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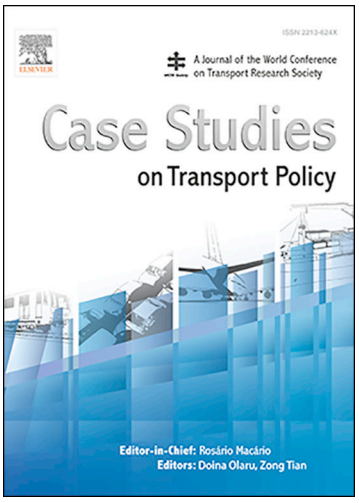

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The Application of Travel Demand Management Initiatives within a University Setting

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1. Introduction

A travel plan is a voluntary based mechanism for delivering transport measures in an area in response to site-related issues, such as car parking pressures, site access limitations and localised traffic congestion to encourage greater use of more sustainable forms of transport including walking, cycling and public transport (De Gruyter et al., 2018; Enoch, 2012; Sweet and Ferguson, 2019; Vanoutrive, 2019). Travel plans can be developed for different environments where large numbers of individuals travel daily to and from including offices, schools, universities and hospitals (Cairns et al., 2010; Curtis and Holling, 2004). Successful travel plans can have significant health benefits, such as improved positive mental health, decreased risk of cardiovascular diseases, improved weight status and decreased mortality (Bopp et al., 2018; Hamer and Chida, 2008; Martin et al., 2014; Norwood et al., 2014; Pucher et al., 2010). However, in recent years, environment and climate policies have encouraged universities to carefully consider the role transport plays in greenhouse gas (GHG) emission production during commuter periods and to come up with solutions to reduce their negative environmental impacts (Cherry et al., 2018).

One solution is to encourage sustainable travel choices through the introduction of travel demand management (TDM) initiatives in travel plans via the workplace, giving employers the unique ability to influence the travel behaviour of large numbers of commuters (Rosenfield et al., 2019). Meyer (1999) defined TDM initiatives as an *'action or set of actions aimed at influencing people's travel behaviour in such a way that alternative mobility options are presented and/or congestion is reduced'.* TDM initiatives encompass the desire to optimise transportation systems for commuters through enhanced accessibility, predictability, information, choice and system performance (Mahmood et al,. 2009). TDM initiatives have been considered to work well within areas of high commuter traffic for three main reasons. Firstly, work places that have introduced TDM initiatives often have the administrative resources to centrally manage a co-ordinated series of benefits and policies (ICF & CUTR, 2005). Secondly, the employee population represents a community of like-minded individuals who are likely to act together which influences the way they commute ensuring a self-sustaining system (Hendricks, 2005). Finally, employers must pay for parking, either directly or through employee contributions, so there is a built in incentive to reduce parking demand.

TDM initiatives have begun to feature predominantly in transport planning and programmes over time, however an understanding of the role and influence of TDM initiatives within a university context is still emerging, particularly in low congestion zones within small and medium sized cities (Akar et al., 2012; Eriksson et al., 2006; Shannon et al., 2006; Sweet and Ferguson, 2019). TDM initiatives within a university setting have the potential ability to influence tens of thousands of commuters, many of whom are students who are likely to develop longer-term positive travel behaviours (Busch-Geertsema and Lanzendorf, 2017; Sweet and Ferguson, 2019). This is of interest to universities as students will be the leaders, policy makers, scientists, consumers, researchers and entrepreneurs and future decision makers (Rodrigo Lozano, 2006; Vicente-Molina *et al,.* 2013; Waas *et al,.* 2010; Zilahy & Huisingh, 2009), and may continue to travel sustainably after leaving education (Balsas, 2003; Curtis & Holling, 2004). Therefore university strategic travel plans provide an opportunity to create factors that impact and influence the travel behaviour of students and employees (Rye, 2002), whilst satisfying the needs

of current and future generations who may lead the change towards travel sustainability (Rodrigo Lozano *et al,.* 2013). However university systems often reinforce seniority, for example staff having priority over parking permit allocation, therefore reasonable alternatives need to be implemented to ensure TDM initiatives are going to be an effective tool to combat traffic congestion (Rodier et al., 2014; Shoup, 2017).

To evaluate the success of TDM initiatives in travel plans in the workplace, this study focuses on the results of a travel plan implemented between 2006 and 2016 at the University of Aberdeen (UoA), Scotland. Staff and students' daily commutes were analysed separately to enable consideration of disparities in socio-economics and lifestyles. During this ten year period, a travel survey was undertaken on a biennial basis with seven TDM initiatives introduced at both university campuses: King's College campus, situated over 35 hectares lying two miles north of Aberdeen's city centre and Forresterhill campus located adjacent to NHS Grampian facilities covering 41 hectares. Both campuses are situated in Aberdeen's central business district (CBD). The paper begins by discussing a review of the literature relating to different university experiences with TDM initiatives implemented for staff and students (**Sections 1.1 – 1.3**) before describing the specific TDM measures introduced at UoA (**Section 1.4**). The next section introduces the travel survey methodology and approach to analysis (**Section 2**). Analysis focuses on four key areas: comparison between staff and students, year, age categories, distance travelled and gender to evaluate the TDM initiatives. In the analysis, a weighted index of TDM initiatives effectiveness was derived. This index was modelled with age group, year of survey and the implemented TDM initiatives as a continuous variable between 0 and 1 based on environmental impact, with 1 being the most environmentally friendly method and 0 being the most environmentally damaging (**Section 3**). The successes and lessons learned through the application of these initiatives at a university level are discussed (**Section 4**).

1.1 Travel demand management in universities: A review of the evidence

Travel plans have become an important part of policy in several European countries and represent an emphasis on managing infrastructure, encouraging sustainable and active

travel and discouraging conventionally fuelled vehicle (CFV) use (Eriksson et al., 2010; Rye et al., 2011). However, for many years CFVs have occupied a central place in the mobility and lifestyle of adults and have *'reshaped citizenship and the public sphere via the mobilisation of modern civil societies'* (Ortar *et al,.* 2018; Sheller & Urry, 2000). Although parking cost is often considered one of the most powerful TDM initiatives and is frequently used within university campuses (Bond and Steiner, 2006; Cherry et al., 2018), individuals who behave habitually are less willing and interested in sustainable alternatives which can be more advantageous in terms of time and cost (Busch-Geertsema and Lanzendorf, 2017; Gärling and Fujii, 2009; Verplanken et al., 1998). Cairns et al (2010) stated that organisations which had constrained workplace parking or increased parking costs reduced the modal share of driving to work by an average of ~25%. Through a combination of education, increased awareness and modifying attitudes through TDM initiatives a modal shift away from CFVs may be achieved (Piras *et al,.* 2017).

Universities are major trip attractors that require the infrastructure needed to support large volumes of commuters on an almost daily basis (Whalen et al., 2013). Therefore, with the correct implementation of TDM initiatives in travel plans, alternative modes of transportation can become more enticing, whilst reducing carbon emissions from transport. TDM initiatives can be classified into two broad types: 'pull' and 'push' measures (Gärling et al., 2002). 'Pull' measures increase the attractiveness of sustainable travel modes and are often considered more appealing because they influence the cost or improve the quality of a service (Eriksson et al., 2008; Sweet and Ferguson, 2019; Taylor, 2006). For example, a study of Kyoto university students in Japan who regularly commute using CFVs who were given a free one month bus pass demonstrated that the habits and frequency of bus use increased during the study period, with CFV use decreasing after the intervention period (Fujii and Kitamura, 2003). The study suggests temporary structural changes may be important for converting drivers towards public transport. Alternatively, 'push' measures encourage individuals to avoid individual car travel modes by making them less attractive through increased costs or less convenient. For example, increasing parking fees whilst simultaneously reducing the number of

available spaces aiming to make it less practical for individuals to drive. However, Riggs (2015) suggests that TDM initiatives cannot be used in isolation and should be implemented in parallel with outreach and marketing which provides individuals with alternatives that work for them personally and resonate with them emotionally (Litman, 2018). Furthermore, the acceptability of TDM initiatives is important to determine whether they will modify travel behaviour and be successful (Eriksson *et al.,* 2006). Evidence suggests that non-coercive 'pull' TDM initiatives are often more acceptable to the public than coercive 'push' measures (Gärling and Schuitema, 2007; Steg et al., 2006). This is likely because 'pull' measures do not necessarily limit an individual's freedom. In addition, if an individual perceives a TDM initiative to be unfair, then there may be opposition from the public regarding their introduction (Gärling and Schuitema, 2007). Previous studies have demonstrated that there is a correlation between perceived fairness and acceptability (Bamberg and Rölle, 2003; Jakobsson et al., 2000). At network level, the impact of travel plans with TDM initiatives is not clear since trips removed may be replaced by others that were previously suppressed by congestion (Rye, 2002). To ensure TDM initiatives and travel plans work in partnership, site-specific problems with congestion, parking and/or transport-related staff recruitment need to be addressed (Ison & Rye,. 2008).

