes were temporary and that people would revert to pre-COVID-19 travel behaviours. One participant perceived a reversion to pre-COVID-19 travel behaviours, although they acknowledged that new travel patterns would form in the coming years due to the changing nature of work and increased WFH.

4.3.2. Work-related travel

There was a consensus that the nature of office work had changed forever, whereby five days in the office had ceased due to COVID-19. Furthermore, in the future, there will be daily work location flexibility which will cause travel behaviour changes, including:

● reduced overall work-related travel;
● the end of long daily commutes (e.g. 2 h each way);
● a time shift (the spreading of peak hours due to greater variance in travel times to offices);
● increased flexibility and WFH that will impact travel patterns and transport demand.

Two overriding work-related changes emerged that would affect urban travel in the future. Firstly, that hybrid working in the office and at home will be permanent, with the emerging norm of three days in the office and two days at home. Consequently, office workplaces will undergo a range of changes, including:

● location- central offices will become decentralised, with work hubs in middle suburb areas and regional centres in Victoria;
● size- office footprints will decrease;
● environments- no longer open plan office model; and
● working style- more intentional coming together and collaboration to maintain connectedness and encourage organisational and team cultures. Also, employers will encourage online meetings and restrain domestic and international business travel.

Participants acknowledged the uneven distribution of WFH and flexible jobs depending on the job location and type (e.g. with the most job flexibility in the CBD). They also recognised that it is currently the preliminary stage of change with a lot of trial and error ahead. However, they perceived that the nature of the CBD would change, whereby workplaces would decentralise with CBD offices having smaller footprints and becoming more residential. Consequently, there was concern about the current CBD-centric transport network and the focus on reinvigorating CBD. Participants thought the current priorities failed to capture the changing transport demands and improvements needed for travel across the city.

"I don't think the government here put much thought into what are the benefits of people WFH, spreading the peak on commute times and connecting with their local districts. What's the balance between supporting city centres and their economies and businesses, but also trying to maximise some of the other benefits that COVID-19 has had on travel patterns and our infrastructure networks."(Private Sector#1).

4.3.3. Public transport and PMV

Participants discussed public transport and PMV recovery as they saw them as interconnected. Participants were surprised by the rebound to PMV and noted that infection fear also encouraged the mode shift of public transport users to PMV. Conversely, participants perceived a lag before public transport patronage recovers to pre-pandemic levels due to infection fear, health measures (e.g. mask and social distancing requirements) and WFH. However, it was perceived that public transport would recover once high vaccination rates are achieved, as well as immigration and population growth in the long run.

4.3.4. Bicycle

Participants wanted to see the greater levels of bicycling achieved during COVID-19 continue. In particular, they hoped that more diverse cyclists and trip types would emerge and bicycling would ultimately become a travel mode. They perceived that the safety provided by separated bike paths is key to encouraging greater uptake. However, participants were concerned about the slow roll-out of separated bike paths, the need for network upgrades, and the inconsistency of infrastructure due to the different levels of government involved. Furthermore, they were disappointed by the recent pushback and removal of temporary bike lanes despite the success of increased levels of cycling during COVID-19.

"If there was a time to try and get government behind funding cycling, it should be now. But we're still struggling because cycling projects are really hard. Because of the land and the maintenance. Who owns the path, who's land is it, who needs to maintain it."(Public Sector#7).

"If (new bike lanes) continue, then that'll have a really lasting and good effect on the city. But there's constant pushback, and not a lot of people, but loud people that are pushing back in different areas. And so different councils that have implemented initiatives…and some of them have backflipped and removed them."(Public Sector#5).

5. Discussion

Pre-COVID-19, TBC research tended to focus on shifting the travel mode from PMV to more sustainable travel modes (Pawluk De-

Toledo et al., 2022). Research in the field consistently identified that travel behaviour change interventions succeeded in changing travel behaviours by 5–15 per cent (Brög, Erl, Ker, Ryle, & Wall, 2009; Chatterjee, 2009; Möser & Bamberg, 2008; Scheepers et al., 2014). This current study showed that COVID-19 revealed that even deeply entrenched habitual behaviours (e.g. commuting five days a week to work by PMV daily) could change and on a large scale, which has enormous implications for the future of urban road networks and transport systems. Furthermore, although WFH research had been around for decades, pre-pandemic WFH was still a niche behaviour (Beck & Hensher, 2021). Consequently, if the scale of change experienced during the pandemic were to endure, it would significantly impact roads use and urban planning. For example, it is estimated that WFH two days a week can reduce PMV commuter trips by 13.8 per cent (Marsden, Anable, Docherty, & Brown, 2021).

