An insight into the impacts of COVID-19 on work-related travel behaviours in the Cardiff Capital Region and following the UK's first national lockdown

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A B S T R A C T

Traveller responses to transport disruptions can be used to understand individual travel choices and the potential barriers restricting the uptake of sustainable travel behaviours. Using the Cardiff Capital Region as the study area, this research employed a cross-sectional survey to determine the immediate and anticipated long-term impacts of the COVID-19 pandemic, as a transport disruption, on work-related travel behaviours. This research identified that COVID-19 had significantly reduced travel frequencies for office-based workers, with reductions identified both during and in the expected frequencies following COVID-19. Similarly, modal changes and intentions to modal shift were identified as an immediate and potential post-lockdown impact. Meanwhile, departure times before and after the pandemic are expected to remain between similar hours. Additionally, no statistical relationships were identified between respondents' socio-demographics and attitudes towards the avoidance of public transport and the exclusive use of a private car in the future. Overall, the research indicated the potential for low-frequency work travel but increased car dependency following the pandemic. This signifies the importance for local policymakers and planners to continue to improve existing active and public transport infrastructure to secure a low-carbon recovery and future.

1. Introduction

With increasing pressures to decarbonise the transport sector in the UK, to meet legally binding emission targets, there has been an on-going debate regarding the usefulness of analysing transport disruptions and individual traveller responses to guide the design of contingency measures and support low-carbon travel behaviours (Marsden et al., 2020; Marsden & Docherty, 2013; Spyropoulou, 2020). When the coordinated system of activities and expectations surrounding a transport network becomes disrupted, 'normal' or planned travel behaviours may also be affected (Marsden et al., 2020). These disruptions can be either known as 'planned disruptions', which often allow commuters to pre-plan travel routes before these events occur (e.g. road closures or strike actions) or unplanned. Unplanned disruptions occur without forewarning, and due to their unanticipated occurrence in locations and times, they have been less regularly researched (Danczyk et al., 2017). Unplanned disruptions include natural disasters and extreme weather conditions, with recent studies focusing on the generated impacts of flooding (Abad et al., 2020; Pregnolato et al., 2017; Zanni & Ryley, 2015) and road bridge collapses

(Danczyk et al., 2017; Shires et al., 2016).

1.1. Unplanned transport disruptions

When an unplanned disruption occurs, network operation suddenly falls within the affected area, caused by either a change in network supply (such as from a bridge collapse) or traveller demand (Khan & Habib, 2018; Spyropoulou, 2020). Danczyk et al. (2017) explained that a change in traveller demand is a result of the "avoidance phenomenon" theory. The theory postulates that geographic areas affected including certain locations, routes and modes would be avoided by travellers due to an increase in perceived generalised costs of travel, usually in the form of increased journey times. Meanwhile, the demand for other routes, destinations or modes increases (Abad et al., 2020; Danczyk et al., 2017). Notably, Danczyk et al.'s (2017) traffic count study identified that across different international unplanned disruptions, network operation gradually returns to the same or a different rate to pre-disruption levels as avoidance of the affected area decreases over time.

The large-scale nature of major disruptions can often result in their

impacts on the local environment and transport network to extend over a prolonged period (Marsden & Docherty, 2013; Reggiani et al., 2015). As a result, the time required for network operation to return to pre-conditions following a disruption can vary significantly over weeks or months. For example, Kattan et al.'s (2013) study reported that it took six weeks after the Mississippi bridge collapse for traffic patterns to recover to pre-collapse conditions. Meanwhile, normal daily underground ridership in Taipei returned to normal 300 days following the SARS outbreak, with full recovery achieved under the conditions of zero (0) reported cases of SARS in Taipei (Wang, 2014).

There have also been cases where transit ridership does not return to pre-disruption levels. This can occur under pro-longed unplanned disruptions where individual traveller responses or changes in trip characteristics may be preferred to previous travel patterns resulting in long-term behavioural changes and a difference in capacity or ridership after a disruption (Danczyk et al., 2017). Thus, a disruption can provide an opportunity for habitual travel behaviours to be disrupted, which can increase the sensitivity and attentive awareness of travel decision-making to potentially give rise to new travel behaviours (Frater et al., 2020; Verplanken et al., 2008). The rise of new behaviours following a point of contextual change which disrupts habitual behaviours is known as Verplanken et al.'s (2008) 'theory of habitual discontinuity'. Whilst voluntary sustained behavioural changes are limited following disruptions, a few studies claim that from a policy perspective, disruptions can provide an opportunity to achieve low-carbon futures (Marsden et al., 2020; Marsden & Docherty, 2013; Spyropoulou, 2020). Collectively, these studies suggest that transport policies can be implemented to support and maintain positive travel behavioural changes individuals' uptake during a disruption.

This case is supported by the outcomes of the 2005 terrorist attack bombings on London's public transport system. The perceived fear of safety associated with public transport, generated from the attacks, led to some long-lasting modal switches to active travel and cycling, in particular (Sung & Monschauer, 2020). Sung and Monschauer (2020) reported that the permanence and attractiveness of cycling behaviours were sustained and induced by several transport policy changes in London following the attacks, such as the congestion charge and improved 'cycling highway' infrastructure. In turn, that provided evidence that prolonged disruptions can induce long-term changes to the dynamics of daily travel demand and shape the future of mobility systems, particularly when complemented with a change in transport policy (Marsden et al., 2013; Marsden & Docherty, 2013). Consequently, research into understanding the impact of COVID-19 on travel behaviours would provide an insightful opportunity for transport policy-makers and local councils to re-assess and improve strategies that encourage active travel behaviours.

1.2. Individual responses to unplanned disruptions

When public transport users are faced with the conditions of restricted mobility from any unplanned transport disruption, travellers must adapt and reconsider their preferred travel plans (Rahimi et al., 2019). With the magnitude of the disruption affecting the decisions made in the short term related to mode choice, route, time of departure, journey times, frequency, destination choice, the cancellation or post-ponement of commuter trips (Khan & Habib, 2018; Marsden et al., 2016; Spyropoulou, 2020; Zanni & Ryley, 2015), an individual's response is determined by their flexibility or "adaptive capacity" influenced by the geographical area, encapsulating the area's transport network, the wider urban system, and an individual's trip characteristics and socio-demographic profile (Rahimi et al., 2019).

Trip purpose or importance is a key variable that affects traveller responses across different transport disruption types (Abad et al., 2020; Kattan et al., 2013; Marsden et al., 2016; Zanni & Ryley, 2015). More specifically, traveller responses tend to differ between work-related and non-work-related trips. Under the conditions of floods in Scotland and

the Philippines, for example, employed individuals were less willing to change their choice of mode or route. Instead, employed individuals prefered to alter their departure times for work-related travel (Abad et al., 2020; Kattan et al., 2013). This is because there is usually less flexibility for cancellations, late arrivals or to rearrange work at a different location, when compared to non-compulsory travel.

Alternatively, under extreme weather conditions in the UK, the frequency or necessity of work-related travel can be reduced with opportunities to work from home during a period of disruption (Marsden et al., 2016). As exemplified by Shires et al. (2016), those travelling five days a week decreased from 63% to 51%, whilst the number of days working at home increased by 46% during the Forth Bridge Closure in Scotland. However, these opportunities depend on employer flexibility, social norms, employment structure or occupation type and supporting infrastructure to allow for workload and meetings to be undertaken at home (Marsden et al., 2016).

Several studies have identified that different public transport users exhibit different levels of adaptability in response to a disruption (Abad et al., 2020; Zanni & Ryley, 2015). With car travellers often exhibiting a greater level of adaptability compared to organised transport modes as they tend to have a wider choice in terms of the scheduling of travel departure, routes and destinations (Zanni & Ryley, 2015). Also, some disruption literature suggests that car users travelling during peak hours prefer to alter departure times than their route or mode choices under extreme weather conditions (Abad et al., 2020; Kattan et al., 2013). Meanwhile, other studies indicate that where disruption conditions such as from flooding or stormy conditions increase road congestion users are more susceptible to switching to public transport modes, train specifically, to avoid congestion and further journey time delays (Zanni & Ryley, 2015).