With the recent COVID-19 pandemic, universities have begun adapting their current teaching styles over 2020 which may influence transport choice going forward as a greater incidence of working from home will also be beneficial in terms of reducing travel and transport emissions. As of March 2020, the UK Government's lockdown measures (as in many countries) limit unnecessary transport and actively encouraging individuals to work from home where possible. The move to online teaching in universities is expected to be maintained with a likely mix of small group teaching and online lectures through to summer 2021. Since both staff and students may not need to travel to and from their university this could have lasting impact on future travel choices and subsequent repercussions for transport emissions. For example, with an increased incidence of working from home someone who previously travelled to campus each day by public transport may in future only visit campus twice a week and decide to travel by

private car. Following lockdown public transport patronage plummeted by as much as 95% in some cities worldwide and it is not clear how quickly (or how far) patronage will recover. As restrictions on travel are lifted, public transport operators and authorities have moved to ensure public transport is safe to use through reduced capacity on buses and trains to ensure social distancing, messaging via Apps to aid decision making about when to travel and improved sanitisation. In parallel, an uptake in private vehicle use is already being witnessed because of the biosecurity fears associated with public transport use. As the UK Government continues to encourage social distancing, it is important that significant behavioural changes and TDM initiatives are implemented as soon as possible to ensure that cities do not return to pre-COVID-19 levels of traffic congestion. Utilising initiatives such as cycling barriers and closing streets to private vehicles, active travel can be encouraged to highlight the benefits of a low cost convenient transport option.

1.2 Student commuter behaviour

The introduction of push and pull measures in smaller or medium sized cities are yet to demonstrate large behavioural shifts if driving is already convenient and congestion levels are low (Hafezi et al., 2018; Riggs and Kuo, 2015; Rivadeneyra et al., 2017; Rodier et al., 2014). Furthermore, student populations are already less likely to commute by CFVs as they live closer to the university than faculty due to university student housing and accommodation provision (Akar et al., 2012; Páez and Whalen, 2010). Fewer young people are sitting their driving test; in Scotland, for example, 36% of men (out of 4,360) and 26% of women (out of 5,210) aged between 17 and 19 passed their driving test in 2016, compared to 32% of men (out of 6,056) and 28% of women (out of 8,019) in 2006. Between ages 20 and 29, 58% of men and 53% of women had passed their driving test (Transport Scotland, 2016).

Students tend to have lower incomes, so travel is constrained by costs and influenced by work and other commitments additional to university study leading to complex travel patterns (Curtis & Holling, 2004). Delmelle and Delmelle (2012) believed that students prioritise money and thus by raising the price of parking permits, a decrease in the number of student drivers would occur. However, increasing the price of parking permits, can lead to increased off-campus parking in surrounding streets, neighbourhoods, or the parking facilities of local businesses (Delmelle & Delmelle, 2012). Such parking behaviour serves to undermine a university's efforts to reduce the use of CFV use (Tolley, 1996) and emphasises the need for a neighbourhood level approach to TDM. Conversely, the cost of travel may push individuals to choose more sustainable travel options thus providing opportunities for public transport operators to respond with promotional offers.

Klöckner and Friedrichsmeier (2011) argued that the mode of transport chosen by university students was influenced by situational and psychological factors. Situational factors include the availability of infrastructure by mode, public transport accessibility, trip characteristics and cost, whereas psychological factors included the individuals' intentions, belief, norms and attributes. Collins and Chambers (2005) established that mode-specific cost, time (distance), and access (especially public transport proximity) and

environmental awareness all influenced transport choice. This suggests that students may make a more conscious decision when it comes to transport choice. Jackson and Howton (2008) concluded, through a pedometer intervention, that students were more likely to walk to their main campus. Students saw the health benefits, and the number of steps taken increased throughout the study period as they aimed to better themselves. Of the 326 participants more than 70% commuted 30 minutes or less and 13% commuted 45 minutes or more, with the remaining participants not answering the question. Therefore to better understand the longer-term effects of TDM initiatives, the several TDM initiatives that were introduced by UoA during the ten year study period to target travel by CFVs are analysed in this paper.

1.3 Staff commuter behaviour

It is assumed, relative to students, that staff have higher incomes and more stable lifestyles with housing location likely to be the largest factor in determining transport mode (Ge et al., 2015; Stockdale et al., 2000). In some rural areas, private CFVs, hybrid (or more gradually electric vehicles (EVs)) might be the only viable mode of transport. Nevertheless, the use of cars can be made more sustainable by introducing TDM initiatives to encourage individuals to car share (Nelson and Wright, 2016). For example, the UoA, the case study in this paper, has begun coordination of car share clubs and Liftshare in Aberdeen with other larger trip generators such as Aberdeen Sports Village, NHS Grampian and Aberdeenshire Council. Although many individuals have anxiety regarding lift sharing due to family (and other) commitments “closed” employee-based schemes have grown in popularity, With the introduction of several TDM initiatives such as reduced fees for parking permits, or a guaranteed parking space at an individual’s place of work lift sharing may be encouraged.

Sprumont *et al.*, (2014) concluded that staff chose to use cars because they believed that travel time was shorter than by public transport. It was also noted that teleworking and flexible work time are important tools when it comes to reducing staff travel. Whalen *et al,.* (2013) established that by replacing annual parking permits with a flexible daily

parking pass, staff were less likely to drive and would thus to consider alternative transport methods.

1.4 The University of Aberdeen's travel demand management initiatives

Several TDM initiatives have been introduced at UoA to reduce CFV use (**Table 1**) Intervention of 'pull' measures include improved cycling storage facilitates (2006), a lift sharing scheme (2007), free inter-campus minibuses (2012) replaced with an extended externally contracted inter-campus shuttle bus service (2014), electric vehicle charging facilities (2017); whilst 'push' measures include abolishing taxi travel claims between campuses (2012), parking permits and a reduction in the number of parking spaces (2009). As pull measures are often more widely accepted, UoA introduced these before introducing stricter push measures. Due to incomplete data records the reduction in numbers of taxi claims are unknown, however the number of parking spaces was reduced by 261 across the two university campuses from 2010.

Aberdeen has a vehicle ownership of ~0.98 cars per household, the highest of Scotland's major cities, reflecting the more prosperous economy of the oil industry, the symbolic nature of car brands and its rural northerly location (personal communication, Aberdeen City Council, 2017). By ensuring changes in parking availability or parking cost, a significant impact on the modal choice of that destination can be made (Melia and Clark, 2018). This was therefore a focus when implementing TDM initiatives at UoA to reduce single occupancy car travel with parking permits introduced around the same time as the number of parking spaces for staff and students were decreased. Although 4 EV charging facilities were introduced at UoA in 2016, to allow more sustainable travel for individuals who have no other alternative to car use, their introduction was after the survey period and therefore they do not influence the survey results and were not included within analysis.

For the 1% of cyclists, Aberdeen has a mixture of off-road paths, shared-use pavements and designated cycle lanes. These cycle lanes are often not well protected with vehicles driving and parking in them. The Active Travel Action Plan (2017 – 2021) established by

Aberdeen City Council acknowledges that the main barrier preventing individuals commuting by bike was safety concerns. To lessen this perception, segregated facilities allowing cyclists to make use of footways were installed along the Third Don Crossing (situated next to King's College campus), however this has not yet been fully utilised by the public due to local housing redevelopment. Cycling has been actively promoted through Cycling Demonstration Town and Bike Week initiatives within UoA. For staff there has also been the introduction of a buy back scheme to allow individuals to purchase a higher quality bike and pay it off monthly. The National Cycle Network Route 1 (North) passes alongside the UoA campus, however staff and students walking on adjacent paths complained about cyclists through feedback given at the end of the survey.

Bus services aim to incorporate sustainable, integrated and accessible transport options within Aberdeen. Aberdeen has two main private bus operators with First Bus operating within the CBD with stops next to campus, student accommodation and Aberdeen's city centre. First Bus use zone-based pricing systems which have continually increased over the past ten years. These fares start at ~£1.50 for the first zone and can rise to ~£2.60 for a single journey (as of December 2019). The introduction of a free inter-campus shuttle bus (currently operated by Stagecoach) was announced to encourage more sustainable transport options between campuses and deter people from driving.

TDM initiatives at UoA were introduced and dovetailed with Aberdeen City Council (ACC) who introduced paid non-residential on road parking around both campuses as condition to allow UoA to obtain planning permissions for new buildings. The characteristics of each TDM initiative is shown in **Table 1.** The intercampus minibus was replaced with a shuttlebus after the first survey.

