Park and Stride for Health and Wellbeing:

Evaluation of a wayfinding intervention to promote active travel to school in Oxfordshire, UK

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EXECUTIVE SUMMARY

In Oxfordshire, and across much of the UK, many children are not engaging in sufficient daily physical activity to promote good health and wellbeing. In Oxfordshire in 2019, only 51% of children met the Chief Medical Officer's physical activity guidelines which recommends doing an average of at least 60 minutes physical activity per day across the week.

An important opportunity to increase physical activity in children is through walking, cycling, scooting or wheeling to and from school – termed 'active travel'. Evidence shows that active travel is associated with increased levels of physical activity in children and with increased future physical activity levels into adulthood. However, there is still much to learn about how local government, and other stakeholders with an interest in promoting active travel, can increase the proportion of children who regularly use active travel to commute to school.

In this project, we designed an intervention to encourage active school travel in primary school children in Oxfordshire using Wayfinding, which involves devising routes that are marked with signage and point-of-decision cues that convey information about orientation and distance to help with navigation and route decision making. We engaged with school communities including students, headteachers, teachers, and parents to understand the school travel environment at each school, the barriers to using active travel to school, and what factors motivate those who do use active travel. Wayfinding routes were implemented along footpaths on frequented walking and/or cycling routes, and between schools and designated car parks from where parents or carers were encouraged to park and walk the remaining distance to school. These routes included interactive, colourful waymarking signs on footpaths, places of interest such as bug hotels, and banners and finger posts to direct the way. The features of each school route were chosen by school students and the routes were chosen in consultation with parents and school staff. The project was promoted as 'Park and Stride'.

Through a detailed evaluation, we aimed to test the acceptability, perceptions and short-term impacts of a wayfinding intervention to increase active travel among primary school children. We also intended to explore methods of data capture for school active travel monitoring, given the known challenges with survey data and frequently low response rates. In this report, we present the design of the intervention and the results from our initial evaluation.

Data from parent survey responses indicated that active school travel increased from 76% pre-intervention to 81% post-intervention across schools where Park and Stride was implemented. This contrasts with a slight decrease in active travel at similarly located schools where no Park and Stride was in place. Although there were insufficient data to robustly test the statistical significance of this result, and this comparative increase may have been due to chance alone, any increase noted is promising particularly given the pre-intervention period was in summer and post-intervention in late autumn; we might expect to see a decrease in active travel over this time due to weather conditions. Parents, staff and pupils reported the wayfinding intervention had enhanced their existing experience of active school travel, though road safety concerns limited independent use by primary school children.

The staff and pupils of St. Joseph's School in Carterton discuss their thoughts on the Park and Stride Scheme at their school in this video - https://www.youtube.com/watch?v=Qc1h2z-TQ6Y

Conclusions

Wayfinding routes have potential to increase rates, and enhance enjoyment of, active school travel and active travel but are likely to be insufficient alone to create significant modal shift and may have greater impact if implemented alongside other interventions which encourage active travel such as school streets that discourage private car use for school commuting. As a place-based intervention they may have additional benefits by encouraging activity along the routes outside of school travel.

INTRODUCTION

BACKGROUND

Physical inactivity increases the risk of poor physical and mental health in children(1,2). In Oxfordshire only 51% of children met the Chief Medical Officer's physical activity guidelines which recommends doing an average of at least 60 minutes physical activity per day across the week(3), though slightly better than the England average(4).

Active travel (e.g., walking, cycling, and scooting), is associated with increased levels of physical activity in children(5–8) and with increased future physical activity levels into adulthood(9). Walking for active travel is one of the most common contributors to total physical activity in children, particularly in younger children(10). An important opportunity for active travel in children is commuting to school. However, the UK National Travel Survey indicates that there has been a long-term decline in the proportion of young people walking and cycling to school in England as well as a reduction in the proportion of primary aged school children allowed to walk to school alone(11). Moreover, high levels of air pollution are harmful to children's health, with studies showing negative impacts on lung function(12). A shift from private motor vehicles to active travel for the school journey could also reduce air pollution in proximity of the school. The promotion of active travel is both a UK(13) and local policy priority(14), with Oxfordshire setting a clear ambition to increase rates of walking and cycling. Achieving modal shift is being delivered across the county in part through infrastructure improvements that seek to improve cycling and walking routes across the county and in part through a Cycling and Walking Activation Programme that addresses the range of barriers to changing behaviour. The use of wayfinding as an intervention to promote active travel forms part of this activation programme.

The evidence for effective interventions to increase active travel to school encompasses interventions ranging from infrastructure changes to more behavioural 'nudge' approaches. However, studies consistently report small beneficial effects of school active travel interventions, and the evidence to date has generally been of poor methodological quality making it challenging to make the case for investment in school travel interventions(5,16–18). Despite these methodological challenges, a number of key interventions stand out as effective or promising. A US programme called Safe Routes to School, implemented educational and encouragement programmes to school children as well as infrastructure improvements. An evaluation of this in the US state of Oregon, showed that the promotional programme alone increased active travel by 5% and when complimented by infrastructure improvements such as covered bike parking, the intervention delivered an increase of walking and cycling of between 5-20%(19).

A review of the evidence for 'walking school buses' found that these resulted in increases in rates of walking to school though the increase was not always significant, and the recruitment and maintenance of a pool of volunteers was a frequently reported challenge(20). A similar approach to walking buses, is the use of 'drop off' points near schools. An evaluation of this approach, in two primary schools in Belgium targeted those children who were driven to school at least once a week(21). Parents who lived too far away to walk were encouraged to drop their children off at a designated 'drop off' spot and a teacher would accompany them to school. The intervention resulted in an increase of active trips from a mean of once per week at baseline to three times after the one-week intervention. Importantly, a key requirement of this approach was that adult supervision was provided, thus it is also reliant on teachers or volunteers which may impact sustainability. The broader literature demonstrates that changes to the built environment can facilitate active travel(22).

In the UK, an approach to increase active school travel which has been gaining support, is the use of temporary street closures (the 'School Streets' schemes). A review of grey literature synthesised the results of 16 school street closures across the UK and found promising evidence of their effectiveness(24). An evaluation of over 300 School Streets schemes in London over 2020 and 2021, showed widespread support among parents (77% of those surveyed were supportive). Benefits on mode shift to active travel were hard to disentangle from mode shift related to the concurrent COVID-19 Pandemic(25). Moreover, School Streets are not suitable at all schools due to school location and geography.