1.3. Travel disruption and COVID-19

One form of travel disruption that remains under-researched is the impact of influenzas and pandemic episodes on individual travel behaviours. The emergence of the severe respiratory illness coronavirus (SARS-CoV2) in Wuhan, China, in December 2019 (Ivanov, 2020) and the developed COVID-19 pandemic has provided a critical and unique opportunity for research. Prior to the COVID-19 pandemic, a singular study investigated the impact of the epidemic SARS on daily public transport ridership in Taipei, Taiwan (Wang, 2014). The study analysed the effects of fresh and residual fear associated with SARS cases in Taipei on underground ridership levels before, during and after the epidemic (Wang, 2014). The study identified that underground ridership in Taipei dropped by 50% during the peak of the SARS outbreak because of travel reluctance linked to fears of contracting the infection, despite the enforcement of social distancing measures (Wang, 2014). On the other hand, the study did not identify the impact of SARS on individual travel characteristics, for example, whether underground users shifted to alternative modes.

Since March 2021, there have been numerous studies exploring the impact of COVID-19 on the travel industry and travel behaviours including special issues such as by the Journal of Transport and Health on the impacts of COVID-19 on transport and health (Musselwhite et al., 2021). Some studies have explored the perception of risk associated to COVID-19 infection and the impact on travel behaviours (Eisenmann et al., 2021; Neuburger & Egger, 2021; Zafri et al., 2021). Zafri et al.'s (2021) study identified that risk perception, income and supportive infrastructure were important factors to the adoption of travel behaviours under the influence of the pandemic, in particular for the expected uptake in active travel post-pandemic in Bangladesh. Similarly, Eisenmann et al. (2021) and Vickerman (2021) explored the increased uptake of working from home, fall in public transport use and changes in attitudes towards modes before and during a lockdown in Germany and the UK, respectively. Meanwhile, other studies have explored the impact of COVID-19 on mode choice and the tourist industry (Ivanova et al., 2021;

Uğur & Akbıyık, 2020).

1.4. Research focus and aims

The overarching focus of this exploratory study is to investigate the impact of COVID-19 on individual work-related travel behaviours, specifically mode choice, travel frequency and departure times in the Cardiff Capital Region, Wales. The study focus on work-related travel is justifiable as throughout the pandemic and the data collection period travel in the UK was predominately restricted to "essential", which allowed for work-based travel because of its impact on the economy. The study provides evidence on the travel-related implications of the COVID-19 pandemic as very little research has been previously documented during previous influenza epidemics or pandemics. Thus, this study has been tailored to address this research gap within the transport and travel behaviour literature.

The study aims to investigate what have been the immediate effects of COVID-19 on work-related travel behaviours; what could be the perceived long-term effects of COVID-19 on work-related travel behaviours and how might the socio-demographic characteristics of an individual might relate to travel attitudes and behaviours in response to COVID-19. The results to these research questions should provide an understanding of the adaptive behaviours of individuals under the conditions of this under researched type of disruption. Existing literature indicates that the prolonged nature of the disruption (Ivanov, 2020), COVID-19, may disrupt travel habits (Verplanken et al., 2008), change preferences and perceptions associated with different modes (Wang, 2014), and reduce travel frequencies, as similarly experienced during the Forth Bridge Closure in Scotland (Shires et al., 2016).

2. Lockdown restrictions in Wales and the Cardiff Capital Region

Since the UK's first national lockdown between the 23rd of March and the 10th of May 2020, restrictions on gatherings, business operations and travel have had a detrimental impact on the transport system (Jolly, 2020). In particular, COVID-19 created a challenge for the public transport system throughout lockdown restrictions because of the perceived increased risk of infection within enclosed and shared spaces (Jolly, 2020). This can be exemplified by travel to public transport hubs in Cardiff, Wales, falling by 85% in April 2020 (Fig. 1) and national train ridership dropping by 95% during the peak of the UK's first wave of the COVID-19 pandemic (Department for Transport, 2020a).

Thus, it has been predicted that the COVID-19 pandemic has induced changes in social norms, and the perceived safety associated with different transport modes (Jolly, 2020). In turn, as pressures increase for local and national governments to secure a low-carbon future, investigating the potential impact of COVID-19 on modal choices and other travel characteristics could provide an informative insight into the extent of radical change necessary to encourage a sustainable-based recovery. In turn, this insight provides the main motivation for this research. Fig. 2 provides a timeline of the easing of COVID-19 restrictions in Wales and the data collection period.

3. Methods

3.1. Study area

The geographic focus of the study is the Cardiff Capital Region (Fig. 3). It consists of 10 local authority areas within Southeast Wales (see Fig. 3). A study area was selected because the geographical area where a disruption occurs can affect how travellers can respond or adapt their preferred travel behaviours to undertake activities.

3.2. Survey questionnaire

For the purposes of this study, an online survey questionnaire was developed. The survey was divided into four sections. The first three sections aimed to capture the temporal aspects of travel behaviours. Respondents were asked to recall travel behaviours prior to the pandemic, state behaviours during the lockdown conditions at the time of data collection, and future work-related travel intentions following a potential relaxation of the lockdown measures. Specifically, the questions focused on analysing the three key travel characteristics across
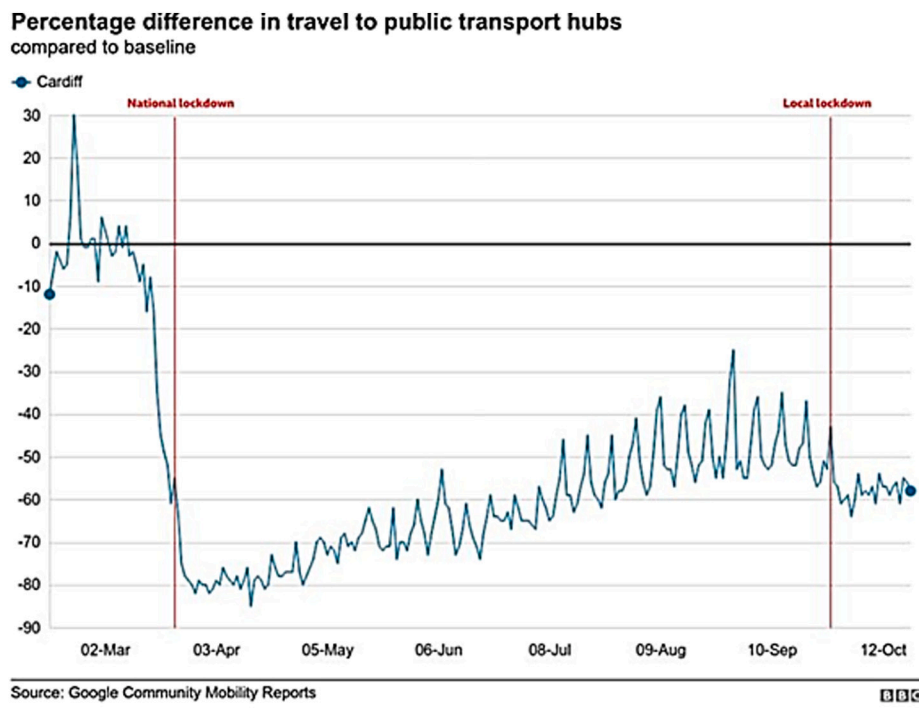