Table 1: Push and pull TDM initiatives introduced at the University of Aberdeen

Year	Push or Pull Initiative	Characteristics of TDM Initiative
2006	**Pull:** Enhancement of facilities for cyclists.	• Covered and uncovered stands and lockers (650 as of 2018). • Cycle lockers available for a deposit (Deposit has remained at £60 since 2006).
2007	**Pull:** Lift Sharing.	• Dedicated web page linked to a nationwide scheme (liftshare.com) • 280 staff and student online users (2018) • Potential to save money (cost of vehicle, fuel and parking permits)
2009	**Push:** Annual Renewable Parking Permits.	• Priced at £220 (as of 2017). • Parking prices are reviewed annually as a direct measure against pay increases and inflation. • Limited Parking - A reduction of 261 available parking space to staff and students from the start of the survey period. (King's College - 845 spaces with 61 disabled spaces and Forresterhill - 352 spaces with 23 disabled spaces) (as of 2017). • No guarantee of a parking space.
2012	**Push:** Abolishing Travel Claims for Taxi fares.	• Removal of eligibility for staff expense claims for Taxi fares between campuses. • Only for exceptional circumstances (for example disabilities and where a staff member has no other option).
2012	**Pull:** Inter-campus Minibus and Shuttle Service for staff and students.	• Free for both Staff and Students on production of university ID card. • Regular service throughout the day. • Door to door service.
2014	**Pull:** Externally contracted Inter-campus shuttle bus for staff and students (including halls of residence to Kings College (0.9 miles)) to replace the minibus.	• Free for both Staff and Students on production of university ID card. • Regular service throughout the day. • Door to door service. • Branded logo for service. • Sheltered bus stops.
2017	**Pull:** Electric charging facilities at King's College and Forresterhill Campus.	• Two charging points at each campus • No charge for electricity. • No parking permit is required when the vehicle is charging.

2 Methodology

2.1 Survey overview and participants

To test the effectiveness of TDM initiatives within the UoA context of a medium sized university campus in Scotland, this study analyses travel survey data using non-parametric statistical tests to determine their impact.

Data collected for this study was made available by the University's Estates Section as part of a biennial staff and student travel behaviour survey conducted in either March or October of the survey year, with those months targeted to ensure the highest response rates possible during the academic calendar. An invitation to participate in a web-based survey was distributed via email to all staff and students between 2006 and 2016. In 2006, respondents had the option to submit their responses in hard copy. From 2010, the survey was distributed to a wider range of staff and students which included more honorary, seconded and temporary staff. This also included distant, access and off-campus students, many of whom do not regularly commute.

The survey was split into two sections. The first section evaluated the socio-economic characteristics of respondents. This included asking questions regarding age, gender and level of education; however personal details were kept anonymous. The second section focused on commuting behaviours. This included the method of transport chosen and reasoning.

Appendix A demonstrates the response rate over the ten year period. Invalid surveys were removed before analysis, to ensure the integrity of the results. To calculate the percentage of completion rate for staff and students the number of staff and students registered in each survey year was used. The staff participation rate increased over the ten year period, averaging at ~64% compared to an average of ~24% of students.

Sampling biases are apparent in the participation rates, biasing towards specific demographics, and as the survey was voluntary, not all categories received responses in all years. For example, there was a limited number of individuals in the over 60s category

for staff in the overall sample with the current retirement age of ~65 years old. Additionally, there were some non-participation in certain sections of the survey. As a result the less than 18 category was combined with the 18-24 category and the more than 60 was combined with the 40-59 age category for both staff and students to retain robust sample sizes between groups.

2.2 Demographics and socio-economics of respondents

For the purposes of analysis, role within the university was split to staff and student as the position held at UoA could allow insight into estimated level of income, which may influence housing location and subsequently mode of transport chosen. Staff respondents had six categories to pick from to determine their position, including full time and part time positions.

On average over the ten-year period, 38.7% of the respondents were academic staff, 31.1% were academic-related (admin and management) and support staff were 28.9%. The employment category of full or part time status varied across the years, with an average of 78.7% of staff being full time. For student respondents, 73.5% of respondents were undergraduate, 14.2% were taught postgraduate and 12.1% were postgraduate researchers. Undergraduate and taught postgraduate respondents had a breakdown of 82% full time and 18% part time. The number of full time and part time staff and students were combined to give an overview of the transport methods chosen by both working arrangements as the current breakdown didn't provide a representative sample so were combined to remove outliers.

Age was split into five categories: less than 18, 18-24, 25-39, 40-59 and more than 60. Due to sample size, there was bias within some demographics. The shared percentage of female survey respondents was higher than the average number of females working within the institution in those given years. Similarly, some age categories were over-represented as compared to UoA demographics. **Table 2** demonstrates the changes in the number of staff and students within the different age categories over the survey period.

Table 2: Age breakdown in percentage of the age categories for staff and student between 2006 and 2016 at the university.

	Staff						Students					
	2006	**2008**	**2010**	**2012**	**2014**	**2016**	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**
Under 18 (%)	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.3	3.0	2.6	3.4	4.5
18-24 (%)	4.0	2.4	2.6	2.4	3.7	2.2	74.0	69.0	70.0	73.3	69.0	67.1
25-39 (%)	35.0	41.5	36.9	33.8	33.7	31.8	18.0	23.9	20.0	18.5	21.3	21.5
40-59 (%)	53.0	48.8	50.3	54.5	51.3	54.4	7.0	5.6	5.5	4.3	4.8	5.8
Over 60 (%)	8.0	7.2	9.2	8.7	10.0	10.8	1.0	0.5	0.7	0.6	0.8	0.8
Returned useable surveys	1,180	1,454	1,411	1,651	2,136	1,753	2,208	2,318	3,175	3,440	4,757	3,639
University group sizes	**3,189**	**2,817**	**2,822**	**3,302**	**6,552**	**4,002**	**13,391**	**13,380**	**22,493**	**21,500**	**17,883**	**19,994**

In addition, estimated distance travelled by survey respondents was collated to give a representation of daily commutes, however this required individual interpretation; therefore, postcode locations drawn from the survey were used to enable prediction accuracy testing. Staff and students were also asked to estimate travel time to the university which is likely highly variable in accuracy with perception of external factors such as traffic congestion during rush hour varying. With the sample sizes, any statistical tests on this would return low power therefore travel time estimates were not used in this analysis.

2.3 Low carbon travel choice index

Although aggregating individual indicators into a composite index is a practical approach it does not always capture the multi-dimensional aspects of sustainability (Dur et al., 2010; Reisi et al., 2014; Saisana, 2011; Zhou et al., 2007). An index can be considered subjective with no single index answering all questions, prompting a need for multiple indicators (Cherchye et al., 2007). Alternatively indexes are valuable to demonstrate results as they limit the presented information and allow for quick and easy interpretation (Freudenberg, 2003). In this study a bounded continuous index was created with each means of transport given a value between 0 and 1 based on estimated carbon intensity, with the value 1 given to the most environmentally friendly transport mode and 0 given to the least environmentally friendly mode (**Table 3**). A simple linear relationship was used to estimate the index value using gCO_2 km^{-1} per person as a predictor (**Table 3**). In addition, it was also assumed that the main method of transportation reported was the only method of travel chosen as although some methods such as train travel required additional travel via the bus and or walking to get to the individual's main campus, train travel was the main method documented by the survey. Furthermore, it was also assumed that all personal vehicles were conventionally fuelled vehicles where life cycle analysis is not accounted for. Estimates for environmental impact were based on the operating emissions from the modes of transport used in previous studies (BEIS, 2018; Logan et al., 2020a, 2020b).

Table 3: The index values distributed to the different methods of transportation based on the proportional to greenhouse gas emissions of each method.

	$gCO_2\ km^{-1}$ per person	Index Value
Car – Individual dropped off and picked up by a private vehicle.	240	0
Car	120	0.5
Car – Individual dropped off by a private vehicle and the driver continues to another site.	90	0.62
Car – Individual is driven to work in a private vehicle by someone who works at the campus.	60	0.75
Motorcycle/Moped	116	0.52
Bus	16	0.93
Train	5	0.98
Cycling	0	1
Foot	0	1

2.4 Analysis approach

To assess the effect the UoA TDM initiatives may have had on staff and student travel choice, the initial approach was to use a linear model. Breaking down the surveys into gender, age and distance travelled groups (360 groups across all size years of survey data) resulted in sample size restrictions that prevented the use of a beta or binomial regression which would normally be utilised to analyse index data under a generalised linear modelling framework.

The analysis was simplified to a non-parametric (no data was normally distributed) approach utilising Wilcoxon for factors that have two groups (staff/student, gender) and Kruskal-Wallis tests for factors of less than or more than two groups (distance, age, year). All analysis was completed using base R (R Core Team, 2017) with data visualisation created using R package ggplot2 (Wickham, 2016). Under this approach inferences could

only be made between the patterns observed in the data and the implementation timing of the TDM initiatives outlined in **Table 1.**

3. Results

Table 4 provides an overview of the results and **Sections 3.1 – 3.5** explain the specific results. A summary of the survey information can be found in **Appendix A** showing the breakdown of survey information across years and staff and student categories. **Appendix B** and **Appendix C** give an overview of the distance travelled by the different age categories of staff and students.

Table 4: Statistical outputs of non-parametric test used to compare groups in Sections 3.1 to 3.4. Data with more than two groups used Kruskal-Wallis tests (χ^2 statistic = **) and data with only two groups used a Wilcox test (W statistic = *).