The use of wayfinding, which involves devising routes that are marked with signage and point-of-decision cues that convey information about orientation and distance to help with navigation and route decision making(15), to encourage active travel for the school journey has not been fully explored, either stand-alone or in conjunction with other measures. though there is some evidence to suggest that wayfinding signs can serve as physical activity prompts by encouraging people to take the stairs or walk in other contexts(27) but to the authors' knowledge, there are no published studies that investigate the impact of wayfinding on active school travel(26).

In this paper we report on a pilot project that investigated the impact of a stand-alone wayfinding intervention on facilitating active travel to and from primary schools in the county of Oxfordshire, South East England (population circa. 690K, area 2605 km). Wayfinding routes were implemented along footpaths along frequented walking and/or cycling routes, and between schools and designated car parks from where parents or carers were encouraged to park and walk the remaining distance to school (referred to here as park and walk). The project was promoted as 'Park and Stride'.

OBJECTIVES

The primary objective was to test the acceptability, use and short-term effectiveness of a wayfinding intervention viz. 'Park and Stride', to *increase active travel to or from school*, among primary school children.

Secondary objectives were to investigate:

- The perceived benefits of, and barriers to, using active travel and wayfinding routes.
- Parent and child attitudes towards active travel and their perceptions of road safety
- The impact on diurnal air pollution close to the schools.

METHODS

EVALUATION DESIGN

This quasi-experimental study used a non-randomised, controlled, before-and-after design. The evaluation was designed as a pilot study, to investigate impact but also to test the feasibility of this approach and inform methods for future implementation and evaluation. A mixed-methods approach was chosen to provide insights into change in active travel as well as the wider impact and influence of the intervention and perceptions of it within the school community. Ethical approval for the quantitative evaluation was provided prospectively by the Public Health England Research Ethics and Governance Group (R&D ref: 449; 13th July 2021) and for the qualitative research elements by the Oxford Brookes University Ethics Committee (UREC Registration No: 201478; 27th April 2021). The detailed methods are set out in the approved protocols, published and freely available on Open Science Framework(28) and summarised below.

'PARK AND STRIDE' WAYFINDING INTERVENTION

The wayfinding intervention was designed and developed using the COM-B model(29), A behavioural analysis was undertaken to understand the key factors that could potentially encourage and enable more parents to walk, cycle or park and walk to school, rather than driving to the school gate, based on published literature and further refined with input from parents and pupils from the participating schools (appendix 1). The key components of COM-B identified as needing to be addressed were: Automatic motivation; Physical opportunity; Social opportunity; Psychological capability. Images of the route activities, maps, leaflets and other resources are in appendix 2. The Park and Stride routes included interactive, colourful waymarking signs on footpaths, places of interest such as bug hotels, and banners and finger posts to direct the way. The features of each school route were chosen by school students and the routes were chosen in consultation with parents and school staff. Tailored maps and leaflets were created for each school, with messages to encourage active travel, based on the values and priorities of each school community e.g., focussed on the environmental benefits or the physical activity benefits.

SCHOOL RECRUITMENT

All 269 primary schools within Oxfordshire were contacted and asked to express their interest in school active travel promoting initiatives, in March and in July 2020. Core eligibility criteria for inclusion were:

- Availability of suitable Park and Stride car park locations
- Commitment from the school to promote and support the pilot implementation
- Capacity to improve rates of active travel (where data were available to assess)

An initial feasibility site visit and desktop search was conducted to identify potential Park and Stride sites. Pupil postcode data were requested from schools to determine likely travel direction and distances to and from schools. Four intervention schools were selected from among those which had expressed interest. Two were located in Oxford City, one in West Oxfordshire District, and the remaining one in Cherwell District. Two control schools (in Banbury, Cherwell District and South Oxfordshire) were chosen based on their location, current active travel rate, involvement in other active travel initiatives and level of engagement to gather survey data. Routine data were not always available on school travel but where these existed, schools were excluded from being control sites if they had active travel rates above 80% due to perceived capacity to improve. Air quality monitoring was not suitable at one of the control schools, therefore, two separate control locations were specified for vehicle and air quality monitoring outcome measures. These were on roads near the main entrance to primary schools, one in Oxford City near Bayards Hill Primary School and one near Carterton Primary School, West Oxfordshire.

COVID-19 IMPACT

School recruitment, intervention development and implementation and evaluation occurred during the height of the COVID-19 pandemic from March 2020 to November 2021. In the UK, primary schools were forced to close to pupils from the start of January 2021 to the 8th of March 2021, except for pupils whose parent(s) were specified as 'key workers'. Once reopened, schools bore an additional administration and illness burden throughout the project, impacting their engagement.

OUTCOMES MEASURES

The primary outcome was the *change in proportion of children per school who 'usually' used active travel to or from school*[1], from baseline to post-intervention, compared to control schools.

Secondary outcomes were:

a. change in frequency of active school travel.
b. number (%) of parents surveyed who are aware of and had used the wayfinding routes, and how often.
c. reasons for mode choice, barriers to active school travel and use of the wayfinding routes.
d. the elements of the routes/wayfinding approach that teachers, parents/carers, and children/young people like and dislike.

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[1] Where active school travel includes walking, running, cycling, scooting, skating, or using Park and Stride, for the longest part by distance of the journey to or from school. 'Usually' was not defined in the survey.

e. perceptions of the wayfinding routes in terms of contribution to active travel, for the school journey and more widely.
f. changes in travel mode assessed by change in vehicle counts from baseline to follow up.
g. changes in levels of NO_2 in ambient air at school sites.

DATA COLLECTION

Data collection methods included an online non-validated parent survey, a pupil hands-up survey conducted by classroom teachers, and vehicle and air quality monitoring pre- and post-intervention outside schools; interviews and focus groups were conducted by an experienced qualitative researcher post-intervention, with parents, pupils and school staff(28).

Data on the primary outcome of usual school travel mode and secondary outcomes of frequency of active travel, use of the wayfinding routes and barriers to active travel or use of the routes (listed a-c above), were collected via the online parent survey. All survey responses were included in the analysis. Data were manually checked for errors.

In the 'hands-up' survey, pupils were asked to report their mode of travel to school that day (by raising their hand), each day for one week (5 days). This survey data is routinely collected in many schools as part of the WOW programme(30) and was collected here to test the feasibility of using this method to assess school travel mode. Schools were asked to complete the survey in July 2021 and again 4 weeks from intervention installation and provide aggregated data by class.

Focus groups and interviews were conducted to explore and understand the key aspects, strengths and weaknesses of the routes with participants (secondary outcomes listed c-e above), and detailed methods are published in the accompanying document. Fieldwork took place between November 2021 and May 2022

To assess changes in vehicle counts on the school road, data were captured over a 7-day period in July (pre-intervention) and at the same locations in November (post-intervention), in both directions, using pneumatic tube counters. Only counts between designated 'pick-up' (14:30-15:15) and 'drop off' (8:00-9:15) time periods, and weekdays were included in the analysis.