Consequently, the COVID-19 pandemic has been a turning point for encouraging more sustainable travel behaviours. Indeed, more than technological innovation, behaviour changes are now perceived to be key to reaching net zero emissions targets (International Energy Agency (2021), 2021). The IEA highlighted that most change would be achieved at the individual level in road transport (IEA, 2021), and the IPCC recently estimated that 67 per cent of greenhouse gas emissions from land transport could potentially be mitigated through behaviour changes (Intergovernmental Panel on Climate Change, 2023).

This study aimed to explore and identify the urban travel behaviour changes that occurred during and are anticipated to become permanent post-COVID-19. This study reviewed the peer-reviewed literature and conducted in-depth interviews with transport stakeholders in Melbourne, Australia. Seven overriding urban travel behaviour changes emerged from both parts of the study, with summary findings presented in Table 3. More similarities than differences were identified across the two study components. This is perhaps due to the global nature of responses, and divergences will emerge as the pace of recovery varies between cities and countries. Key areas of consensus included:

- WFH significantly increased during the pandemic and is anticipated to continue;
- overall travel patterns changed with less travel during the pandemic and are projected to be sustained due to WFH;
- that public transport trips significantly decreased throughout the pandemic and are expected to remain low post-pandemic;
- PMV trips significantly decreased initially during lockdowns but quickly rebounded; and
- active travel increased during the pandemic and is expected to continue post-pandemic.

The interview participants were more pessimistic about travel mode shifts and saw a reversion to pre-COVID-19 travel modes. It is concerning that participants perceived that despite experiencing extended exposure to travel behaviour change, people would revert to their pre-COVID-19 travel behaviours. This contradicts the potential positive outcomes of the pandemic identified in previous research.

Other concerns included that public transport will take a long time to recover, although this was discussed at a general level, whereas individual modes could experience different recovery rates. Indeed, understanding the different recoveries of each public transport mode is critical. The literature review component of the study revealed that research on WFH and public transport post-pandemic have mainly been studied. What is currently missing is research on active travel and sharing modes, which were both considered vital to improving road travel sustainability in the decade leading up to the pandemic.

Although the view emerged in the study that COVID-19 also caused less sustainable road behaviours. For example, pre-COVID-19, an increasing number of commuters bicycled to work but stopped bicycling during the pandemic. Globally, road space was reallocated to bicycling with pop-up bike lanes and the opportunity to encourage more bicycling. However, the opportunity to radically improve road allocation to encourage more bicycling seems haphazard, at least in Melbourne.

COVID-19 was a unique experience, causing widespread exposure to a range of urban travel behaviour changes for an extended duration, which had not previously occurred in the research field (Pawluk De-Toledo et al., 2022). In this study, PMV use emerged at the centre of all the interrelated urban travel and associated behaviours. Directly, PMV trips dramatically decreased during COVID-19 but quickly rebounded, with more single occupancy PMV trips and more drop-off and pick-up trips. These behaviours highlight that

Table 3

Summary of during and post-COVID-19 travel behaviour change results from post-COVID-19 peer-reviewed literature and transport stakeholder interview responses.

Behaviour	Post-COVID-19 literature		Transport stakeholder interviews	
	During COVID-19	Post-COVID-19	During COVID-19	Post-COVID-19
WFH	Increased	Will continue & encourages trip avoidance	Increased	Will continue & encourages trip avoidance
Travel patterns	Less travel	Less travel	Changed patterns	Changes in work-related travel; Reversion to pre-COVID-19 modes
Public transport	Decreased	Long recovery	Decreased	Long recovery
PMV	Decreased & rebounded	Conflicting views	Decreased & rebounded	Conflicting views
Bicycling	Increased	Increase from pre-COVID levels	Increased	Increase desired
Walking	Increased	Increase from pre-COVID	Increased	–
Shared mobility	–	Variance expected between modes	Decreased & changed patterns of rideshare	–

PMV use behaviours could indeed be worse post-pandemic. PMV use was also influenced by mode shift away from public transport and changing travel patterns due to greater WFH. This study found that WFH could encourage contradictory long-term travel patterns. On the one hand, WFH could encourage PMV trip avoidance and alleviate traffic congestion. Alternatively, this study found that WFH could also lead to more PMV purchases and more trips for other non-work-related trip purposes. Overall, WFH would result in a greater daily variance of travel patterns.