Fig. 1. Impact of COVID-19 on public transport hub use, Cardiff (Google Mobility Reports, 2020 cited in BBC 2020).
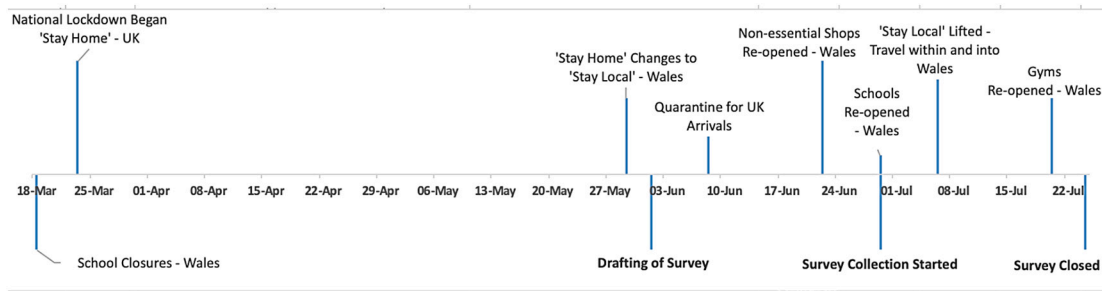
Fig. 2. Timeline of the COVID-19 response – Wales in the period March–July 2020.
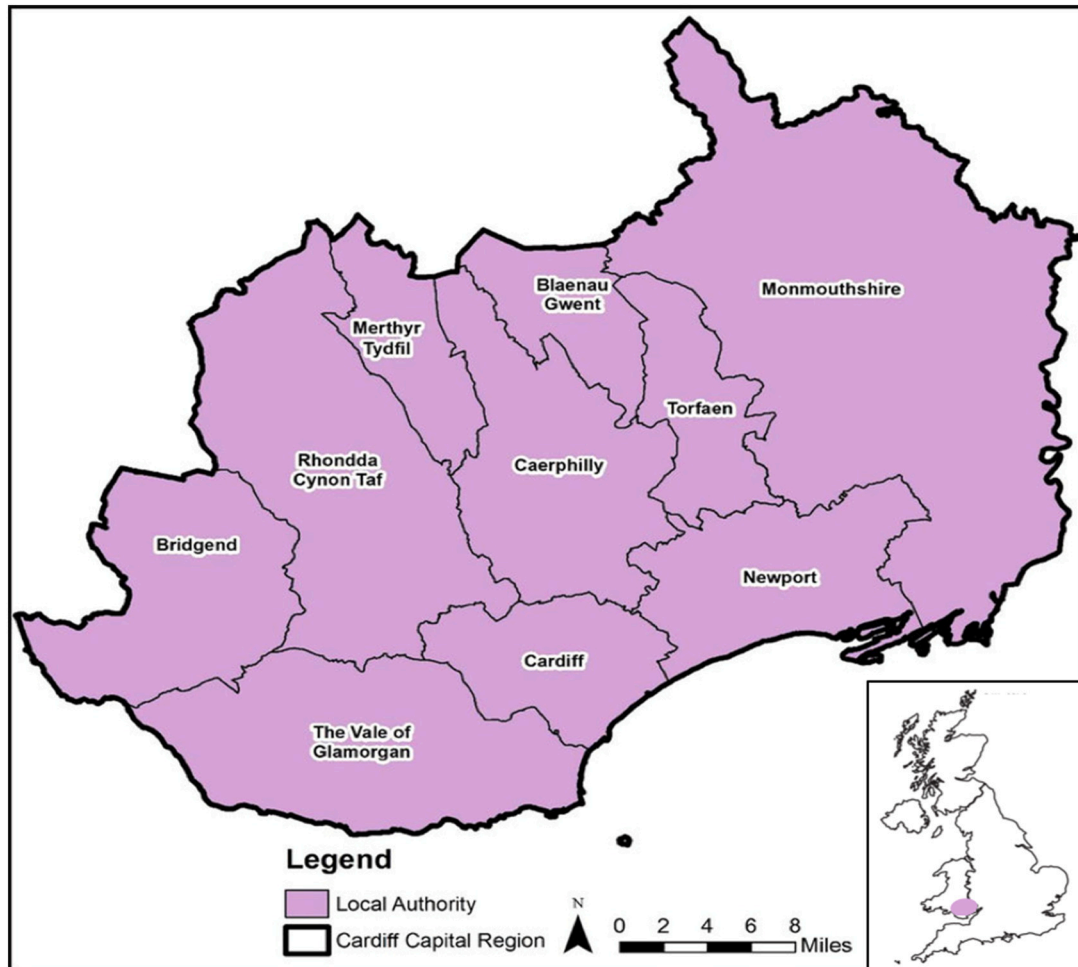

Fig. 3. Local authority areas within the Cardiff Capital Region.
(Source: Beel et al. (2018)).

these time-periods and included: travel frequency, mode choice, and departure times to and from work. The data on these travel characteristics were collected to enable a comparison and analysis of the immediate and potential long-term effects of COVID-19 on work-related travel behaviours.

Supplementary questions focused on capturing respondents' attitudes towards the availability, consideration and preference of travel options, habitual travel choices and the ability to and future of working from home. These responses were collected to understand the adaptive capacity of respondents' work-related travel and the potential long-term outcomes on travel behaviours in response to the COVID-19 pandemic in Wales. The final section of the questionnaire collected socio-demographic information from respondents. Table 1 summarises the

content and provides a justification for each section in the questionnaire.

3.3. Sample and survey implementation

To ensure respondents were eligible to complete the questionnaire, participants were asked to confirm that they were in employment (part-time or full-time) before the pandemic; were 18 years of age or older; and lived within the Cardiff Capital Region. There were no respondents who mentioned that they were furloughed at the time of undertaking the survey and one respondent mentioned that the pandemic had led to their retirement.

The questionnaire was administered on the online platform 'Qualtrics'. The survey was then distributed through social media posts,

Table 1

Summary of the survey questionnaire's content.

Section	Themes/summary of questions
BEFORE the pandemic	• Aimed to capture 'starting positions' of respondents in terms of work-related trip characteristics prior to the pandemic such as mode choice (Abad et al., 2020; Zanni & Ryley, 2015), workplace distance (Marsden et al., 2016), time (Abad et al., 2020) and frequency of travel (Shires et al., 2016) • Likert-scale questions were aimed to capture perceptions of mode choice, mode preference, and travel habits to test Verplanken et al.'s (2008) 'theory of habitual discontinuity' – i. e., whether the pandemic has had disrupted habitual travel behaviours and increased respondent's awareness to potentially result in new travel behaviours. • Availability and quality of alternative travel options for work-related travel to determine the adaptive capacity of individuals in response to disruptions (Marsden et al., 2016; Rahimi et al., 2019).
DURING the pandemic	• Whether respondents had continued commutting to work during the lockdown and related on their travel characteristics • Ability of respondents to continue with their usual workload from home (Shires et al., 2016) and their perceived comfort of using different transport modes during the pandemic
AFTER the pandemic	• Possible long-term impacts of the pandemic • Perceived travel-to-work intentions and patterns • Perceptions and attitudes towards different transport modes and trip characteristics following the pandemic
Socio-demographics	• Socio-demographic characteristics including age, gender, occupation type, location and household characteristics in line with Abad et al. (2020), Khan and Habib (2018), Shires et al. (2016), Shires et al. (2019) and May (2011)

mailing lists and online newsletters by local organisations and councils located within the geographical area of the Cardiff Capital Region. The scale of the study area was selected to examine the broader impact of COVID-19 on work-related travel. The survey went live between the 29th of June and the 24th of July, after the UK's first wave of COVID-19 infections and deaths.

3.4. Analysis plan

The analysis plan involved the use of two forms of statistical analyses. Firstly, descriptive analysis was conducted to describe, aggregate, and present the survey-questionnaire data in an illustrative format. The use of descriptive analysis allowed for patterns within the data to be identified and to illustrate the make-up of the sample population and their travel behaviours before COVID-19. Secondly, statistical inference was employed to deduce the overall impact COVID-19 has had on travel behaviours. Chi-square was used to examine potential statistical associations between groups of respondents and their mode choices before and during the pandemic. Also, paired sample *t*-tests allowed for the comparison of mean travel and work-from-home (WFH) frequencies across between time periods of the day. The statistical tests were selected to meet the initial set of objectives. Statistical inference was utilised to respond to the research questions which aimed to explore the immediate effects and potential long-term effects of COVID-19 on work-related travel behaviours. Whilst, both statistical inference and descriptive analysis were utilised to understand how the socio-demographic characteristics of an individual affect travel attitudes and behaviours in response to COVID-19.