Dataset	Question	Test statistic	df	p-value
Both Staff & Student*	Staff vs Students	11,480	-	<0.001
Staff**	Year	45.1020	5	<0.001
Student**	Year	4.0739	5	0.5388
Staff**	Age	1.3303	2	0.5142
Student**	Age	23.654	2	<0.001
Staff**	Distance	59.579	5	<0.001
Student**	Distance	154.77	5	<0.001
Staff*	Gender	3,873.5	-	<0.05
Student*	Gender	5,349	-	0.2934

3.1 Overall comparison between staff and students

Significant differences between the environmental impact of travel by staff and students over the ten-year dataset were found (**Figure 1**). We compared the two categories directly

to determine if there was any distinct variation between the two categories. This was because there are likely differences between staff and students in terms of income or distance, therefore analysis provides an overview of the results before categories are broken down into year, gender and age.

Median comparisons indicated students travelled on average more by low emissions transport methods, predominantly walking or cycling, though they showed greater variation across the full range of travel options. While the range of the calculated index values were equal between staff and students (0.5 to 1) staff exhibited significantly lower median index values (demonstrated through kernel density displayed by the violin plots in **Figure 1**). The above 0.5 median scores for both groups are likely a trait of the index used as only drop off and return home had an index score of less than 0.5. The bi-modal density indicated in students is likely indictive of a significant split in travel choice between walking or cycling and more affluent students who have access to a car, though there was no data collected to confirm this.

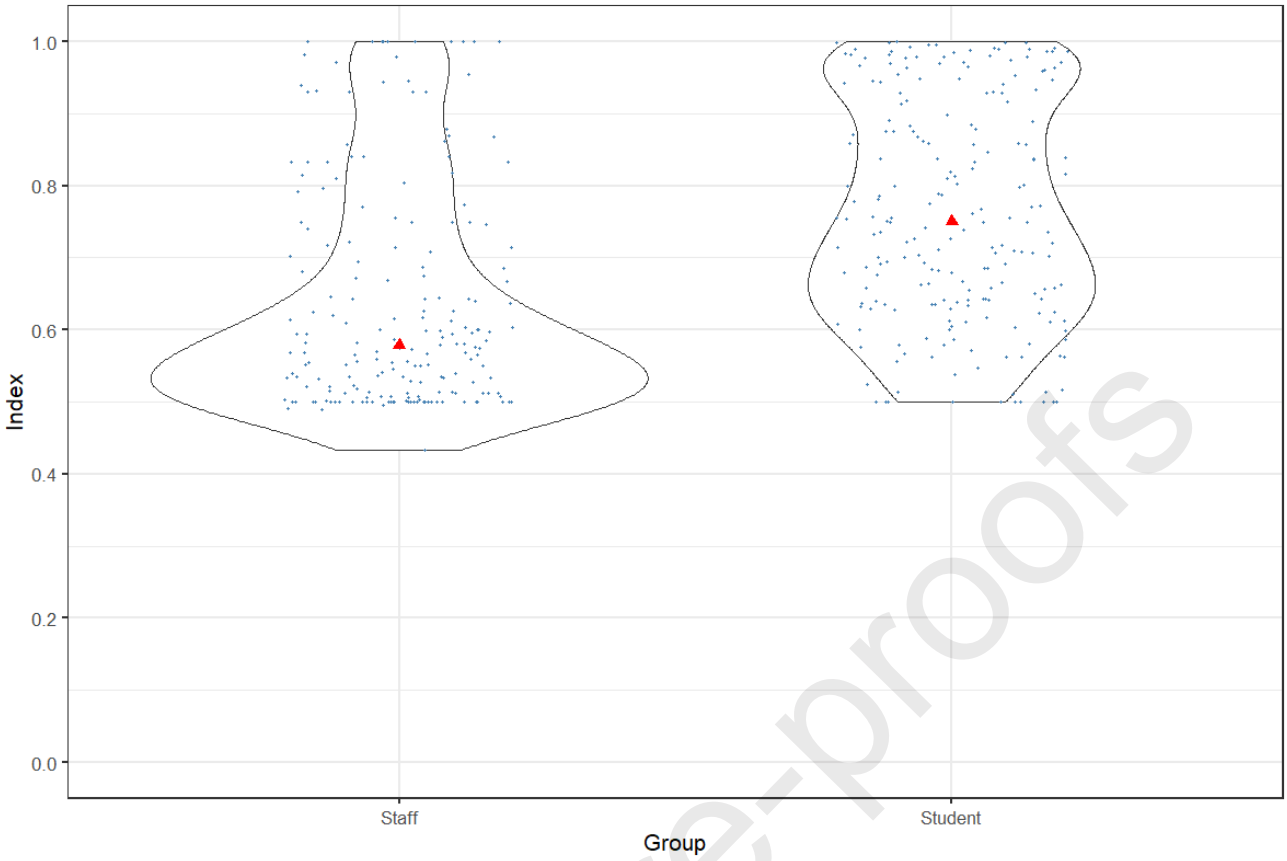

Figure 1: Violin plot showing index variable of mean environmental impact of travel choice variation within staff and student groups. Shape indicates a rotated kernel density of the data for each group. Blue dots represent sample value for a given group of data, red triangle indicates median of the group.

3.2 Year

The index groupings across the survey years indicated that students were consistent in their travel choice and therefore there is no difference between years (see **Figure 2** and **Table 4**); this is likely indicative of consistent accommodation location (student rentals tend to be in the same area year to year), and financial means influencing transport choice. Whilst staff choice of housing is more flexible generally due to better financial situations, however this could be dependent on external factors as staff living further away from campus may have better financial stability up until 2008 before the financial crisis. There is an overall significant decreasing trend across years by staff (**Figure 2**), with a significant increase in sample density around the 0.5 indicating a shift to many staff individually driving.

The shift observed within staff travel choices between 2008 and 2010 is the converse result that would be expected after the implementation of parking permits in 2009, as it indicates a greater proportion of the survey sample were choosing personal transport methods and therefore likely incurring parking permit costs. This could be indicating that the TDM initiatives implemented within the university (at that time) were not having the desired effect as there is no adequate alternative in place to cater for those that require more flexible transport options. TDM initiatives such as parking permits are likely to act as a deterrent to students whereas free bus travel between campus may encourage sustainable travel. Only a small proportion of students utilise both campuses so therefore may not be definable within the data. Information was not collected to separate these groups out specifically.

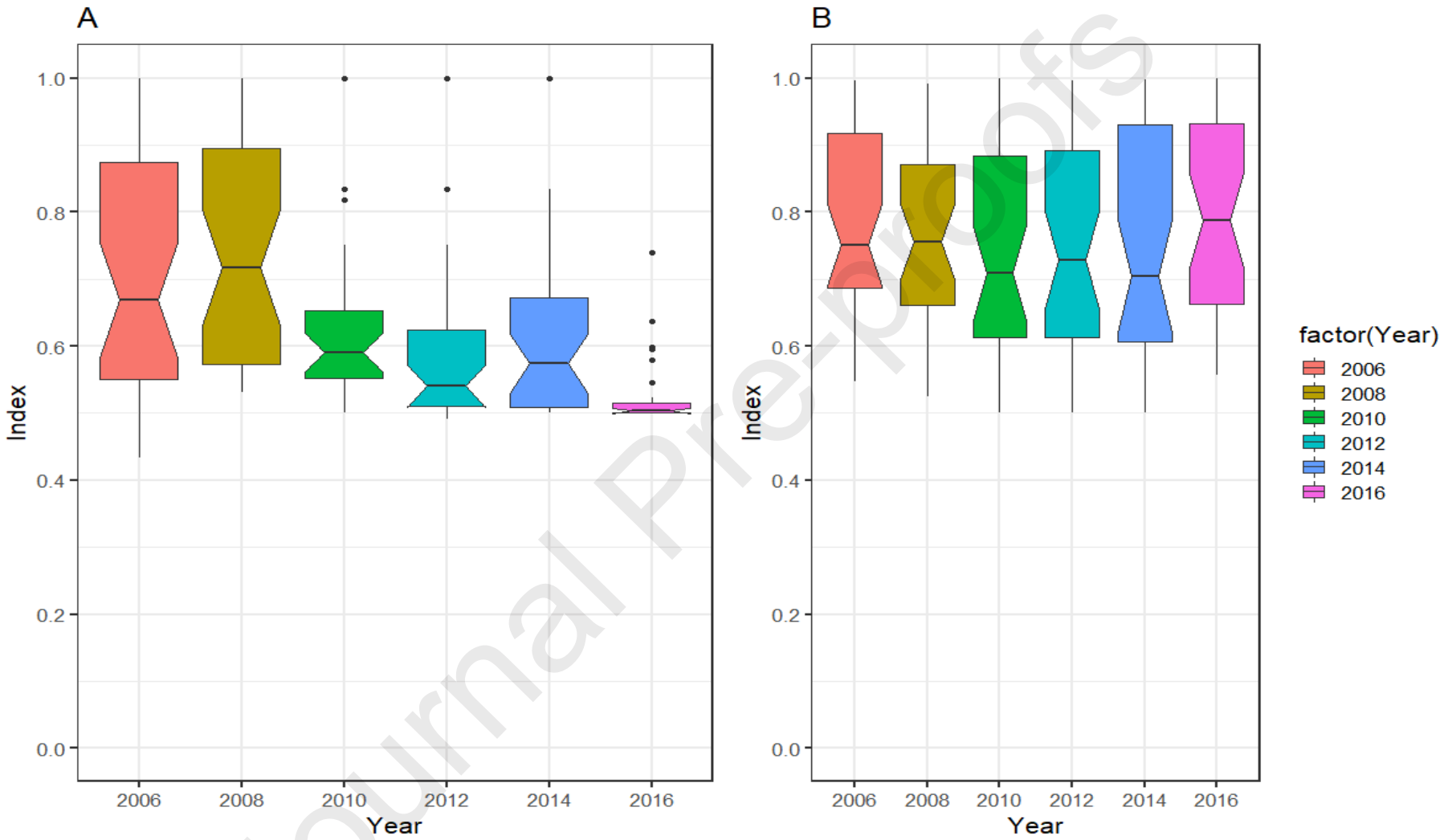

Figure 2: Box plot showing index variable of mean environmental impact of travel choice variation within staff (A) and student (B) groups over survey years.