The level of nitrogen dioxide (NO_2) in ambient air was measured pre- and post-intervention as a marker of air quality. NO_2 was measured pre-intervention (from the 08/07/2021-22/07/2021) and post-intervention (from the 01/11/2021-10/12/2021) using Alphasense Ltd. Electronic Diffusion Tubes(31).

APPROACH TO ANALYSIS

Primary outcome analysis included descriptive statistics and significance testing using regression analysis where the data meet the required assumptions, carried out in STATA 16.0(32). Logistic regression was used to the impact of the intervention on active school travel as 'usual' mode. Thematic analysis(33) was used for analysis of transcriptions of the qualitative data. Further detail, including analysis methods for the air quality data are published in detail elsewhere(28).

RESULTS

SCHOOLS

Detailed information about the four intervention and two control schools, is included in the school profiles (appendix 3).

RESPONDENTS

The online survey was sent to parents at all intervention and control schools for completion between the 3rd and 29th of November 2021. In total 181 parents responded to the parent survey (reporting travel for their eldest child at school), 71 for control schools and 110 for intervention schools (Table 1).

Table 1. Characteristics of respondents (parents) and their school travel journeys.

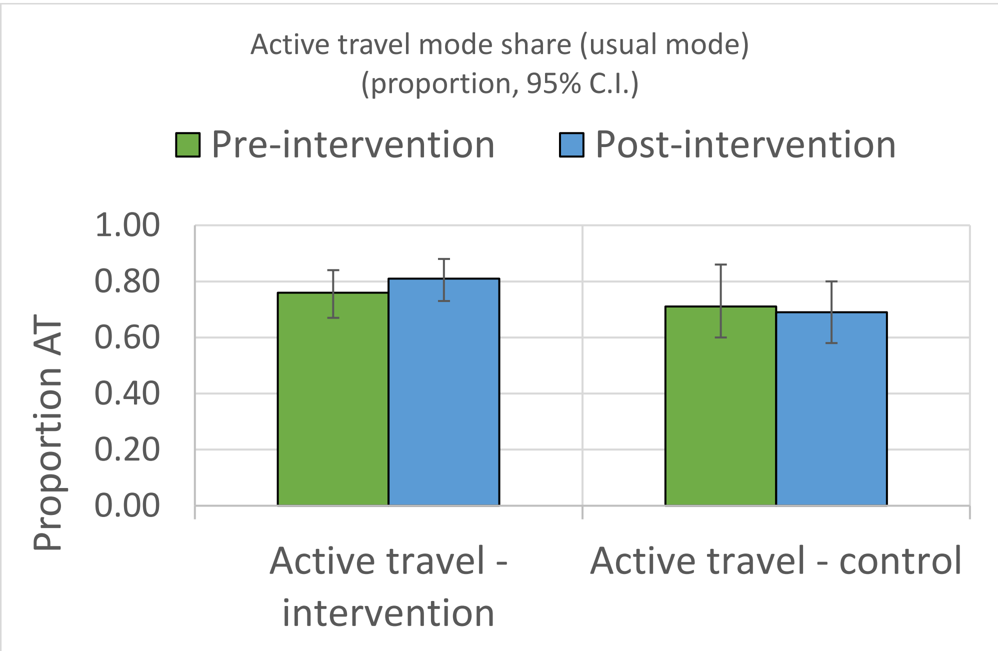
	Control	**Intervention**	**Total**
Year group (eldest child)	**n=71**	**n=110**	**n=181**
Reception or Year 1	10 (14%)	33 (30%)	43 (24%)
Year 2 or 3	21 (30%)	34 (31%)	55 (31%)
Year 4 or 5	26 (37%)	28 (26%)	54 (30%)
Year 6	14 (20%)	14 (13%)	28 (15%)
Distance to school	**n=67**	**n=103**	**n=170**
Within 500m	22 (33%)	21 (20%)	43 (25%)
500m to 1km	31 (46%)	42 (41%)	73 (43%)
Over 1km	14 (21%)	40 (39%)	54 (32%)
Journey time (usual mode)			
Up to 10 min	24 (34%)	40 (37%)	64 (36%)
10-15 min	30 (42%)	34 (31%)	64 (35%)
15- 20 min	9 (13%)	24 (22%)	33 (18%)
More than 20 min	8 (11%)	12 (11%)	20 (11%)
Journey type	N=70	N=109	N=179
School only	52 (74%)	69 (63%)	121 (67%)
Combined	17 (24%)	39 (36%)	56 (31%)
Car share	1 (2%)	1 (1%)	1 (1%)

Ethnicity (child)			
White	65 (92%)	91 (85%)	156 (88%)
Asian or Asian British	1 (1%)	7 (7%)	8 (4%)
Mixed	5 (7%)	5 (5%)	10 (6%)
Black	0	1 (<1%)	1 (<1%)
Prefer not to say	0	3 (3%)	3 (2%)
Disability			
Parent or carer	3 (4%)	6 (5%)	9 (5%)
Child	4 (6%)	1 (1%)	5 (3%)

TRAVEL MODE

There were insufficient data to describe results on travel mode by school, per protocol, therefore results are presented comparing intervention schools to control schools. Pre-intervention, 76% (95%CI 68%-85%) of intervention school respondents (n=81) usually travelled to school actively increasing to 81% (n=89) (95%CI 74%-89%) post-intervention (Fig. 1), a change of 4.7%-points, (95%CI for the difference: -6.4%-15.8%). Among control schools, pre-intervention 71% (n=48) (95%CI 59%-82%) reported active travel compared to 69% (n=50) (95%CI 58%-80%) post-intervention, a reduction of -1.5%-points (95%CI for the difference: -17.1%-14.2%). The difference between intervention and control schools was not significant.

Figure .1 Proportion of parents surveyed reporting active travel as usual mode.



There was a slight reduction in the proportion of children walking to school at intervention schools but increases in scootering and park and walk (Table 2). The proportion travelling by car decreased, (by 2%-points) in comparison to a 5%-point increase in control schools.

Table 2. Respondents reported travel mode as % of all responses, pre- and post-intervention for intervention and control schools.

	Intervention		**Control**	
	Pre-	**Post-**	**Pre-**	**Post-**
Travel mode (%)	**n=71**		**n=110**	**n=181**
Walking	57	55	66	65
Cycling	7	7	0	1
Scooting	5	8	1	3
Park and walk	7	11	3	1
Car	18	16	22	27
Other	6	3	7	4

The biggest predictors of active travel post-intervention were active travel in the baseline period and living within 500m of school, yet accounting for these factors, parents from intervention schools were significantly more likely to report active travel post-intervention compared to those from control schools (OR 2.69 p=0.080) (Table 3). Data on other potential confounders was not available. School site was not included as an independent variable as there were insufficient data point from some sites.