4. Results and discussion

4.1. Sample characteristics

The sample size for analysis included 211 responses. Respondents lived within nine out of the ten local authority areas located within the Cardiff Capital Region, with 71.7% of the sample population's workplace located within the city of Cardiff. Table 2 provides a summary of the

Table 2

Sample characteristics (*N* = 211) vs. in employment population, Cardiff (*N* = 196,500) (Official National Statistics, 2020a).

Socio – demographics		Sample %	ONS %
Gender	Female	56.9	55.3
	Male	42.7	44.7
	Other	0.5	–
Employment status	Full-time	82.0	67.0
	Part-time	18.0	32.5
Occupation type	Managers, directors and senior officials	23.2	10.3
	Professional occupations	46.0	27.9
	Associate professional and technical	10.4	17.3
	Administrative and secretarial	10.0	8.6
	Skilled trade occupations	2.8	6.5
	Caring, leisure and other services	3.3	9.4
	Sales and customer service	4.3	7.3
Age	18–24	1.9	13.1
	25–34	15.7	26.5
	35–49	48.8	29.3
	50–64	31.8	23.7
	65 or over	1.9	3.7
Education level	Level 2 or below (e.g. GCSEs)	6.2	–
	Level 3 (e.g. A-levels or equivalent)	15.6	–
	Level 4 and above (e.g. university degree)	78.2	–
Household size	1	12.3	–
	2	31.3	–
	3	23.7	–
	4 or more	32.7	–
Car access	Yes	87.2	–
	No	12.3	–

socio-demographic profile of participants. The sample broadly reflected an office-based commuter population in full-time employment.

A statistically significant difference was identified between the sample group and the Official National Statistics (2020a) dataset of people in-employment in Cardiff. This was a result of the non-probability sampling technique used to collect the sample. The sample was over representative of full-time workers in professional and managerial occupations, who were predominantly aged between 35 and 65 (80.6%) years of age when compared to figures by the Official National Statistics (29.3%).

4.2. Mode choice, habits and preferences prior to COVID-19

This subsection captures the travel related choices and perceptions prior to the COVID-19 pandemic. Fig. 4 shows that the main mode for work-related travel within the sample was the private motor vehicle (56.9%), a lower proportion used for work-related travel in Cardiff (66.0%) (Cardiff Council, 2017). Meanwhile, 29.4% of the respondents stated that their main mode for work-related travel was by public or
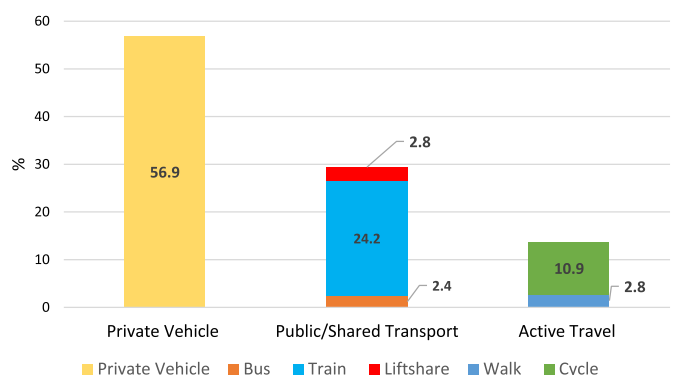
Fig. 4. Respondents' mode choices before COVID-19 (*N* = 211).

shared transport including train, bus, and lift-sharing whilst the remaining 13.7% of respondents walked and cycled to work.

Fig. 5 indicates that 68% of all respondents (strongly or somewhat) agreed that their choice of mode for work-related travel was used out of habit, which was in line with studies by Verplanken et al. (2008) and Frater et al. (2020). However, the results of a Chi-square test indicated that there was no significant difference between respondent's mode choice for work-related travel and habitual use ($\chi^2 = 1.198$ (2), $p = 0.549$), with similar proportions of private motor vehicle (PMV) users and public transport/active travel (PT/AT) users agreeing to the statement. There was no statistical relationship between mode choice and that being respondents' preferred mode choice ($\chi^2 = 1.146$ (2), $p = 0.564$). However, across all mode types, 84% of respondents (strongly or somewhat) agreed that their selected mode choice was also their preferred mode for work-related travel. The similarly shared consensus of modal preference, indicates the role preferences had across all mode choices (Marsden et al., 2016). For example, 83% of all PMV users and 83% of all PT/AT users agreed to the statement.

On the other hand, a statistical association was identified between mode choice and respondents' 'rarely reconsidering the use of alternative modes for work-related travel' ($\chi^2 = 9.036$ (2), $p = 0.011$). Whilst equal proportions of PMV and PT/AT users agreed to rarely reconsider the use of alternative modes for work-related travel, PMV users were more likely to disagree with that statement. Over 52% of respondents across all mode types agreed to 'rarely reconsider their choice of mode'. This finding could be explained by the presence of habitual behaviours from routine commuting, or mode preference, a liking for one mode over others, resulting in little consideration on other available transport options (Verplanken et al., 2008). Alternatively, factors such as an individual's income or existing transport infrastructure may limit the availability of mode choices (options) and in turn, a respondent's ability to consider using alternative transport modes for work-related travel (Zafri et al., 2021).

Additionally, a statistical relationship was found between mode choice and the 'chosen mode being the respondents only available travel option for work-related travel' ($\chi^2 = 33.841$ (2), $p = 0.000$). For example, respondents who (strongly/somewhat) agreed that their main mode of travel was their 'only available travel option' were more likely to be PMV users (64.1%). Whilst 69% of all PT/AT users strongly/somewhat disagreed that it was their only available travel option for work-related travel.

Finally, a statistical association was identified between mode choice and reconsidering their choice of transport during different weather conditions (Chi-square = 1.434 (2), $p = 0.488$). Overall, 76% of all respondents strongly disagreed with the statement, by similar proportions of PMV and PT/AT users.

4.2.1. Mode choice

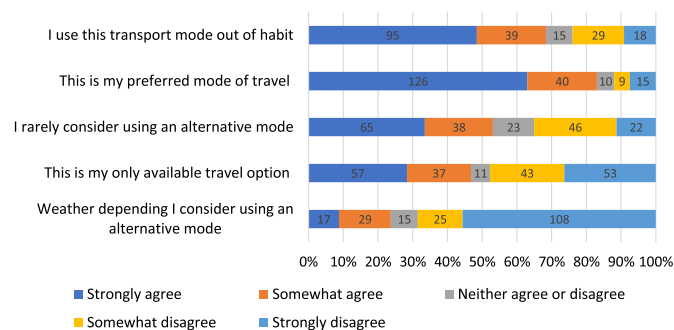Respondents were asked to rank their level of comfort when using different transport modes for commuting based on the conditions of COVID-19 at the time of this study.

As shown in Fig. 6, the weighted ranking scores[1] indicated that private motor vehicle was the most preferred mode of travel at the time of the data collection (29th June–24th July 2020). This was expected as it would reduce the chances of infection from contact with non-family members. Cycling and walking ranked 2nd and 3rd, respectively. Shared or public-transport modes including lift-share, taxi and public transport were the least preferable modes for work-related travel during the pandemic, respectively. The ranking position of lift-sharing could be explained as individuals might know their respective travel partners, when compared to taxi or public transport use. In line with UK government guidelines to avoid public transport use at the time, public transport was perceived to have the highest risk of infection by the sample and provided evidence in support of reduced public transport use and mode shift to lower risk modes, such as private motor vehicles and cycling, during the pandemic for work-related travel.

Under the conditions of the pandemic, the modal demand of public and shared transport can be expected to decrease due to a higher perceived risk of infection by COVID-19 thus supporting Danczyk et al.'s (2017) "avoidance phenomenon". In contrast to other disruption studies, the avoidance of specific modes is usually supported by avoiding anticipated increases in journey times (Shires et al., 2019; Spyropoulou, 2020).