3.3 Age categories

Only students showed a significant difference between age categories (**Figure 3**), with decreases in low carbon travel choice index with increasing age group.

Staff showed no significant difference between age categories with all age categories showing a similar trend across time. The year 2006 showed the greatest variation in index value for all age groups, and 2016 showing the least suggesting that all staff travel choices have been similarly impacted by socioeconomic factors.

The generally lower per age group value for staff compared to student observed is thought to be largely down to younger staff having greater financial means than their student counterparts, with students therefore more likely to choose transport options that have a decreased financial burden, such as active travel (i.e. walking or cycling) and where they are unable to do this, using public transport.

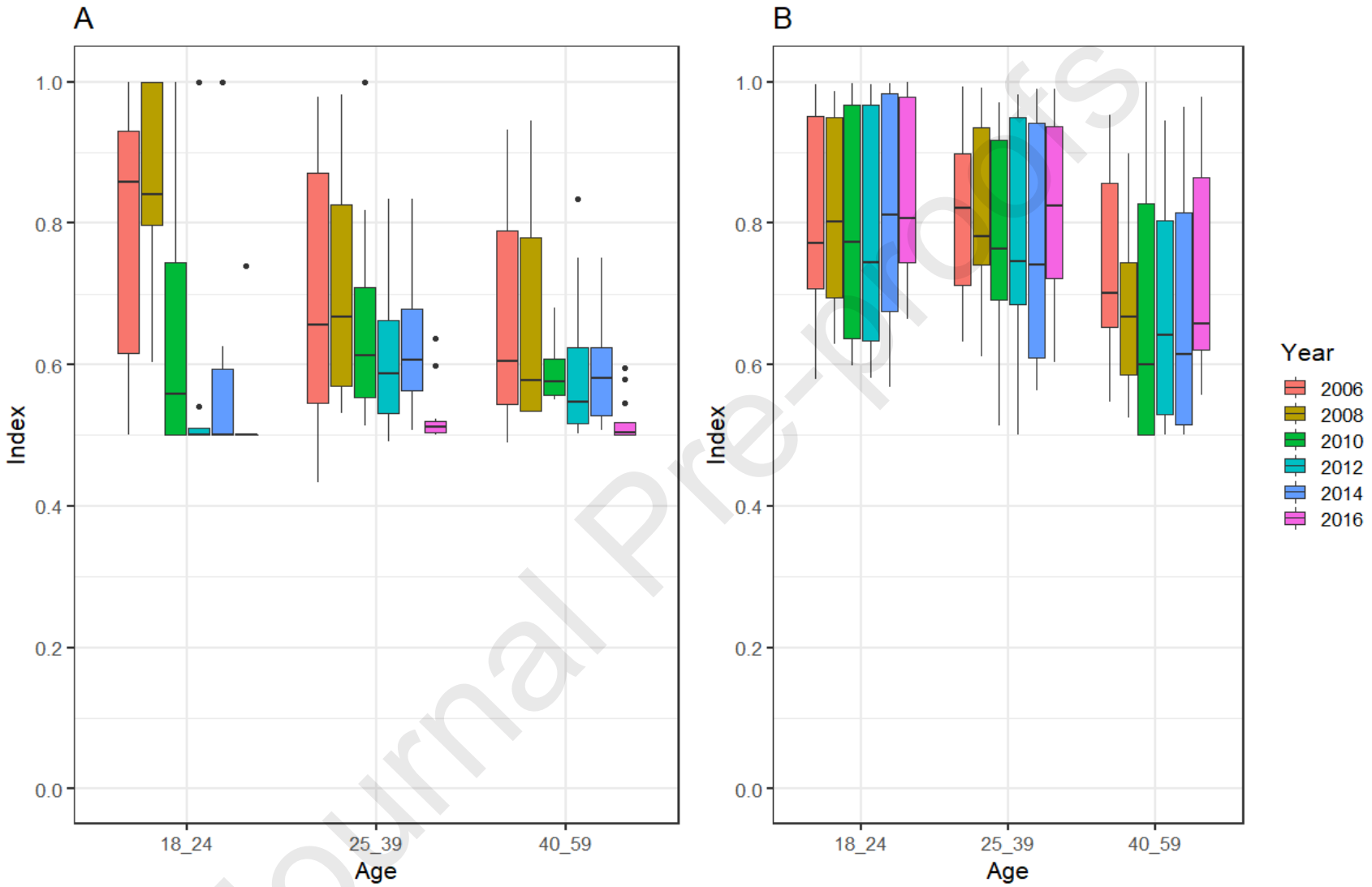

Figure 3: Box plot showing index variable of mean environmental impact of travel choice variation within (A) staff and (B) student groups with age categories.

3.4 Distance travelled categories

With increasing distance from home to campus both staff and students show a similar trend with significant differences in groups, decreasing in median index value from less than one mile to between 11 and 20 miles before a slight increase at more than 20 miles (**Figure 4**). Whilst both categories show the same trend, students score a slightly higher index value. The overall trend is to be expected as the greater the distance the less flexible the travel options. Cycling and walking for example are not generally favoured over more than a few miles, though with the provision of cycle storage, facilities are useful as a visual advert to encourage sustainable travel when these options are possible.

The indicated increase at more than 20 miles for both staff and students could be an indication of a distance 'tipping point' where consumers begin to choose shared or public transport over personal transport, increasing the index value used in this analysis. The use of public transport and TDM initiatives such as lift sharing are likely responsible for this increase. Lift sharing was only by 280 staff and students in 2018, showing that some TDM initiatives are only beneficial to a small proportion of individuals at the university. With small sample sizes across years and distance groups, analysis was not able to be split further to answer this question in more detail. A key difference is shown between the groups at between one and two miles, suggesting students are likely to choose more sustainable travel up to larger distances, likely for financial reason.