Table 3. The intervention group as a predictor of active travel post-intervention. Results of logistic regression

	Odds ratio	**95% CI**	***p*-value**
Intervention	2.69	0.89-8.14	0.080
Active travel pre-intervention	35.00	11.8-103.9	0.000
Living within 500m of school	1	-	-

Pupils' reported school travel mode ('hands-up' survey) included substantially larger samples post-implementation. Results showed no clear difference comparing intervention to control schools (appendix 4).

FREQUENCY OF ACTIVE TRAVEL

Pre-intervention, 70% of all respondents (similar in control and intervention schools) used active travel 4 or 5 days per week. Respondents increased their frequency of active travel pre-to post-intervention in control (76%) and intervention schools (75%). Children who reported living closer to school used active school travel more frequently (appendix 4).

SURVEY REPORTED REASONS FOR TRAVEL MODE AND BARRIERS

Among those who 'usually' used active travel to school post-implementation, the top three reasons for choice of travel mode were *convenience*, to *maintain or improve health* and because they *enjoy travelling that way*. Specifically, among those who usually park and walk, the top reasons were the *need to drive for an onwards journey* e.g., to work, the *weather* and the *distance being too far*; similar to those who usually drive to school (but don't park and walk). For those families who used active travel, most reported this was because both the parent and the child wanted to.

Of those who reported driving to school pre-intervention, across all schools, 79% (n=27) also reported driving to school in post-intervention. The main barriers to active school travel were needing the car for onwards journey and the distance being too far (or taking too long to walk and having insufficient time). Some people reported a lack of footpaths or crossing points as a reason for not walking or scootering more among other reasons such as needing the car for onwards journeys. Barriers to cycling were different between those who usually drive and those who use active travel. Drivers reported the main barriers as needing the car for onwards journeys and it being too far or taking too long. Active travel users reported the barriers to cycling as being road safety concerns, their child not being able to ride a bike and lack of cycle paths or adequate street lighting.

THE PARK AND STRIDE WAYFINDING INTERVENTION

Among parent survey respondents from intervention schools, 59% (n=65) had used the 'Park and Stride' routes, with 70% of these using it more than 4 times per week, 31 (28%) were aware of it but hadn't used it and 14 (13%) were unaware or only somewhat aware of it. Most of the feedback on the wayfinding routes was positive. The two key themes highlighted in respondents' survey comments were the fun and enjoyment of the wayfinding routes and that they helped incentivise children to walk, speeding up the journey.

"We have always walked this route to/from school but the pavement paint has made it more fun and energetic for all of us." (Survey participant)

"We use them as markers- 'wait by the stars for me' or a way of speeding up then journey 'who can get to the hopscotch first?!'"(survey participant)

A small number of parents reported they felt the routes were not safe due to lack of crossing points, or proximity to kerbs. Several reported that there were not enough activity markings, or routes didn't extend far enough, or weren't located in their neighbourhood.

"There is no safe crossing to cross [road name]…" (survey participant)

"I wish there were more of them with more activities" (survey participant)

Feedback from parents, staff and pupils via interviews and focus groups demonstrated the intervention impact on the targeted components of COM-B, the behavioural model underpinning the intervention and highlighted where it was insufficient to address these elements (Table 4). A detailed report on the methods and results from these qualitative interviews and focus group has been prepared and is submitted alongside this evaluation report.

Table 4. Park and Stride wayfinding intervention impact on COM-B assessed via focus groups and interviews

COM-B element	Evidence of influence on COM-B component
Psychological capability	Parents, staff and pupils who engaged with the qualitative research were generally knowledgeable about the aims of the 'Park and Stride' wayfinding routes. Although knowledge of the scheme was generally good parents and staff emphasised that use of the 'Park and Stride' wayfinding routes and new approaches to capitalising on its potential should be regularly promoted.
Social opportunity	Parents and staff did not report that active travel was the norm in any school or that there had been noticeable change. Car travel to the school gate and parking continued to be problematic at all sites. Some parents and staff suggested that further measures, such as School Street closures, were needed to help normalise active travel and that the 'Park and Stride' wayfinding intervention was insufficient as a sole measure.
Physical opportunity	Parents, staff and pupils reported that the routes were very well-marked and easy to follow. The locations of the designated parking areas were less well known or used Parents reported in interviews and surveys that they felt the routes were not safe in places due to lack of formalised crossing points, proximity to kerbs, on-street and pavement parking and a lack of separated walking and cycling infrastructure. These factors impacted parent's willingness to let their children use the routes independently.
Automatic motivation	Many parents, pupils and staff reported how the wayfinding markings had greatly enhanced their previous experience of moving to and from school. Some families had altered their route to take in more of the activities and generally parents emphasised how much more enjoyable walking, cycling and scooting had become. Such was the appreciation of the existing routes that there were requests for more activity markings, additional types of activities, extensions to routes and additional routes to serve more neighbourhoods from pupils and parents

VEHICLE MONITORING

Vehicle count data were captured for seven locations: four intervention schools, one control school and two near-school control locations. Across all sites apart from one intervention site, vehicle counts decreased from pre- to post-intervention. Control sites appeared to have a greater reduction in car counts than intervention sites (appendix 4).

AIR QUALITY

NO_2 levels measured at school locations followed expected seasonal variation and the similarity in the distribution of concentrations at each school was notable. There were no appreciable differences in levels of NO_2 measured at intervention or control schools and no significant impact on NO_2 levels at follow up in intervention schools compared to control. Exploratory analysis was undertaken to compensate for the seasonal trends in NO_2, using concentrations measured in the hours adjacent to drop-off and pick-up hours as a seasonally local datum for normal conditions at drop-off and pick-up time in the absence of active travel measures. This analysis offers some visual indication of a positive impact arising from active travel measures. Mean values at drop-off tended to be higher than those in drop-off adjacent hours, pre-intervention whereas at post-intervention, mean values in the drop off hour are generally lower than those in the drop-off adjacent hours. However, this difference was not statistically significant. A similar relationship was not discernible in the pick-up period. See appendix 5 for full results.