4.3. Immediate impact of the COVID-19 lockdown

4.3.1. Commuting to work and working from home

During the lockdown, 20.4% ($N = 43$) of the sample continued to commute to work at least once a week. The majority of those respondents (67%; $N = 29$) who continued to commute to work at least once a week were managers, directors and senior officials or had professional occupations. Overall, there was a 48.8% reduction in respondents' commuting to work five days per week pre-lockdown (54.5%) and during the lockdown (5.7%) (see, Fig. 7). The fall in traveller demand and, in turn, traffic volume conforms to Danczyk et al. (2017) findings following unexpected disruptions. The remainder of the sample did not commute to work (79.6%) during the lockdown.

Out of the 172 respondents who did not travel to their workplace during the lockdown, 81.5% worked from home at least once a week, which is a 34.1% increase when compared to the proportion who worked from home at least once a week before lockdown (47.4%).

Fig. 8 indicates that the proportion of the sample that worked five days per week increased by 45% under the conditions of COVID-19, resulting in the average number of days working from home to increase from 0.8 days to 3.7 days per week. A paired sample *t*-test confirmed that there was a statically significant difference between the mean number of days individuals worked at home before and during the pandemic ($t = -15.926$; $p < 0.05$).

The increase in days worked from home and the proportion of the sample able to work from home (82%) suggests that the sample population had a high adaptive capacity under the absence of travel during lockdown (Marsden et al., 2016). This was further confirmed as 44% and 35.5% of the sample stated they were able to continue with their usual workload or slightly less than usual when working from home, respectively. However, the level of adaptive capacity was not equal across the sample as 8.2% of respondents stated difficulties working from home because of their occupation type or explained by respondents as an impact of home-schooling and childminding during the pandemic.

Fig. 5. Respondents' habits, preferences, and the reconsideration of alternative modes, across all mode choices ($N = 211$).

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[1] Weighted ranking score = (top ranked mode is given a score of 6 x the number of times chosen as top) + (second top ranked mode is given a score of 5 x number of times chosen as second top) + …; 6 corresponds to the number of modes available.
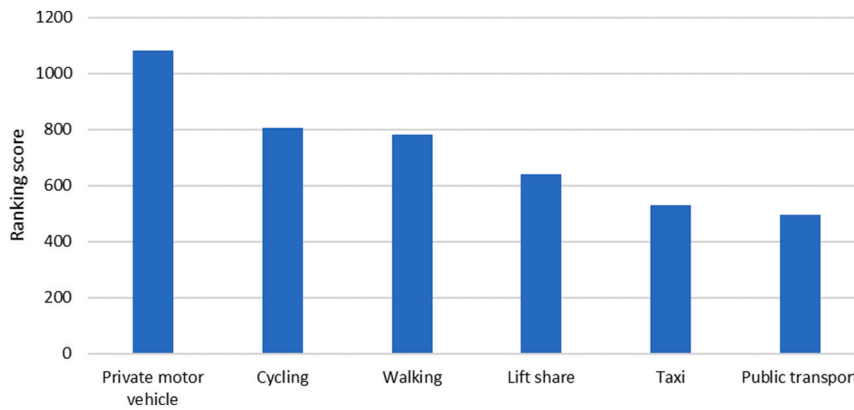
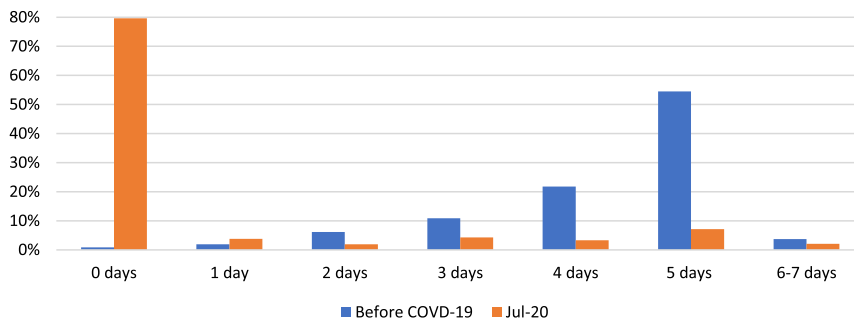**Fig. 6.** Weighted ranking scores of preferred transport mode during the COVID-19 pandemic (June–July 2020).

Fig. 7. Typical number of days commuting to the workplace before and during the lockdown.
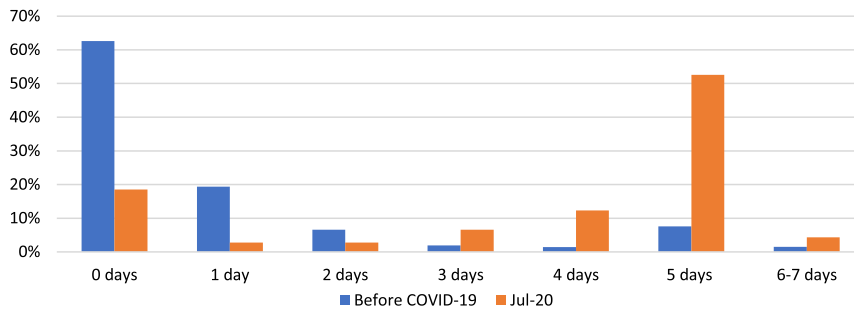

Fig. 8. Average days worked from home.

4.3.2. Mode choice and shifts

As shown in Table 3, of the 40 respondents who continued to commute to work at least once a week during the lockdown, 75% did not change their main mode of transport. The respondents who changed their mode of transport, 12% shifted from train (prior the pandemic) to bicycle and private motor vehicle (during the lockdown).

Similarly, as before the pandemic, private motor vehicles remained the predominant mode choice for work-related travel during the lockdown followed by cycling. Meanwhile, public transport use fell by 98%

when compared to users during (1) and riders before (52). The reduction in train ridership corresponds to the Department for Transport's (2020b) statistics, which state that rail and tube usage within the UK went down by 95% between April and June 2020, during the peak of the pandemic. The sample indicates that COVID-19 generated a greater decline in train use (98%) within the Cardiff Capital Region, when compared to the 50% reduction in train and underground ridership during the peak of the SARS outbreak in Taiwan (Wang, 2014).

4.4. Expected impacts of COVID-19

4.4.1. Future travel frequencies

As shown in Fig. 9, the proportion of respondents who regularly commuted to work four and five days per week would be expected to decrease by 11.4% and 35.3%, respectively, when compared to the commuting frequency before COVID-19. Whilst the intended frequency of commuting to work 0–3 days a week within the sample is expected to increase by 26.6% after the pandemic.

The results from a *t*-test indicated that, at a 95% confidence level,

Table 3
Respondents' modal shift before and during lockdown.