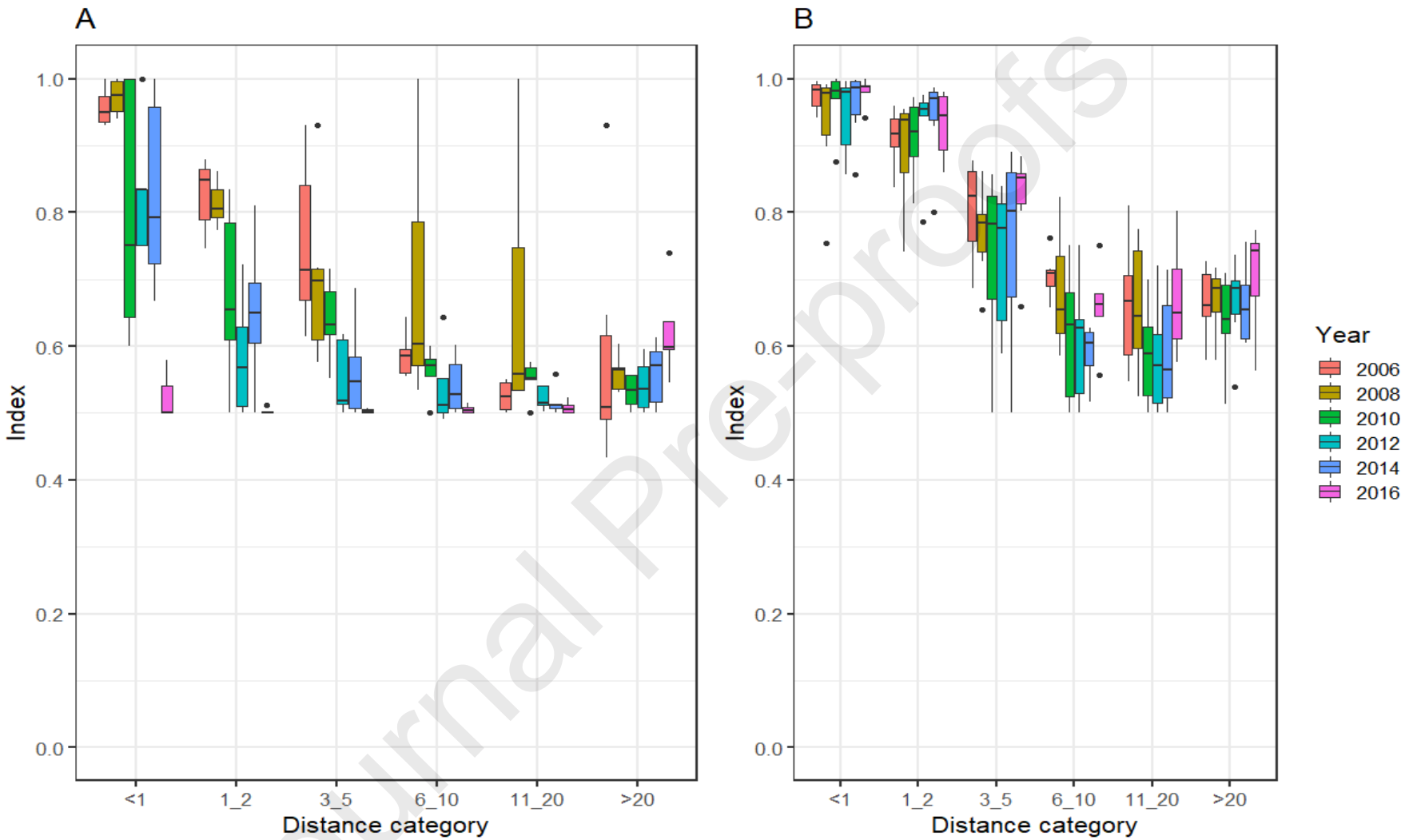

Figure 4: Box plot showing index variable of mean environmental impact of travel choice variation within (A) staff and (B) student groups with distance.

3.5 Gender

As suggested by anecdotal comments within the survey feedback, there were significant differences between gender in staff (see Figure 5). This was not apparent in student data which indicates that external personal travel requirements were a significantly influencing factor at least in the early years of the survey period. This could be linked to female individuals taking on the family caring role, with females more likely to need to link child requirements (e.g. schools or shopping) trips together which may be harder to achieve on public transport alone as times and trip routes may vary day to day. Less students are influenced by family requirements therefore there is a more equal male to female balance.

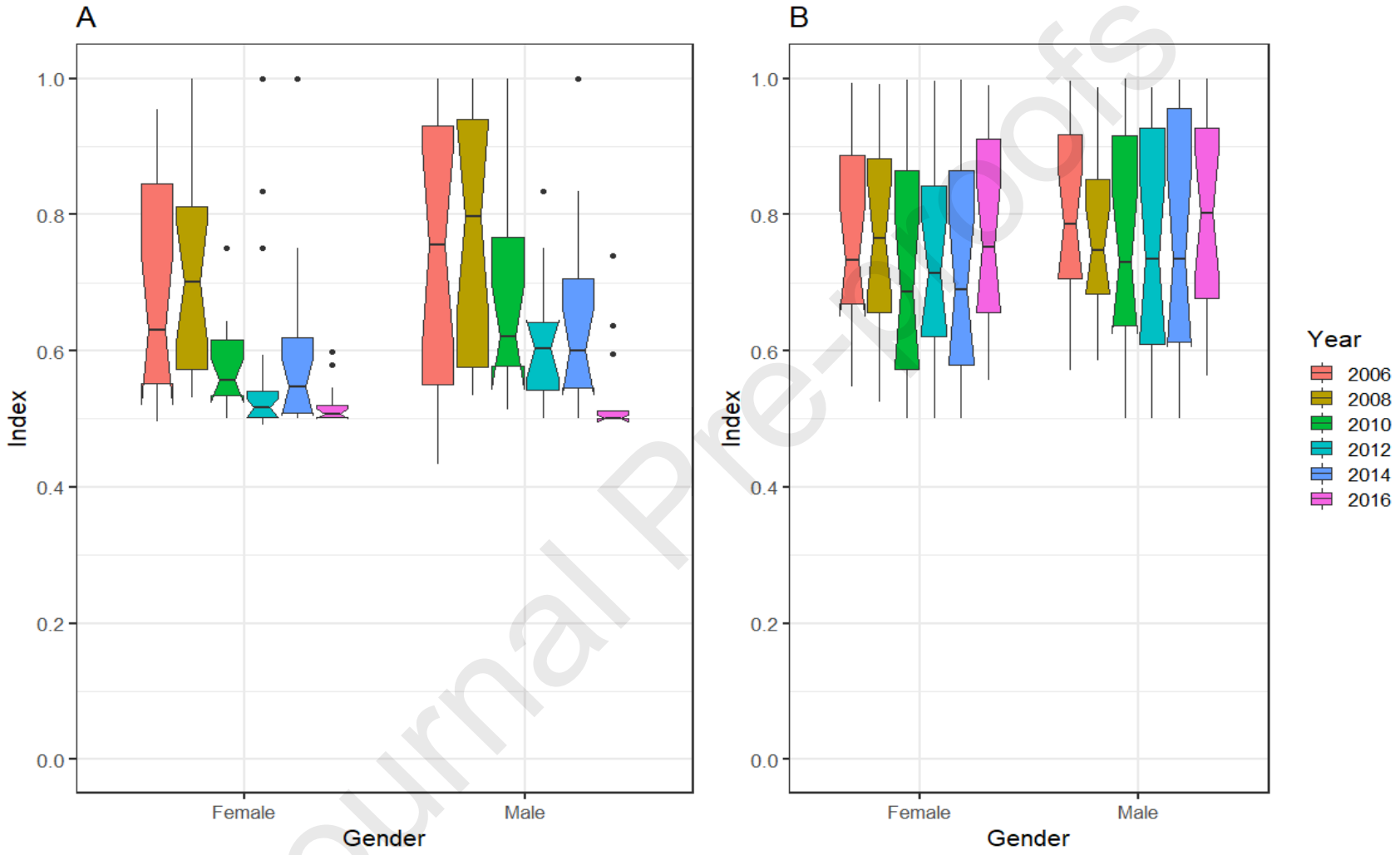

Figure 4: Box plot showing index variable of mean environmental impact of travel choice variation within (A) staff and (B) student groups with gender.

3.6 Number of days attending the university in a week

The number of days staff and students attended the university was analysed to determine how regularly they are commuting. On average, 63% of staff attended the university five days a week. Alternatively, 30% of students commuted five days and 36% commuted more than five days a week.

In August 2016, a 'nine-day fortnight' was introduced as a compressed working arrangement, allowing professional services staff to work their contracted hours over nine-days as opposed to ten-days. For academic staff, working from home has become more common from at least 2010, although not actively encouraged. This is important to consider for future surveys as staff who only work on campus one or two days a week may chose unsustainable methods, with many switching more to personal transport even after restrictions are reduced post COVID-19. Although this is not strictly a TDM initiative, more home working could affect the results of the travel survey with individuals choosing convenience as they will see it as an overall reduction as they are travelling less.

4. Discussion

Within this study, the effectiveness and influence of some push and pull TDM initiatives on staff and students at the UoA were analysed as the results highlight that long-term consideration of TDM initiatives is required. Results indicated that age and distance travelled were a significant explanatory variable in travel trends for both staff and students, demonstrating that social factors must be considered when considering how to encourage and ensure sustainable transport choices are chosen. Furthermore, for staff, the year of survey was also demonstrated a significant difference. Staff showed gender differences indicating that females are more likely to choose more carbon intensive options in their travel choice. This may be due to family composition, economic situation, living costs or health problems restricting transport choices. This highlights that travel plans and TDM initiative implementation will likely struggle to make a significant impact on transitioning to sustainable travel alone and need to be implemented within a wider regional system of public transport and facilities (cycle lanes etc.) encourage lower carbon travel choices.

Results indicate that it is difficult to say how successful TDM initiatives have been at UoA. This could be down to three key factors; firstly, the societal demands have not been fully

considered during the implementation stages and this is important since behavioural change initiatives place the burden of responsibility on individuals. In extending a TDM to a wider scale, there is a need to apply learnings from social practice theory, which suggests that changes need to be made to things that are not only transport-related; an example of this would be the 'nine-day' working week or working from home under COVID-19 restrictions. Secondly, the survey data collected was numerically limited in sample size and by the survey structure. Furthermore, one limitation of the survey was it did not ask staff about new working arrangements such as the 'nine-day fortnight' and therefore staff were aggregated. Therefore future survey analysis should be expanded in further surveys. Finally, (future) TDM measures need to be informed by knowledge of the determinants of travel behaviour. This is potentially a failure of the TDM implementation process, with a top down approach missing societal indicators that are now showing up from the surveys as reducing their effective implementation. Due to the small survey size it is difficult to conclude if the effects from an individual institution will have a significant impact within the wider area.

For staff, CFV use was the most popular mode of transport, however the introduction of the push measure parking permits did not influence transport choice and encourage more sustainable transport alternatives. Several factors are likely behind high CFV use for staff including demographics, residential location, road network changes, congestion levels or quality of the public transport network. A better understanding of the demographics of car users may allow travel planners to better develop a more realistic travel plan. For example, although gender and family status were not directly analysed, the family caring role can play an influencing factor when choosing transportation methods. For example, a 2016 female survey respondent stated that *'My travel choices are determined by school drop-off and pick-up arrangements for my children'* and a male respondent stated, '*need to drop a child at school then partner at work*'. Similarly the impact of national economic status may have been a factor in the trends observed. Residential location and travel choice likely fluctuates with housing prices and personal finance situation, both of which are highly influenced by the national economy. Up to the 2008 survey, the increases could be linked to a sense of financial stability and increases in disposable income. The drop post-2008 could be the result of the opposite of this, within household work travel being coordinated and therefore a switch to personal transport options. This highlights that

TDMs are likely only effective under certain economic scenarios and the need for a broader, efficient public transport network which caters for as many commuters needs as possible.