The interviews revealed reasons underpinning travel behaviours, which could be vital for identifying possible solutions. For example, the interviews provided insight into the persistence of rigid 9–5 office hours (even with WFH), which conflicts with school start times (between 8:30 and 9 am). Consequently, time pressure forces workers towards PMVs, which could be discouraged if there was greater starting time flexibility.

This study revealed that there is still much uncertainty about how these travel behaviours will evolve, significantly impacting emerging road systems. Indeed, WFH could lead to new unsustainable road user behaviour. For example, while traffic congestion to the CBD was reduced during the pandemic, participants observed more suburban congestion. Indeed, the interview participants were critical of the continued CBD-centric transport policy, which may have suited Melbourne pre-pandemic but will be significantly inadequate for the city if the high level of WFH continues. There needs to be a city-level rethink about the road and transport network to accommodate trip-making changes and network demand.

Overall, the current study found that work-related travel behaviours are most likely to endure in the long term, with new travel patterns emerging. This is mainly due to WFH looking likely to continue. However, it is unclear what frequency of WFH will endure; in the Melbourne setting, the interview revealed three days in the office and two days WFH is the emerging norm. Furthermore, associated travel behaviours of people that WFH are still unclear, although this study highlighted a range of possible scenarios. Therefore, despite the potential sustainability benefits of travel behaviour changes experienced during COVID-19, the results also highlight the future uncertainty and concern that less sustainable travel behaviours could emerge with PMVs potentially even more dominant post-pandemic. Indeed, this concurs with a recent report that found globally, in addition to the rapid rebound to PMVs, a growing trend of buying larger, sports utility-type vehicles, making road transport systems even more unsustainable (International Energy Agency, 2022).

Overall, the comparison of results from the literature review and interviews in the current study comprehensively synthesises and refines knowledge about the range of travel behaviour changes in cities during and anticipated post-COVID-19. Furthermore, this study has enabled the identification of critical future topic areas, which will be outlined in the final section.

6. Conclusion

The COVID-19 pandemic caused unexpected and radical travel behaviour changes (Delbosc et al., 2022). Indeed, if travel behaviour changes experienced during COVID-19 endure, more sustainable transport systems are anticipated to evolve (Büchel et al., 2022; Zhang & Zhang, 2021). Consequently, this study aimed to explore the city-level travel behaviour changes during COVID-19 and the permanency of these travel behaviours.

The key contributions of this study are threefold. Firstly, it consolidates knowledge about the wide range of interrelated urban travel behaviour changes experienced during and anticipated post-COVID-19. In particular, the threat of greater PMV dominance in the future. Secondly, it synthesises current knowledge of recent post-COVID-19 travel behaviour change research. Thirdly, this study demonstrates that transport research can be strengthened by complementary qualitative studies, such as interviews and thematic narrative literature reviews, by unearthing new ideas and more insight into the reasoning behind travel behaviours.

However, this study has several limitations. Participants were purposively recruited, so there is selection bias in this study and participant self-selection bias whereby non-selection bias occurred by those that refused to participate. Furthermore, interviews focused on transport stakeholders; however, additional qualitative research with other key groups would be valuable (e.g., separate focus groups with employers and employees to explore the barriers to maintaining specific modes and potential solutions). There are also temporal and locational limitations; the interviews focused on Melbourne, Australia and were conducted in mid-2021. Indeed, due to the nature of academic publishing, there is a time lag between conducting the study and its publication that should be considered. The study could have yielded different results if different cities or points in time had been studied. However, comparing the interview results with the broader research field has strengthened the study and increased the generalisability of the results.

Given the similarity of government responses globally to the pandemic (e.g., locking down cities, mandating WFH, enforcing curfews), there were a lot of common themes between the interviews and the broader body of literature. However, we anticipate that more differences will emerge when actual post-COVID-19 data is collected instead of the perceived behaviours used in previous studies. Especially given that cities will probably experience differences in recovery. Indeed, now that countries are learning to live with the virus, it is an opportune time to investigate whether these intended behaviours are actually emerging.