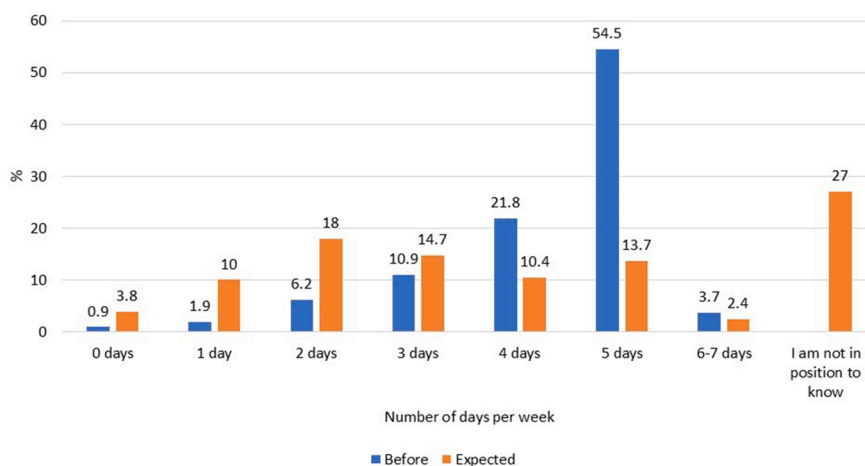| Mode (before)	Mode change (during)			
	Car or van	Train	Bike	Total
Car or van	27	–	1	28
Train	4	–	1	5
Bike	–	–	7	7
Total	31	0	9	40

Fig. 9. Respondents' number of days commuting to work before the pandemic and expected number of days.

there was a statistically significant difference between the mean number of days per week respondents commuted to work before the pandemic (4 days) and the intended frequency after the pandemic (2.9 days) (*t*-test = −11.863; *p* = 0.000). The intended reduction in work-related travel following COVID-19 was supported by the high proportion of respondents (79%) who agreed to the statement "the opportunities of working from home may reduce the frequency of work-related travel in future for my occupation". This can be explained by national statistics which highlight that higher professional roles were more likely to have opportunities to work from home than elementary occupations (Official National Statistics, 2020b). Notably, this sample has an uneven ratio of predominately higher-level occupation types (see, Section 4.1).

Despite the preferences of working from home within the sample, factors such as the flexibility of employers to support home-working and occupation type may affect the intended reduction in travel frequencies developing after COVID-19 (Marsden et al., 2016; Shires et al., 2016). However, 39.8% of the sample believed it was very unlikely or somewhat unlikely to continue travelling with the same frequency for work as before the pandemic. This is a significantly higher proportion than the 8% who believed it was unlikely their previous commuting frequencies would return following the Forth Bridge Closure (Shires et al., 2016). The higher level of certainty within the sample could be explained by two respondents who provided additional comments that working from home during the lockdown offered "a better work-life balance especially in professional and remote services". However, the "necessity for travel is still necessary" but likely to be reduced to a "couple of journeys per month" instead of weekly travel with destinations varying based on meetings.

4.4.2. Expected mode choices

Table 4 indicates that private motor vehicles remained the main

choice of travel to work-related travel. However, private motor use intentions within the sample are expected to increase by 2.3% post-COVID-19. Similarly, the proportion of active travel users is expected to increase, from 13.7% to 22.7%, by a greater proportion than by private motor vehicle. Meanwhile, future public transport ridership is expected to decrease within the sample by 11.4%, with 6.6% of users intending to shift their main mode of transport to private motor vehicle and 5.2% to active travel. The intended shifts could be explained by the changed perception of preference and risk of infection attached to public transport, analysed earlier.

Similarly to other disruption studies, 'active travel loyalty' has been identified, as all active travel users intend to maintain their main mode of choice following the pandemic (Khan & Habib, 2018). Table 4 also highlights that some private vehicle users prior to COVID-19 intend to shift to active travel following the pandemic. The expected shifts could be explained by the lockdown travel restrictions, which disrupted routine and habitual travel choices, to provide an opportunity for individuals to reconsider their main mode of transport to work, thus aligning to Verplanken et al.'s (2008) habitual discontinuity theory.

Table 5 provides evidence that the pandemic may have encouraged respondents to reconsider their main choice of transport. The results from a Chi-square test indicated a significant difference between mode choice before the pandemic and individuals reconsidering their future mode choices (*p*-value = 0.01 < 0.05). Notably, similar proportions of public transport and private motor vehicle users stated they either strongly or somewhat agreed that the pandemic had made them reconsider their main mode of transport for work-related travel. Having said this, one respondent reported 'a change in modal use from public transport to a private motor vehicle because of moving to a new house amidst the pandemic and limited access by different modes between their new home and workplace'.

Table 4
Mode choice before vs. expected mode choices after COVID-19.

Mode choice before	Expected mode choice after			
	Private motor vehicle	Public/shared transport	Active travel	Total
Private motor vehicle	111 (52.6%)	1 (0.5%)	8 (3.8%)	120 (56.9%)
Public/shared transport	14 (6.6%)	37 (17.5%)	11 (5.20%)	62 (29.4%)
Active travel	0 (0.0%)	0 (0.0%)	29 (13.7%)	29 (13.7%)
Total	125 (59.2%)	38 (18.0%)	48 (22.7%)	211 (100%)

Significant difference. Chi-square = 228.706 (df = 4), *p*-value = 0.000.

Table 5
Reconsideration of mode choice because of COVID-19 (*N* = 205).

Mode choice (Before)	To what extent do you agree with the statement: I have reconsidered my main transport mode			
	(Strongly/somewhat) Agree	Neutral	(Strongly/somewhat) Disagree	Total
Private motor vehicle	28 (13.7%)	15 (7.3%)	72 (35.1%)	115 (56.1%)
Public transport/active travel	39 (19.1%)	12 (5.9%)	39 (19.0%)	90 (43.9%)
Total	67 (32.7%)	27 (13.2%)	111 (54.1%)	205 (100.0%)

Significant difference. Chi-square = 9.036 (df = 2), *p*-value = 0.011.

4.5. The way forward

4.5.1. Geographical context

Geographical context was highlighted as a barrier preventing respondents from reconsidering alternative transport due to "very few choices" other than private motor vehicles. Fifty-seven percent (57%) of respondents provided additional comments concerning the quality of public and active travel infrastructure.

Four respondents focused on issues surrounding the 'frequency', 'timetabling' and 'doubled journey times' of public transport when compared to the private motor vehicle use. In turn, preventing further use of public transport within the sample. One respondent stated: "public transport is not practical for work-types with varying work times set by meetings and appointments… and [to visit] several varied locations in one day". This importantly highlights how future public transport improvements should respond to changing work patterns, to secure a low-carbon future within the Cardiff Capital Region.

Additionally, cycling infrastructure concerns could be hindering greater use of active travel as a main mode of transport. This can be exemplified by one respondent who believed they could cycle to work but "the roads are far too busy and dangerous". This view was similarly shared by an experienced cyclist, who switched from cycling three (3) days a week to 100% bike use, stating that "[Whilst] I am confident on the road with traffic around me, this [cycling every day] has shown that the cycling infrastructure requires improvement". Additionally, another cyclist emphasised how cycling "saves time [and] keeps me fit" but had concerns about "0 plans to link Cardiff Cycle paths". These concerns could explain the questionnaire results which indicate that 40.7% of the total sample or 61% of all transport users who answered the question and stated that the quality of cycling infrastructure was 'bad' or 'extremely bad'.

Despite the on-going impact of COVID-19, respondents reflecting on the need for public and active travel infrastructure improvements suggests an interest in use and explains the low proportions of public and active travel users within the sample, compared to a private motor vehicle, before the pandemic. Additionally, it highlights the difficulties for the area to overcome a car-dependent recovery from COVID-19 with the infrastructure's existing quality.

4.5.2. Attitudes towards different modes

Fig. 10 shows that 85.8% of respondents strongly or somewhat agreed that under the conditions of the pandemic, they preferred to travel by private car than by public transport. Similarly, 83.2% of the sample population stated that they strongly or somewhat agreed to avoid the use of public transport for a while following the pandemic, indicating a potentially slow recovery of public transport ridership. Whilst 62.4% stated they would prefer to exclusively use private travel. These claims can be supported by one respondent who stated "[I used to use a] combination of bike and train to travel to London. I will be re-thinking train use in the future, sadly".

Interestingly, 37.9% of participants agreed to have reconsidered cycling as a mode of transport for work-related travel during the pandemic. This provides supporting evidence to Marsden and Docherty's (2013) study, which suggests that disruptions can provide an opportunity for positive, sustainable travel futures. However, the low proportion of individuals that reconsidered cycling could be explained by trip distances, and poor active travel infrastructure as highlighted above.

There were no statistically significant associations identified between the socio-demographics of respondents (e.g. age, gender, household composition or educational levels) and their attitudes towards favouring the use of private travel and future avoidance of public transport for work-related travel. This was also the case for those who reconsidered the use of cycling during the pandemic. The results similarly resonate studies by Zanni and Ryley (2015) and Abad et al. (2020), which reported that age, gender and educational levels have no statistical influence on adaptive travel behaviours when faced with an unexpected transport disruption.