Broader socio-economic situation could be suggested as the reasons for the outliers observed throughout the data presented here. Generally, the staff data contained more groups of individuals acting outside the expected boundaries of these groups. While difficult to prove without further questioning of participants (GDPR rules prevent this), it could be hypothesised that these outliers are examples of individuals choosing (using distance as an example, see **Figure 4**) either less environmentally modes for shorter distances due to family commitments or having great financial means to choose low emissions transport methods at longer distances or just a more convenient alternative existing. This socio-economic hypothesis explains the outliers at both ends of the index variable spectrum however we are unable to prove this conclusively with the data available.

Future surveys need to consider interactions between family caring roles (elderly, disabled or child dependents) and gender identities to understand if TDM initiatives influence travel behaviour within these situations. Several studies have highlighted that women, especially mothers, are more likely to work on a part time basis or have other working time reducing arrangements (including job sharing, temporary reduction of hours, term time only working patterns) for the sake of the children's well-being, particularly before they reach school age (Chung, 2018; Scott and Clery, 2013). As with all primary caregivers, this demographic is the least able to make drastic changes to their daily activity and the most affected by employer sanctions and financial penalties instilled to shift to a more sustainable transport option. This may highlight why there was an increase in female staff in the 25-39 and 40-59 age categories who chose to commute by CFVs.

However, as a result of the COVID-19 outbreak, working from home will likely become more common, which will likely have a significant influence on transport options. At the beginning of the pandemic in the UK, road transport emissions decreased, however once restrictions have fully lifted individuals are more likely to travel by personal vehicle than from public transport as a method to reduce exposure to infection risk. Therefore shifting

towards low carbon transport will become more urgent. As the UK Government has implemented legislation to ban the sale of new petrol and diesel CFVs (including vans and hybrid vehicles) by 2035, low emission vehicles are likely to become more dominant. To reduce vehicle ownership, some places of work have vehicles owned by rental or car club companies which are available for hourly rentals. This not only reduces vehicle ownership but allows individuals the freedom of a CFV/EV when required for a short period of time (e.g. during the working day) as well as reducing congestion.

The CO_2 emissions from staff vehicles decreased within this study and was likely due to the technological improvements of newer vehicles being purchased within the survey period, despite the number commuting by CFV increased (this was determined analysing registration date of staff cars within the survey). The UoA introduced four EV charging points in 2017 as a pull measure for more sustainable personal vehicles, although this was not analysed during this survey. Introduction of EV charging facilities was highlighted in the 2016 survey with 21 respondents indicating that their introduction would encourage them to purchase an EV as public transport was not an option. However, since the average EV has a range of ~170km and only 15% of staff live >20 miles away the installation of charging points may not act as an incentive to drive EVs as range should not be a limiting factor. Furthermore, due to vehicle range, individuals may not need charging facilities, but they would address range anxiety and might encourage more sustainable driving. However, if the electricity is not generated from renewables any emissions benefits will be diminished. Although taking alterative low carbon public transport such as electric or hydrogen buses or trains would be better for the environment in terms of per person per kilometre travelled, switching towards EVs over CFVs will reduce the level of emissions produced (Logan et al., 2020a). However introducing TDM measures that will encourage this transport modal shift including an interlinked system allowing individuals to park for free if using an EV, may encourage a shift towards EVs. However, as only four EV charging points have been introduced so far on campus, future survey analysis will need to be conducted to determine if these will influence transport choice and whether this will meet demand.

It should be noted that during the survey period, car use may have been influenced by the construction of the Aberdeen Western Peripheral Route (AWPR). Although it was

completed after the survey period, staff may be partially encouraged by the AWPR to move to more distant locations. In addition, there have been large developments in affordable housing within Westhill, Kintore and Inverurie closer to the CBD without a commensurate increase in public transport, further encouraging car use.

For students, the most popular method of transport was to commute by foot. There are several likely reasons for this including cost. For example, the introduction of annual parking permits influenced student transport choices with a ~7.1% reduction of CFVs used to commute within the ten year period. This is very likely also influenced by costs of learning to drive and associated costs such as car insurance which is reflected in the reduced number of young people sitting their driving tests. Furthermore, with the increased student accommodation built within the CBD, with larger expansions in 2008 and 2014, students are living within walking distance of the university so there is a reduced need for transport.

During the survey period, bus use was the second most popular method of transport for students. There was an increase in use of the inter-campus shuttle bus to between 8,000 and 10,000 passengers per month (term time) and ~3,000 per month (outside term time). It could be assumed that staff bus usage remains relatively constant throughout the year and therefore 3,000 of the int term passenger numbers could be considered staff, though exact numbers are unknown. This increase in use is likely due to additional information being available about the service and allowing individuals to use the system as a park and ride facility, including allowing passengers to bring bikes on the buses which started after 2014. This may not have been fully reflected within the survey as there is currently only one survey post this initiative implementation. To truly assess the impact the impact of the shuttle bus, in future travel surveys encouraging participants to discuss whether or not they used multiple transport methods, i.e. commuting via CFV and using the campus shuttle bus, would allow a greater understanding of its usage and whether this could be upscaled. In addition, asking respondents how often they need to travel to one campus from the other may be necessary to establish the impact of this shuttle bus service. Inference could then be drawn between free-shuttle and pay-bus travel choices (the survey data presented here did not go into this detail). This would also allow a greater understanding of park and ride options if respondents were also asked where they leave

their vehicle. To see the true the environmental benefits of bus use, replacing the existing buses with electric or hydrogen alternatives would decrease emissions.

With greater awareness it is arguable that individuals could see the benefits of active or alternative transport. For both staff and students, rail travel remained a relatively unpopular transport method, however through improvements to the network, usage could be increased for staff and students living further away from campus. Reopening local railway stations at would allow easier access and some 2016 survey respondents indicated they would use the train provided there was also a direct bus to UoA.

Improvements to TDM initiatives at the UoA could occur through an integrated approach to sustainable transport planning with neighbouring organisations, like NHS Grampian, Robert Gordon University and the city and county councils, allowing an increased availability of more environmentally friendly alternatives. The results of our study have slightly contradicted Rye (2002) one of whose recommendations is that for a TDM initiative to be successful it needs to be implemented at a small-scale. This is primarily because smaller organisations generally do not have the resources for these initiatives and their transport problems tend to get absorbed into the surrounding areas through over spilling car parks feeding into the surrounding streets (Rye, 2002). Introduction of stricter parking measures within the CBD may encourage alternative transport uses such as the bus or using designated areas out with the CBD for park and ride. However, both these methods may be difficult with a large proportion of parking privately owned. The need to interchange could be considered quite burdensome for individuals with caring responsibilities as they would potentially have journeys that take longer and don't facilitate 'escort trip' functions. To mitigate this, one solution may be to refine eligibility criteria for parking permits, for example, individuals who live within a one/two-mile radius would be prohibited to purchase them (unless necessary, i.e. they have disabilities/caring responsibilities), or by allowing individuals with disabilities/caring responsibilities or individuals car sharing to have a reduced price. Alternatively, allowing CFVs with three or more passengers to drive within the bus lanes during peak times may result in increased lift sharing. These measures however require co-ordination between local and central Governments, travel planners and local transport authorities.

5. Conclusion

The results of this study indicate that the introduction of push and pull TDM measures, made minimal impact on the transport choices made by staff and students at UoA. To encourage sustainable transport use and through the introduction of TDM initiatives, a more collective approach with other large business and industries such as NHS Grampian, Robert Gordon University and the city and county councils would be needed.

Furthermore, results indicate that even with the implementation of TDM initiatives, external factors, including the cost of fuel, may influence a reduction of CFV use. Through a more integrated approach with wider combination of initiatives and clear goals shared between other large institutions, travel plans can be adapted to enable a larger scale operation influencing travel in areas of key and essential workers and could encourage individuals to use more environmentally friendly alternatives.

As the UK universities transition to work from home and online within the next year as a result of COVID-19, transport choices will likely change, this represents a golden opportunity for the introduction of TDM measures and the success or otherwise of this should be taken into consideration in future surveys. With travel plans designed for schools and other places of education, this may allow greater influence and adoption of sustainable methods of transport which can be carried on post-education.