This study identified a wide range of urban travel behaviours that emerged during the pandemic, which if sustained, could improve the sustainability of road travel. Now that behaviours have stabilised, further studies are needed to identify the impact and relative importance of each travel behaviour on encouraging more sustainable behaviour. Indeed, this is the next critical step in research, so a concerted effort can then be made to understand the psychology behind the most important behaviours, whereby they can be better supported and encouraged. This study focused on identifying and explaining emerging travel behaviours and did not examine the psychology behind the behaviours, which would be a valuable research direction so sustainable travel behaviours can be encouraged in the long term.

This study highlights opportunities for the further development of the post-COVID-19 travel behaviour change field of research. We have identified seven overriding behaviours and associated changes that warrant further investigation. Indeed, a future quantitative

survey to complement and build on this study would be beneficial. Furthermore, this study used a thematic narrative literature review approach. In the future, other types of reviews would be valuable. For example, a systemic review that could statistically measure the levels of behaviour change post-pandemic would improve our understanding.

Furthermore, this study solidified that through the pandemic, WFH became an integral influence on urban travel behaviour. There was consensus that greater WFH will be a permanent change post-pandemic, which will cause enduring travel behaviour changes. However, it is still unclear whether WFH will result in significantly less travel or greater PMV purchases and trips. So ongoing research is needed to monitor how WFH evolves and its impact on urban travel behaviours given the pivotal role WFH could have on future travel demand in cities. Indeed, if WFH is sustained better understanding of local trip-making is needed so that traffic congestion is not simply redistributed across the entire city. Also, in future transport studies (particularly work-related), WFH should continue to be studied in conjunction with travel behaviours. Less known is the impact changed working and travel patterns will have on travel for other trip purposes, which would also impact the sustainability of the transport networks.

Further research is also needed to improve our understanding of the factors that influence the decision to use public transport. Especially infection, health and cleanliness should be further examined so that transport operators can quickly address concerns and expedite public transport recovery. Also, rideshare and other emerging modes of transport in urban travel pre-COVID-19 received limited attention in recent research. Therefore, rideshare-specific research should be conducted to improve our understanding of how it is emerging post-COVID-19 for different trip purposes and the factors influencing users.

Furthermore, future transport sustainability depends on the extent PMVs become either more or less dominant post-COVID-19. Therefore, PMV patterns and preferences warrant further investigation. Finally, to ensure that people do not revert to pre-COVID-19 travel behaviours (e.g., reduced walking and bicycling), we should improve our understanding of the factors underpinning these modes and why it could be challenging to maintain them in the future.

This study has improved our knowledge of the impact of COVID-19 on urban travel behaviours both during and anticipated post-pandemic. In doing so it makes a valuable contribution to understanding the changed urban transport landscape as the world emerges from the pandemic. In addition, this research provides essential insights if faced with future natural events that disrupt travel behaviours. Likewise, the study is helpful for researchers and practitioners working in the field by highlighting post-COVID-19 transport topics requiring attention.

CRediT authorship contribution statement

Katherine Pawluk De-Toledo: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft. **Steve O'Hern:** Conceptualization, Supervision, Writing – review & editing. **Sjaan Koppel:** Conceptualization, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Appendix

Appendix 1

Table: Overview of post-COVID-19 travel behaviour peer-reviewed articles (n = 41).

Author	Date online	Journal	Behaviour	Study location (s)	Study country	Research method	Date conducted
(Tsavdari et al., 2022)	Sep-22	Social Sciences	Public transport	Thessaloniki, Greece	Greece	online survey	May 2021