Additionally, the association between mode choices before the pandemic and attitudes towards modes were analysed. The results in Table 6 identified a statistical association between mode choice and preferences of private vehicle over public transport ($p = 0.019$). Additionally, a statistical association was identified between mode choice and the reconsideration of cycling, and between mode choice and future exclusive use of private car. Meanwhile, no statistical association was identified between mode choice and avoidance of public transport ($p = 0.062$), suggesting mutual concern across all transport users.

4.5.3. Departure times

Respondents recalled their departure times before COVID-19 and stated their future departure times after the pandemic between their home and the workplace. Fig. 11 indicates that hours commuting from home to work are expected to remain similar to departure times before COVID-19, between the hours of 6:00 and –9:00, within the UK's national weekday peak travel hours (Department for Transport, 2017). However, 7.7% of respondents indicated intentions to travel after peak travel hours following the pandemic, whilst 13.3% indicated future departure time uncertainty. Following a Chi-square test, a statistical association was confirmed between departure times to work, before and after the pandemic ($p = 0.000$).

Similarly, the results from a Fisher's exact test identified a statistical association between the start commute times from work to home, before and after the pandemic ($p = 0.000$). Fig. 12 indicates that commute hours from work to home remain similar, before COVID-19 and after, between 15:00–19:00. However, there is an expected 5.2% increase in the proportion of the sample returning home at an earlier time between 15:01–16:00. This may suggest that fewer hours are necessary at the office, given expected increases in the number of days working from home in the future. The expected increase in days working from home could also explain why 14.2% of respondents were unable to comment on their future departure time intentions or as a result of structural
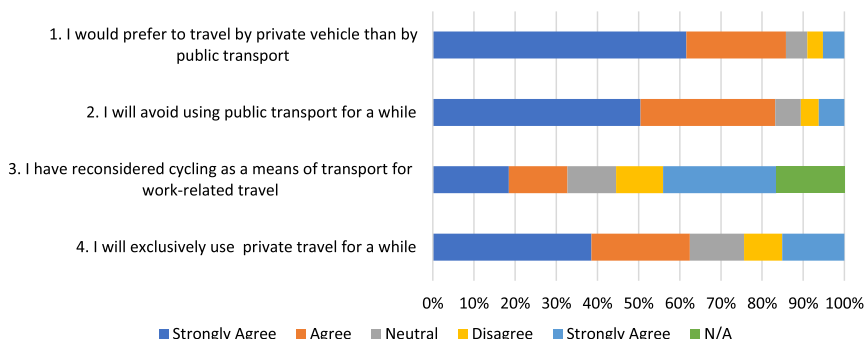

Fig. 10. Impact of COVID-19 on attitudes towards modes.

Table 6
Socio-demographics, mode choice and attitudes towards modal statements.

Attitudes towards modes during the pandemic	Gender	Employment status	Education	Household size	Age	Mode choice
I would prefer to travel by private vehicle than by public transport.	3.518 (2); 0.172	0794 (2); 0.672	1.792 (2); 0.408	4.543 (2); 0.103	3.864 (4); 0.425	**11.872 (4); 0.019**
I will avoid using public transport for a while.	1.844 (2); 0.398	2.455 (2); 0.293	0.611 (2); 0.737	1.627 (2); 0.443	3.059 (4); 0.548	**8.983 (4); 0.062**
I have reconsidered cycling as a means of transport for work-related travel.	3.650 (2); 0.161	1.045 (2); 0.593	0.802 (2); 0.670	0.928 (2); 0.629	2.673 (4); 0.614	**12.629 (4); 0.013**
I will exclusively use private travel for a while.	0.397 (2); 0.820	0.082 (2); 0.960	0.355 (2); 0.837	0.877 (2); 0.645	4.529 (4); 0.339	**46.385 (4); 0.000**

Numbers in the table indicate 'Chi-square test (d.f.); p-value'.
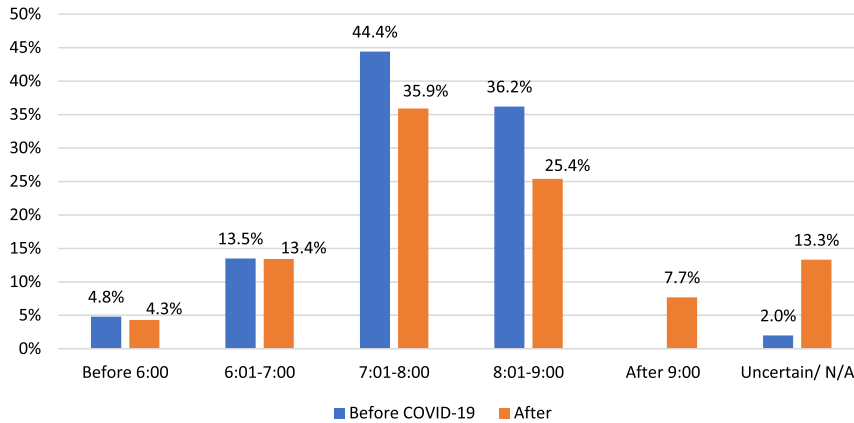Fonts in bold indicate a significant association at 99% confidence level.

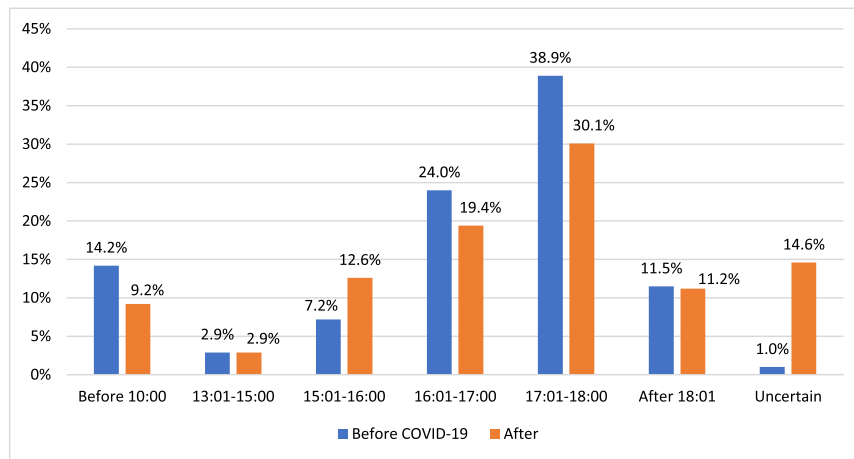**Fig. 11.** Departure times from home to work.

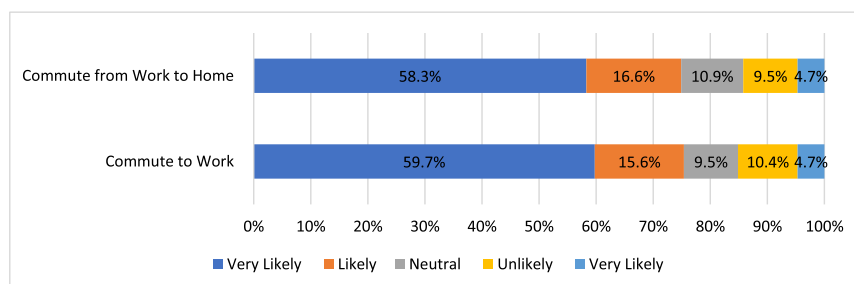**Fig. 12.** Departure times from home to work.

Fig. 13. Likelihood departure times are to be the same time as before the pandemic, after the pandemic $N = 211$.

employment changes, such as redundancy and retirement during the pandemic.