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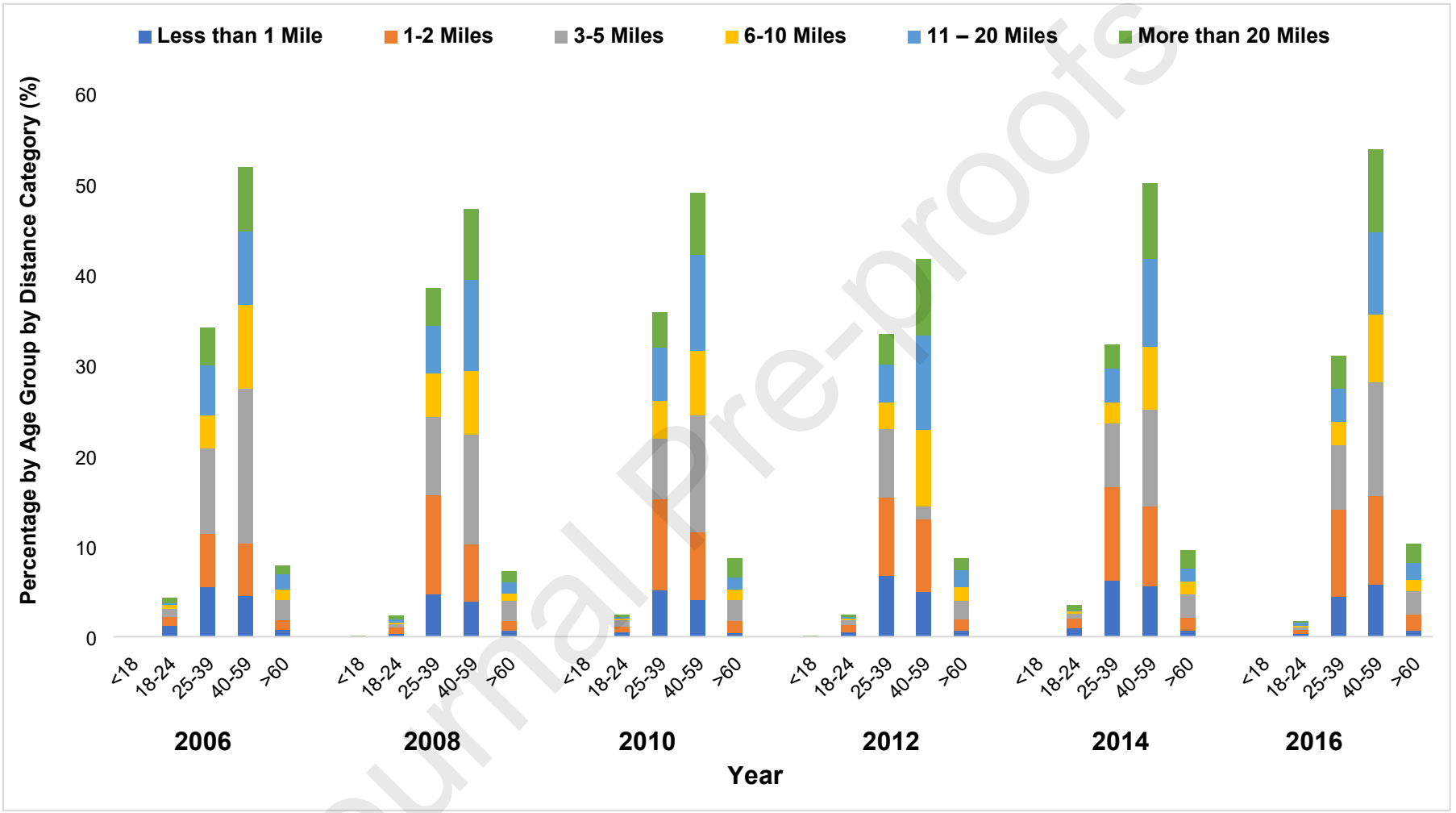
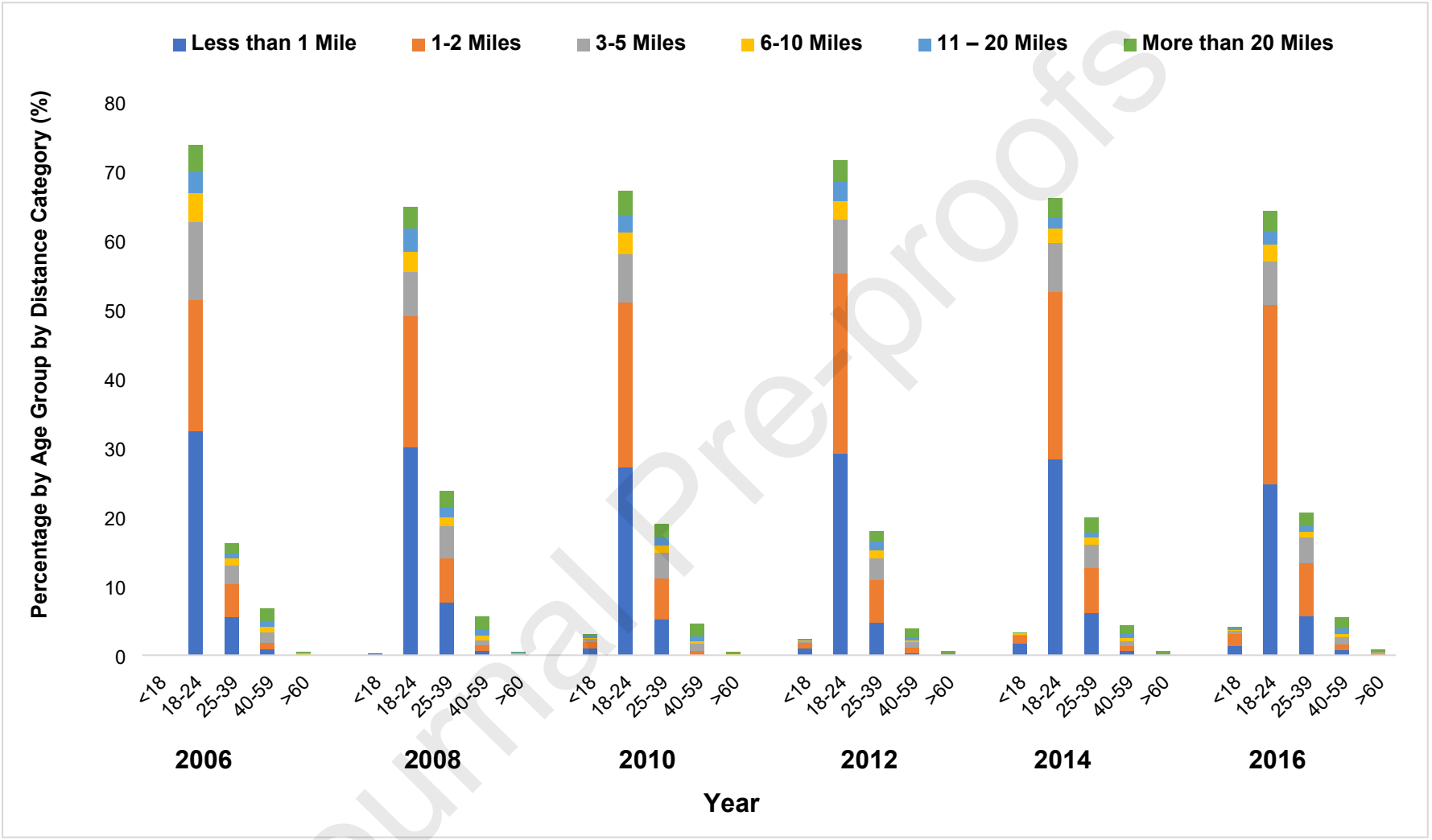
Appendix A: Breakdown of survey data released between 2006 and 2016.

Year	2006	2008	2010	2012	2014	2016
Total Number of Staff at the University	3,189	2,817	2,822	3,302	6,552	4,002
Total Number of Students at the University	13,391	13,380	22,493	21,500	17,883	19,994
Total Surveys Distributed	16,580	16,197	25,315	25,424	24,449	24,000
Total Number of Surveys Returned	3,403	3,795	4,611	5,119	6,921	5,411
Unusable Surveys	15	23	25	28	28	19
Total with Unusable Surveys Removed	3,388	3,772	4,586	5,091	6,893	5,392
Total Number of Staff Returns	1,180	1,454	1,411	1,651	2,136	1,753
Total Number of Student Returns	2,208	2,318	3,175	3,440	4,757	3,639
Percentage Completion Rate (with invalid surveys removed) (%)	20	23	18	20	28	23
Percentage Completion Rate of Staff (%)	47	58	56	66	85	70
Percentage Completion Rate of Students (%)	16	17	23	25	34	26

Appendix B: Percentage of staff age and distance travelled to their main campus.



Appendix C: Percentage of Students Age and Distance Travelled to their Main Campus



Author contributions

K.G.L. led the writing, conceptualization of ideas and designed the methodology with contributions from A.H. and J.D.N.. C.O. gathered the data before analysis. K.G.L. analysed the data with contributions from J.D.C.. All authors contributed to the drafting and revision of the article and gave final approval of the final version of this manuscript before submission.

Highlights

- Individual employer-level travel demand management initiatives had minimal impact.
- Parking permits did not deter conventionally fuelled vehicle users.
- Age and employment status can influence travel behaviour.
- External factors (fuel prices or residential location) can be of great influence.
- Campus measures should be integrated with area-wide travel demand management plans.