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Author	Date online	Journal	Behaviour	Study location (s)	Study country	Research method	Date conducted
(Rahman Fatmi et al., 2022)	Sep-22	Transportation Research Interdisciplinary Perspectives	WFH	Central Okanaga region of British Columbia	Canada	online survey	November 2020- January 2021
(Kogus et al., 2022)	Aug-22	Transportation Research Part A	WFH	Israel & Czechia	Israel & Czechia	online survey (survey agencies)	Israel: 22 April-2 May 2020; Czechia: 8–14 June
(Beck, Nelson, & Hensher, 2022)	Aug-22	International Journal of Sustainable Transportation	Public transport	Greater Sydney Metropolitan Area & South East Queensland	Australia	online survey	Wave 4a July (5th to the 7th) 2021
(Stefaniec et al., 2022)	Aug-22	Journal of Transport Geography	WFH	National	Ireland	online survey	7 June- 16 July 2021
(Delbosc et al., 2022)	Aug-22	Transport Policy	WFH	Melbourne, Australia	Australia	online survey	mid 2020-
(Mashrur et al., 2022)	Aug-22	Transportation Research Part A	Public transport	Toronto, Canada	Canada	online survey	first 2 weeks July 2020
(Ceccato et al., 2022)	Jul-22	Transportation Research Part D	WFH, travel mode	Padova, Italy	Italy	online survey	July-Sept 2020
(Hsieh & Hsia, 2022)	Jun-22	Journal of Transport & Health	Public transport- metro	Kaohsiung City, Taiwan	Taiwan	Survey via face-to-face interview	mid 2020
(Behrens & Newlands, 2022)	Jun-22	Journal of Transport and Supply Chain Management	Travel behaviour	10 countries in Sub-Saharan Africa	Sub saharan Africa	Expert Delphi survey	Wave-1: 29 July 2021; Wave-2: 30 August 2021
(Downey et al., 2022)	Jun-22	Transportation Research Part A	Public transport	National	Scotland	online survey (Qualtrics)	3 &17 February 2021
(Mohammadi et al., 2022)	May-22	Transportation Letters	WFH	National	US	online survey (Qualtrics)	April- October 2020 & November 2020- May 2021
(Nelson & Caulfield, 2022)	May-22	European Transport Research Review	Travel behaviour	13 countries	global	ITF Working group info survey to member countries	Survey Jan-April 21
(Luan et al., 2022)	Apr-22	International Journal of Environmental Research and Public Health	Travel mode	Qingdao, China	China	online survey	Wave-1: 1–20 June 2020; Wave-2: 15–30 October 2020
(Mashrur et al., 2022)	Feb-22	Transportation Research Record	Public transport	Toronto, Canada	Canada	online survey	mid 2020
(Bagdatli & Ipek, 2022)	Jan-22	Transport Policy	Travel mode	Istanbul, Turkey	Turkey	online survey (Google forms)	14 May to June 9, 2021
(Jain et al., 2022)	Dec-21	Transportation Research Part A	WFH	Melbourne, Australia	Australia	online survey (Qualtrics)	Jun-Aug 2020
(Moens, Lippens, Sterkens, Weytjens, & Baert, 2022)	Nov-21	European Journal of Health Economics	WFH	Flanders	Belgium	online survey	25–31 March 2020
(Olde Kalter et al., 2021)	Nov-21	Transportation Research Interdisciplinary Perspectives	WFH & PMV	National	Netherlands	online survey & 1 week martphone-based GPS-data	April 2020
(Balbontin et al., 2021)	Sep-21	Journal of Transport Geography	WFH	8 countries	Australia, South America, South Africa	online survey	August- December 2020
(Currie et al., 2021)	Sep-21	Transportation Research Part A	Travel behaviour	Melbourne, Australia	Australia	online survey (market research company panel)	26 June 2020 & 8 August 2020
(Barbour, Menon, & Mannering, 2021)	Aug-21	Transportation Research Interdisciplinary Perspectives	WFH	National	US	online survey (Qualtric)s	July- August of 2020