Overall, the pandemic is unlikely to affect departure times between the workplace and home, as travelling is expected to remain within the peak morning and evening travel hours. The results in Fig. 13 provide further evidence, as 75.4% and 74.9% of respondents stated that they were very or somewhat likely to start their commute from home to work, and work to home at the same time as before COVID-19, respectively. The similarity in departure times between before and after the pandemic supports the inflexibility for late arrivals and hours of the working day for work (Abad et al., 2020). But findings also suggest that commuters anticipate no additional time travel delays when returning to the workplace. This can be expected as the nature of the disruption does not have a 'spatial' scale which affects the supply of transport or restricts access to locations, unlike the implications of a road or station closure (Spyropoulou, 2020). Thus, reducing the likelihood of route or traffic flow changes when traffic flows return after the pandemic.

Having said this, the negative perceptions of public transport and intended shift to private travel for work-related travel, as previously mentioned, could result in traffic conditions changing. For example, a decrease in mean speeds, traffic flows and travel times (Spyropoulou, 2020), particularly if these intended modal changes become permanent instead of temporary travel adaptions as a result of COVID-19. Notably, given the prolonged nature of the disruption, there is an increased chance for permanent modal shifts (Marsden et al., 2016).

5. Conclusion

This study was aimed to capture evidence from Wales, UK and in particular, its capital's region, on travel behaviours before and during the COVID-19 pandemic including intentions under post-pandemic conditions. To provide an insight into the likelihood of a car or sustainable transport recovery; a direction for transport policies in support of low-carbon transport and to highlight possible barriers, which may affect the future of sustainable transport within the Cardiff Capital Region and beyond.

The results identified that the greatest, immediate impact COVID-19 had on individual travel behaviours was on the frequency of work-related travel and days worked at home per week. Respondents indicated to a high level of certainty that reduced work-related travel and increased days worked from home could be a long-term outcome of COVID-19. This was confirmed by a statistically significant difference between travel frequencies before COVID-19 and expected future travel frequencies after. Notably, the proportion of respondents travelling to work five days per week is expected to fall by 35.4% when comparing travel frequencies to before and expected frequencies after the pandemic.

The permanence of modal shifts identified and reduced future use of public transport is uncertain. Particularly, as the pandemic is on-going, enabling current attitudes towards public transport based on COVID-19 subject to change. However, it can be expected that in the long-term, following the pandemic that public transport ridership levels will return, as evidenced by Wang (2014) study, which identified that underground ridership recovered after zero cases of SARS. The Department for Transport's (2020b) recent statistics provides supportive evidence that public transport ridership levels are beginning to recover, with bus ridership at 52% and train at 35% of its capacity before the pandemic. However, recovery should be expected to be slow as 83.2% of respondents strongly agreed and somewhat agreed to avoid the use of public transport, for work-related travel, for a while following the pandemic.

Given the prolonged nature and impact of COVID-19, there is an increased possibility that temporary and intended changes in travel behaviours by the respondents could become permanent (Marsden et al., 2016). Notably, respondents' preferences towards private motor vehicles and intended shift suggest 59.2% will use private motor vehicles as their main mode of transport following COVID-19. Whilst the intended use is not as detrimental as it could be, with 82% of the sample claiming to have access to a car for work-related travel, this does indicate a predominately car-based recovery. In turn, this will likely re-enforce car dependency, which was high before the pandemic, within the Cardiff Capital Region.

The intended increase in active travel use and potential reduction in future travel frequencies should not be relied upon to secure a low-carbon future within the Cardiff Capital Region. Thus, it is urged that policymakers' aim to relieve the predicted car-dependent recovery within the Cardiff Capital Region to reduce the generation of associated negative externalities of car travel.

As suggested from the study's findings, improvements to public transport and active travel infrastructure are required. These improvements will be important to increase the accessibility and convenience of public transport, to re-encourage intended shifts back from private vehicles after the pandemic. Additionally, improvements would help to secure permanent behavioural changes for those who shifted to active travel during the pandemic and encourage those who would like to or intend to shift. This could be achieved through the revision and maintenance of existing active travel plans within and between counties, under the existing Active Travel Act (2013) Wales. Sung and Monschauer's (2020) study supports and evidences that improvements to cycling infrastructure following the London public transport bombings encouraged a 2.5% long-term increase in cyclists.

Additionally, a local policy recommendation would be to push forward the dates of the existing plans for the Cardiff Congestion Charge (2024) to help reduce existing car-dependency (Cardiff Council, 2020). This is because Marsden and Docherty's (2013) research highlights that disruption periods can provide a tractable opportunity for changes in transport policies, which radically support a low carbon change. Thus, to overcome potential increases in congestion and parking space demand, which could result in the policy implication of reversing progress already made through the Clean Air Cardiff Project, the recommendation of implementing the Congestion Charge sooner can be justifiably supported (Cardiff Council, 2020). The focus on Cardiff, specifically, is justified as 72% of the sample commute to Cardiff for work.

Furthermore, the expected increase in single-occupancy car use for office-based workers during and following the pandemic could result in transport-related policy implications for employers and their existing work-place travel plans. More specifically, it could be predicted that there will be an increased demand for office-based parking, as the research findings indicate that public transport use and car-pooling were less favoured modes for work-related travel, under the conditions of COVID-19. In turn, reduced parking access and potentially increased congestion could act as a barrier to workers to travelling to work, creating financial costs employers may need to absorb (Santos et al., 2020). Thus, employers will need to revise work-place travel plans to re-encourage sustainable transport use, including investment into secure bicycle parking facilities for employees, to maintain and encourage further active travel use. Additionally, office-based employers may need to reconsider options for flexible hours for employees, to overcome possible issues associated with reduced public transport capacity whilst social distancing measures are in place.

This research was undertaken following the first wave and peak in coronavirus associated deaths and infections. Since this research, the UK has undergone two additional lockdowns. In turn, there is an increased chance that changes in travel behaviours indicated, at the time of this research, may become permanent. For example, the 12% of the sample who shifted from train use to private car and active travel use for work-related travel during the lockdown. The main route for future research would be to re-conduct this study using a different case study area or after the pandemic disruption period to assess whether travel behaviours induced by COVID-19 were temporary or permanent. This information would be particularly insightful for local councils to understand whether recent and on-going improvements to active travel infrastructure, such

as the extensions of temporary pavements and cycle lanes installed because of COVID-19, had successfully encouraged and maintained users.

5.1. Study limitations

Given the circumstances under which this research was undertaken, it does not come without limitations. Convenience sampling was deemed appropriate given the requirement for rapid survey deployment and governmental restrictions, such as social distancing during the survey collection period.

The sample under-represented Cardiff's part-time employees. A possible explanation for the larger proportion of full-time working respondents and respondents with higher-level occupations, professional and managerial positions, specifically, were that these workers were less likely to lose their jobs or be furloughed during the pandemic and more likely to have increased access to work emails and opportunities to work from home. The latter increased the ability of those respondents to participate in the survey. The lower proportions of those below 35 and above 65 years of age could be explained by the respondents' occupation type and those who were more likely to commute. Having said this, the sample was of adequate size to support the internal consistency of the analysis, and thus to be able to test associations and obtain a feel of perceptions and intentions of typical office full-time workers, especially of people in professional and managerial positions.

Another limitation of this study was that individuals were asked to state their future travel intentions following the pandemic, which were then used to predict the long-term impact of COVID-19 on travel behaviours. This is a limitation because the stated intentions relied on respondents to make unbiased estimates on their future travel behaviours (Shires et al., 2019). Additionally, the accuracy of stated intentions is likely to be limited as travel behaviours have a temporal nature. Thus, as the disruption was on-going after the data collection period, there is a possibility that social norms, the respondent's attitudes, and circumstances (e.g. employee flexibility) may change (Marsden et al., 2016). In turn, this could result in a respondent's actual travel decisions (e.g. mode choice) following the pandemic, to differ from their stated intentions. Thus, this study must be viewed as a snapshot of the Cardiff Capital Region, resulting in generalisations from the study to be limited and restricted to long-term predictions.

CRediT authorship contribution statement

Charmaine Angell: Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. **Dimitris Potoglou:** Conceptualization, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

We have no conflicts of interest to disclose.

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