LESSONS LEARNED

Appendix 6

DISCUSSION

The Park and Stride wayfinding intervention led to a small (5%), increase in the proportion of children who used active travel as their usual mode of school travel, compared to a slight decrease at control sites, though there were insufficient data to robustly test the statistical significance of this result. The pre-intervention period was in summer and post-intervention in late autumn; we might expect to see a decrease in active travel over this time due to weather conditions, so the reported increase in active travel mode share in intervention schools is promising. Parents from intervention schools were more than twice as likely to report use of active travel in the post-intervention period than those from control schools, even accounting for use of active travel pre-intervention and the distance to school. It is notable that there was a 4-percentage point increase in use of park and walk at intervention schools, compared to a 2-percentage point decrease at control sites, given this intervention had a specific focus to encourage park and walk, as well as active school travel more generally. There was no notable change in frequency of active travel over the time-period in intervention and control schools.

Among those who did not use active travel, the reasons for travel mode choice and reported barriers to active travel were predominantly needing the car for an onwards journey, or the distance being too far to walk or cycle (or insufficient time), in line with the wider evidence that distance to school is one of the biggest predictors of walking or cycling to school with larger distance from school being strongly associated with lower rates of active school travel(8,34–37). Among those who reported their travel mode as park and walk, the reasons for doing so were the same. In rural areas where factors such as distance from school, lack of suitable footpaths or cycle lanes, and lack of access to public transport may create barriers to walking or cycling for the entire school journey, use of park and walk may therefore be particularly applicable. No rural schools were included in this pilot. The intervention sites were located in market towns and Oxford city. There is a need for such schemes to be tested in higher density inner City locations where distances to school may be shorter and less of a barrier to behaviour change.

Monitoring of vehicle counts and NO_2 at school locations did not identify any material differences between control and intervention locations. This may reflect the marginal reported changes from survey data and the challenges in disaggregating any changes in traffic or air quality from background changes, impacted by the variation in road type and baseline levels across measurement locations. As such, for small pilots with few school locations and a short time period, these may not provide valuable additional outcomes to assess potential benefits of active travel.

The wayfinding intervention identified and highlighted nearby parking places to enable park and stride addressing convenience or the need for onwards journeys but it also intended to address motivation for both parents and children, through making the routes fun. The colourful and playful nature of the wayfinding routes aimed to enhance enjoyment of walking and cycling to school and through this increase reflective motivation. The results indicate this was successful, with most comments on the wayfinding routes being positive and highlighting the enjoyment of parents and children when using them. Indeed, a wider benefit of interactive wayfinding routes in enhancing the local environment in terms of attractiveness and playability was strongly drawn out in interviews and focus groups, though it is important to note the parental concerns over safety of the routes that remain a barrier to independent school travel. An area for further research is to investigate whether the use of such wayfinding routes is sustained or requires re-activating at the start of each school year.

This pilot project has some limitations. The total number of parents sent the survey was not recorded but based on the total school rolls for included schools, the online survey response of 181 was low; and varied greatly by school, limiting the robust evaluation of the magnitude of impact on active travel. The parent survey and parent interviews are likely subject to response and self-selection biases, as well as social desirability bias therefore could represent an overly optimistic assessment. The intervention development process highlighted that committed engagement from schools is required to ensure wayfinding routes are suitable for school communities and well promoted by the school. Schools' appetite to engage with this type of intervention may be associated with greater interest in promoting active travel and higher active travel rates.

Implementation delays largely driven by COVID-19 resulted in a window of only 3-4 weeks from implementation of the Wayfinding routes to data collection. This may in part explain why 13% of parents surveyed from intervention schools were not aware of the routes and a further 28% had not used them. The wide-ranging participation in the focus groups and interviews (parents/care/ staff and pupils) is a strength of the qualitative evaluation. This qualitative assessment helped contextualise the results in relation to the underpinning COM-B behavioural analysis; highlighting behaviour change components that were influenced by this intervention and those the intervention was unable to change.

Research shows that travel decisions of primary school age children are typically dictated by parent's needs(8)or parents' perception of barriers(38), therefore interventions need to address the barriers to parental choice of active travel. The behavioural analysis highlighted the need to increase 'physical opportunity' for active travel. The wayfinding intervention aimed to do so by providing car parking nearby so that those who experienced unmodifiable barriers to use active travel for the entire journey, (too far to walk or needed the car for an onward journey), were able to walk or cycle part of the way. The high proportion of parents who reported driving to school pre-intervention who continued to do so post-intervention, indicates that for this group of parents, the wayfinding intervention is insufficient to produce behaviour change. School staff highlighted a benefit of the wayfinding routes, as valuable, sustainable infrastructure on which to build future interventions promoting active school travel e.g. WOW (30).

Park and Stride wayfinding routes are not suitable for all schools due to the physical environment; factors such as lack of nearby parking and suitable footpaths or road crossings. As new schools and developments are planned, suitable walking and cycling routes, and safe park and stride locations should be considered to facilitate active travel from those living further from school. The implementation of wayfinding routes around existing schools would benefit from interventions beyond paint, signage and engaging features; particularly those that improve safety for active travel.

In Oxfordshire, a pilot implementation of the School Streets active travel intervention showed a small increase (6%) in active travel among intervention schools as reported via parent surveys(39). This wayfinding intervention showed a similar increase in active travel yet was a far less restrictive intervention, when considered in terms of the Nuffield Ladder of Interventions, which frames how intrusive or proportionate a policy intervention is(40). School Streets also target physical opportunity as a driver of behaviour change - conversely by *decreasing* the opportunity to drive to the school gate. These interventions are complimentary. Issues raised by parent focus groups as part of the Oxfordshire School Streets pilot included a) parents' need to drive for work; b) those living outside the catchment may not have other options than driving e.g., live in rural areas where there is insufficient infrastructure for children to safely cycle on roads with the national speed limit; c) the roads to school are too narrow and busy for children to cycle(39). Offering suitable park and stride locations with wayfinding routes overcomes some of these issues and may increase the engagement and success of School Streets and should be an avenue for future research.

CONCLUSIONS

Wayfinding interventions have the potential to increase active travel in schools. As a standalone intervention, modal shift may be small, but an important wider impact is greater enjoyment of walking and cycling to school for primary school aged children and their families. The infrastructure elements potentially form a basis for further behaviour change interventions. Sustainability of impact and cost-effectiveness have not been assessed here but should be priorities for future research. Wayfinding interventions may have greater impact on travel behaviour if implemented alongside School Streets, or other measures which restrict parking outside schools, promote road safety, or encourage active travel.

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Ethical approval

Ethical approval for the quantitative evaluation was provided prospectively by the Public Health England Research Ethics and Governance Group (R&D ref: 449; 13th July 2021) and for the qualitative research elements by the Oxford Brookes University Ethics Committee (UREC Registration No: 201478; 27th April 2021).