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Author	Date online	Journal	Behaviour	Study location (s)	Study country	Research method	Date conducted
(Khadem Sameni et al., 2021)	July 21	Transport Policy	Public transport-subway	Tehran, Iran	Iran	online survey	Wave-1: July 2020; Wave-2: April 2021
(Nayak & Pandit, 2021)	Jul-21	Transport Policy	WFH	National	India	online survey (google forms)	Wave-1: end March 2020 3 weeks; Wave-2: end March 2021 2 weeks
(Carrese et al., 2021)	Jul-21	Transport Policy	Travel mode	Rome, Italy	Italy	traffic data,Bluetooth data, floating car data & ticket validations at subway stations	Pre: first 2 weeks February 2020; during: 2 May 20—3 June 2020
(Beck & Hensher, 2021)	Jun-21	Transport Policy	WFH	National	Australia	online survey	August-October 2020
(Zhang & Zhang, 2021)	Jun-21	Transport Policy	Travel behaviour	Changzhou, China	China	Travel, land use & socioeconomic data, from personal trip surveys, a land use database & statistical yearbooks. Technology data: technology shares, energy intensities & fuel-specific emission factors	conducted 2020 didn't used pre-COVID-19 data because 1 year of data needed
(Christidis, Christodoulou, Navajas-Cawood, & Ciuffo, 2021)	Jun-21	Sustainability	Travel behaviour	EU	EU	Combined EU travel survey & detailed strategic transport model	2018 EU Travel Survey & TRIMODE
(Thombre & Agarwal, 2021)	Jun-21	Transport Policy	Travel mode	Urban areas in India	India	online survey using (Google forms)	20 March-30 June 2020
(Elias & Zatmeh-Kanj, 2021)	Jun-21	Transport Policy	Public transport-train	Israel	Israel	online survey	Wave-1: mid-April- mid-May 2020; Wave-2: first two weeks December 2020
(Das et al., 2021)	May-21	Transport Policy	Public transport to PMV	Regional areas	India	online survey	April 29–30 May 2020
(Aaditya & Rahul, 2021)	May-21	Transport Policy	Travel mode	National	India	online survey (Google forms)	May 20- June 31 2020
(Hensher et al., 2021)	Apr-21	Transportation Research Part A: Policy and Practice	WFH	National	Australia	Ongoing online survey	March- April 2020
(Awad-Núñez et al., 2021)	Mar-21	European Transport Research Review volume	Public transport & shared mobility	National	Spain	online survey	end April 2020 for 2 weeks
(Kopsidas, Milioti, Kepaptsoglou, & Vlachogianni, 2021)	Mar-21	Transportation Letters	Public transport	Athens, Greece	Greece	online survey (Survey monkey)	April- May 2020
(Nguyen & Armoogum, 2021)	Mar-21	Sustainability	WFH	Hanoi, Vietnam	Vietnam	online survey (Google forms)	From 20 April 2020
(Zhang et al., 2021)	Jan-21	Transport Policy	Travel mode	Worldwide	Worldwide	online expert survey	end April- end May 2020
(Nguyen, 2021)	Jan-21	Transportation	WFH	Hanoi, Vietnam	Vietnam	online survey (Google forms)	from 20 April 2020
(Shokouhyar et al., 2021)	Jan-21	Sustainable Cities & Society	Public transport & shared mobility	Global	Global	3 phase delphi expert survey	April-July 2020
(Beck & Hensher, 2020)	Aug-20	Transport Policy	Travel behaviour & WFH	National	Australia	ongoing online survey	23 May − 15 June 2020

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Author	Date online	Journal	Behaviour	Study location (s)	Study country	Research method	Date conducted
(Beck et al., 2020)	Aug-20	Journal of Transport Geography	WFH	National	Australia	ongoing online survey	Wave-1: 30 March-15 April; Wave 2: 23 May- 15 June 2020

Appendix 2. . Overview of post-COVID-19 travel behaviour peer-reviewed literature

		N (Studies) 41	
Main Journals	Transport Policy	13	
	Transportation Research Part A	6	
	Transportation	1	
	Transportation Research Interdisciplinary Perspectives	3	
	Journal of Transport Geography	3	
Behaviour	WFH	18	
	Travel mode	6	
	Travel behaviour	5	
	Public transport	10	
	Private motor vehicle	2	
	Shared mobility	2	
Research method	Travel data	1	
	Expert Delphi surveys	2	
	Self-reported traveller survey questionnaires:	38	
	online	37	
	face-to-face	1	
	Additional data sources	2	
Number of survey waves	1 wave	34	
	2 waves	5	
	3 waves	1	
Length of survey in field	1 week	3	
	2 weeks	7	
	3 weeks	2	
	1 month	9	
	6 weeks	2	
	2 months	4	
	3 months	4	
	5–6 months	2	
		Published articles	Study location
Main countries	Australia	10	8
	United States	4	2
	India	4	4
	Greece	3	2
	Canada	3	3
	Netherlands	3	0
	Italy	3	2
	Israel	2	2
	Japan	2	0
	Iran	2	0
	South Africa	2	0
	Vietnam	2	2

(*continued*)

		N (Studies) 41	
	Spain	2	0
	China	0	2
Geographical level	City	16	
	Regional	2	
	National	15	
	cross country	3	
	Continent	2	
	Global	2	

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