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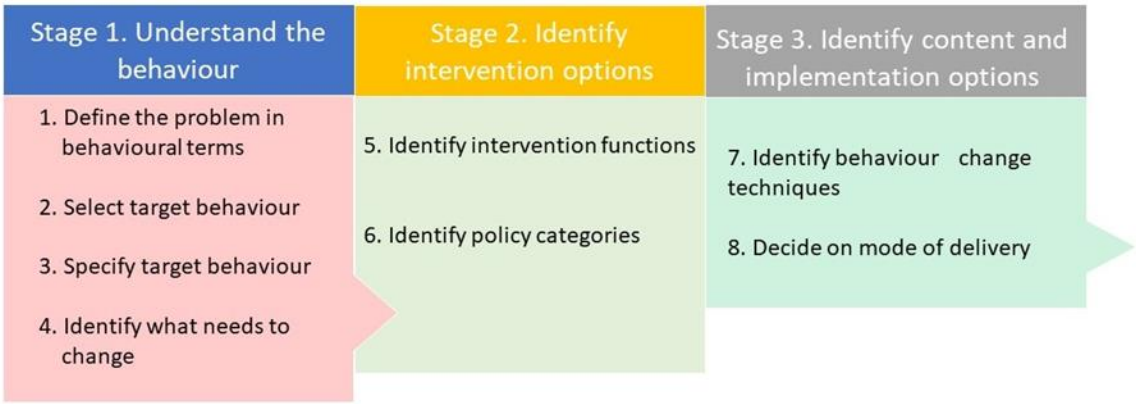
APPENDIX 1. COM-B ANALYSIS AND APPLICATION OF THE BEHAVIOUR CHANGE WHEEL TO INTERVENTION DESIGN

We applied the theoretical behaviour change framework, The Behaviour Change Wheel (BCW) (Michie, Atkins and West, 2014) to the development of the intervention. This helped to determine what behaviour(s) we were aiming to change and how best to affect them.

In brief, the BCW is a model that synthesises multiple behaviour change theories and distils this into a core model: the COM-B model. The COM-B model proposes that to encourage and enable the desired behaviour, it is important to consider aspects of Capability, Opportunity and Motivation to carry out this behaviour. Figure 1 depicts the stages of the BCW.

Figure A.1. BCW overview



Stage 1 Understand the behaviour

The problem to be address here is that too many parents drive their children to the school gate, causing congestion, air pollution and road safety issues. Conversely too few parents and their children use active travel modes to commute to or from school, not making the most of this opportunity to incorporate active travel into their children's day. The specific target behaviour is therefore the parents' behaviour of choosing to travel actively (or not). The aim of this intervention is to encourage and enable parents (or carers) to walk, scooter or cycle their children to school, at least part of the way and to avoid dropping off children at the school gate by private car.

Behavioural analysis of the target behaviour of active school travel

The behavioural analysis (Table 1) was based on evidence from the published literature and discussion with parents at included schools, as part of the design process. The key components of COM-B identified as needing to be addressed were:

Psychological capability –providing knowledge of safe, easy routes and free parking places available nearby, as well as knowledge of the benefits of walking and cycling to 'encourage' behaviour change.

Social opportunity – creating an environment where active travel is the norm, and car travel to the school gate is frowned upon, or not considered the norm. Through the school's commitment to and promotion of the Park and Stride wayfinding routes as the 'preferred' mode for school pupils. This also emphasised the social norm of parking unsafely or illegally near the school gate as unacceptable.

Physical opportunity – providing a space for those who need to drive, to park and walk, taking a safe, well-marked route. This aimed to tackle issues of needing a car for driving onwards after the school run, convenience or simply living too far away to walk or cycle. We did not have the authority within this intervention to decrease the physical opportunity to drive to or park near the school gates.

Automatic motivation – making the journey fun for children and adults alike, through fun and colourful activities and games *en route* to increase desire to walk or cycle as the preferred mode.

The Park and Stride car parks and wayfinding routes most strongly address the *physical opportunity*, and the *automatic motivation* (fun and enjoyment). The aspects of psychological capability and social opportunity are tackled more subtly by the promotional materials and communications around the wayfinding route installations

Table 1. COM-B analysis.

COM-B component	**TDF domain(s)**	**What needs to be in place (or to change) for the target behaviour to occur?**	**Aspects addressed by Park and Stride scheme?**
Physical Capability	Physical Skills	Parents and children physically able and have sufficient physical fitness to walk or cycle the required distance. Includes being free of disability, long term conditions, acute injury which would prevent them from actively travelling.	Park and Stride sites close to the school may enable those who would find it difficult walking from home to park and walk
Psychological capability	Knowledge Cognitive & interpersonal skills Memory, attention & decision making Behavioural regulation	Parents having the knowledge of routes and parking places available and knowledge of the benefits from more active travel Interpersonal skills of parents to persuade kids and push back against pressure from children to not walk Children knowing the benefits of active travel and wanting to do it, not wanting to come by car. Parents perceiving the routes as safe (to use accompanied) Parents knowing how long takes to walk/cycle (i.e., believing it not to be too long)	Park and Stride wayfinding routes mainly address the knowledge of routes and available, free parking. As part of the scheme, school leaflets were produced to outline the benefits of more active travel, tailored to the school based on the views of parents, staff and pupils Pupils were engaged in the design of the school banners to promote the scheme, including drawing posters showing the benefits of active travel. As part of the delivery, school-based air quality activities will be implemented to increase the pupils' knowledge of the benefits of active travel for reducing air pollution

Physical opportunity	Environmental contextual & resources	Parents need to have the time for walking (especially for parents/carers who are working or who have other commitments after the school run). Children not having to carry a lot which makes walking or biking difficult Parents may have difficulty with younger siblings who need to tag along, so the scheme needs to enable parents to accommodate other children. Having access to bikes/scooters helmets lights etc. There needs to be space for bikes at school and at home if people are to cycle Safe driving and parking amongst parents who do drive to school/Park and Stride sites to enable people to feel safe when actively travelling to school. May include infrastructure to remove barriers for disabled people to walk or accompany their child while they walk Parents/carers being able to bike to accompany children if they wish (skills and equipment) Bad weather can make it uncomfortable, or children need special wet weather clothing – need to consider what can be done to address this need.	This scheme largely addresses the time constraints for people who cannot walk or cycle from home or need to drive onwards from the school run (or to bring other younger children). Being able to park nearby and walk a short distance aims to overcome this barrier As part of the scheme, schools were encouraged to consider Walking Buses along the Park and Stride wayfinding routes to also address the time constraints barrier. Other concurrent projects addressing physical opportunity that could be delivered alongside the Park and Stride scheme can facilitate access to bikes/scooters; and pilot School Streets interventions can restrict car access to the school gate.
Social opportunity	Social influences	Provide a safe neighbour/light neighbourhood Provide routes free from bullies or other negative influences Demonstrate that AT is the social norm – car travel being frowned upon. A barrier may be parents with anxiety around schools and social engagement (car is protective against having to interact with people – easier in current context with mask wearing and social distancing promoted)	The Park and Stride scheme provides an opportunity for parents to have fun and engage with their children on the route to school. The school commitment to the Park and Stride can be used to demonstrate that active travel is the norm and car travel to the school gate is not acceptable. This can be delivered through the associated

		Provide an opportunity to spend time with their kids uninterrupted doing something fun and interesting Promote the social side of it for children – walking with their friends, or the same route.	communications messages delivered by the school alongside Park and Stride
Reflective motivation	Goals Intentions Beliefs about consequences Optimism Beliefs about capabilities Professional/social role & identity	Parents wanting to increase their physical activity and their children's physical activity Parents wanting the best for children's health physical and mental Generate belief around the benefits of walking – more mentally alert and ready for the day including the belief that it is worth it – both in terms of PA and pollution, safety, and time. Kids able and encouraged to set and achieve goals Teachers to be role models for active commuting	The Park and Stride scheme can be used as a platform for other initiatives that encourage physical activity and the benefits to health of being active.
Automatic motivation	Reinforcement Emotion	Need to enhance the journey and create enjoyment – drive motivation by making parents and children want to do this not just need to Need to engender an emotional connection with kids and parents e.g., watching the changes of seasons.	The Park and Stride routes create a fun route to school and aim to make the journey enjoyable. Pupils were involved in the choice of activities for their school to enhance a sense of ownership and allow them to choose the activities they would enjoy most. Activities such as 'I spy' sheets are included to encourage parents and children to engage with nature and the environment together on the route to enhance this sense of enjoyment and engagement.

Stage 2 – Identify intervention functions and policy categories.

Intervention functions and their suitability for increasing active travel via Wayfinding were assessed. The functions of Education, Persuasion, Incentivisation, and Environmental restructuring met the criteria.

Policy categories

The possible policy categories are:

1) Communications/marketing, 2) Guidelines, 3) Fiscal measures, 4) Regulation 5) Legislation 6) Environmental/social planning 7) Service provision.

The most suitable for this intervention are **communications** and **environmental/social planning**. Regulation would be helpful but may impact acceptability and equity. **Service provision** may also be used through *concomitant interventions* such as bike libraries.

Stage 3. Identify intervention content -Behaviour Change Techniques and mode of delivery

The following BCTs were identified as possible options to include in the pilot, showing which ones were ***included in the pilot*** and other BCTs that could be included in future, to reinforce the Park and Stride wayfinding approach. Many of these will be school led.

BCTs	Description	Implemented in Park and Stride
INCLUDED		
2.2. Feedback on behaviour	Monitor and provide informative or evaluative feedback on performance of the behaviour *(e.g., frequency, duration)*	Via school news and social media, via street tag or WOW where these are used in conjunction. **Park and Stride communications to schools (though some of this is done through reporting to the school, more can be done to build on this, and can be school led)** **Schools can use the WOW tracker to support this.** **Street tag communications/tracker for those involved.**
5.1. Information about health consequences	Provide information (e.g., written, verbal, visual) about health consequences of performing the behaviour	Education and communications/promotional materials to highlight benefits of reduced car use on the children's physical and mental health (increased physical activity, better concentration, reduced exposure to pollution) **Included in Park and Stride resources**

5.2. Salience of consequences	Use methods specifically designed to **emphasise** the consequences of performing the behaviour with the aim of making them more memorable (goes beyond informing about consequences)	School activities e.g., air quality monitoring at school gates versus in school garden or nearby park **Park and Stride resources post-implementation**
6.1 Demonstration of the behaviour (modelling)	Provide an observable sample of the performance of the behaviour, directly in person or indirectly e.g., via film, pictures, for the person to aspire to or imitate (includes 'Modelling').	School staff champions modelling behaviour (School staff could be encouraged to be more active as role models) **Park and Stride school engagement and communication/promotion materials**
7.1. Prompts/cues	Introduce or define environmental or social stimulus with the purpose of prompting or cueing the behaviour. The prompt or cue would normally occur at the time or place of performance	Coloured lines or drawings on the road from school showing a park and stride route **Park and Stride installation** **In future, to include local tags and points in Street tag.**
8.4 Habit reversal	Prompt rehearsal and repetition of an alternative behaviour to **replace** an unwanted habitual behaviour	Park and Stride **w**ayfinding routes - encouraging change of habit (of driving) even if this is initially through shorter walks which are achievable and help break the habit of driving. **Park and Stride installation and communication/promotion materials**
12.1 Restructuring the environment	Change, or advise to change the **physical** environment in order to facilitate performance of the wanted behaviour or create barriers to the unwanted behaviour (other than prompts/cues, rewards and punishments).	Wayfinding signs and routes and dedicated parking locations to promote active travel. **Park and Stride installation**
POTENTIAL FUTURE BCTs		
1.1. Goal setting (behaviour)	Set or agree on a goal defined in terms of the behaviour to be achieved	School based activities: Class goal or individual child goals – set these and write in homework books or through specific. **Park and Stride resources**

13.3 Incompatible beliefs	Draw attention to discrepancies between current or past behaviour and self-image, in order to create discomfort (includes ***'Cognitive dissonance'***)	Education and comms materials (e.g., do parents believe they do the best for their child's health? For the environment? How does this align with their behaviour if they drive?) **Park and Stride communication/promotion materials and social media**
10.5. Social incentive	Arrange verbal or non-verbal reward if and only if there ***has been*** effort and/or progress in performing the behaviour (includes '**Positive reinforcement**')	e.g., class or year group recognition through school assemblies or newsletters. **Park and Stride resources and communication/promotion materials**
10.1 Material incentive (behaviour)	Inform that money, vouchers or other valued objects ***will be*** delivered if and only if there has been effort and/or progress in performing the behaviour (includes ***'Positive reinforcement'***)	School incentives for most increase in active travel (compared to other schools?) or incentives for classes to increase AT more than other classes? **Park and Stride resources and communication/promotion materials**
9.2. Pros and cons	Advise the person to identify and compare reasons for wanting (pros) and not wanting to (cons) change the behaviour (includes '**Decisional balance'***)*	Could be done via social media as part of comms to kick off the wayfinding routes or part way through to encourage use **Park and Stride communication/promotion materials**
13.2 Framing/reframing	Suggest the deliberate adoption of a perspective or new perspective on behaviour (e.g. its purpose) in order to change cognitions or emotions about performing the behaviour (includes '**Cognitive structuring**')	Education and comms materials (e.g., towards framing **walking as the safe option** because of lower pollution, lower carbon, fewer cars at the school gate) **Park and Stride communication/promotion materials**
1.9. Commitment	Ask the person to affirm or reaffirm statements indicating commitment to change the behaviour	School based activities: Children making commitments to their class/parents making commitments to their child's class e.g., to work towards a school reward; writing in and sending photos or

		written notes of commitments and putting them on a class poster **School led Park and Stride resources**
5.3. Information about social and environmental consequences	Provide information (e.g., written, verbal, visual) about social and environmental consequences of performing the behaviour	Education and comms materials to highlight benefits of reduced car use on the environment, as well as children's health (via reduced pollution). **Park and Stride resources**
5.4. Monitoring of emotional consequences	Prompt assessment of **feelings** after attempts at performing the behaviour	School activities – hands up survey of how walking and cycling makes them feel, or how physical activity makes them feel. Social media/comms after initial couple of weeks. **Park and Stride communication/promotion materials**

APPENDIX 2. PARK AND STRIDE WAYFINDING ROUTE RESOURCES, IMAGES, MAPS AND LEAFLETS

Hanwell Fields leaflet


park &
STRIDE


PARK
and
STRIDE
HANWELL FIELDS COMMUNITY SCHOOL
SPORT ENGLAND
park &
STRIDE
OXFORDSHIRE
COUNTY COUNCIL

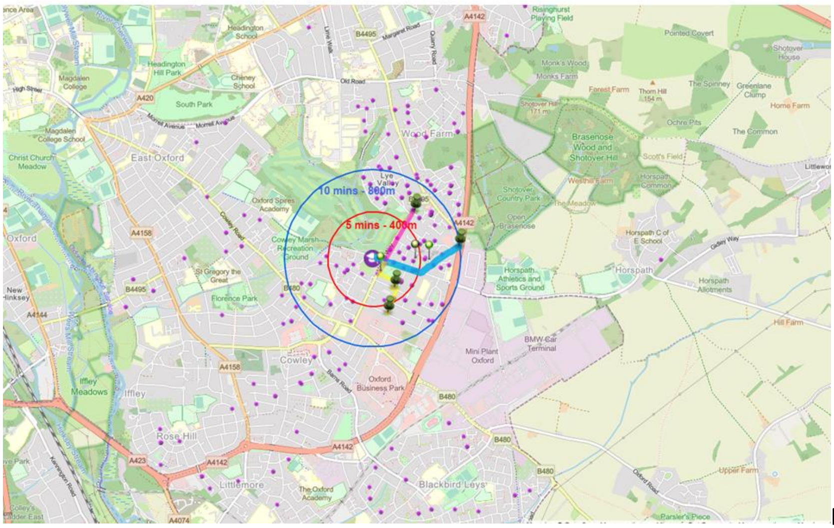

EVERYONE I KNOW LIKES HOPPING AND JUMPING BEFORE SCHOOL.
ME TOO!
TRY THE FUN PAVEMENT GAMES AND ACTIVITIES TO GET YOUR MUSCLES AND MIND WORKING.
WHEN I WAKE UP OR FEEL TIRED, I STRETCH MY BODY BY MAKING IT AS LONG AS I CAN.
Hanwell Fields Community School
School
Hanwell Fields
Hardwick
Start
Dukes Meadow Drive
Winter Gardens Way
Meadowsweet Way
Hereford Way
Guernsey Way
Pascal Pl
Lapsley Dr
Ushter Dr
Winchelsea Cl
Ashmead Rd
Rother Rd
Highlands
Warwick Road
Fitree Cl
Cheviot Way
Sussex Dr
Glyndebourne Gardens
Ferriston
Harlequin Way
Beaumont Rd
Horsham Cl
Red Poll Cl
Angus Cl
Devon Way
Forge Way
Longelandes Way
High Furlong
Woodfield
Ironstones
Danesmoor
Daimler Ave
Riley Dr
KEY
Parking – Free car park or considerately on the street
Fingerpost sign
Directional bollard
Pavement games and activities
Fitness trail
Stepping stones

APPENDIX 3. SCHOOL PROFILES (INTERVENTION AND CONTROL SCHOOLS)

Sandhill Community Primary School, Headington, Oxford		
Number of pupils	272	
Ward: **Barton and Sandhills**		
Ward Profile	**Ward**	**England/County**
Population age (% 0-15)	25%	England 19%
Ethnicity • % White (total) • % next most common ethnic group	 76% Asian (12%)	 England 86%
% Children living in relative low-income families.	21%	England 18% Oxfordshire 11%
IMD -% living in the 20% most deprived neighbourhoods in England)	21%	England 20%
% obese at year 6	23%	England 20% Oxfordshire 16%
Pupil attainment at KS2 (average point score- the ‘expected level’ is 27)	28	England 29 Oxfordshire 29
Air pollution, (NO_2) (a score >1 indicates that the levels of pollution exceed national standards of clean air)	0.5	England 0.4 Oxfordshire 0.4

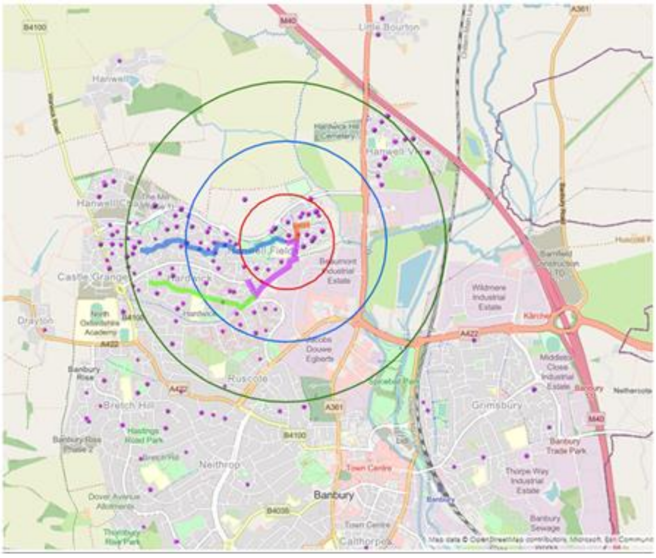
Pupil Postcode Map

Tyndale Community Primary School, Cowley, Oxford		
Number of pupils	364	
Ward: **Cowley Marsh**		
Ward Profile	**Ward**	**England/County**
Population age (% 0-15)	17%	England 19%
Ethnicity • % White (total) • % next most common ethnic group	 67% 20% Asian	 England 86%
% Children living in relative low-income families.	23%	England 18% Oxfordshire 11%
IMD -% living in the 20% most deprived neighbourhoods in England)	0%	England 20%
% obese at year 6	24%	England 20% Oxfordshire 16%
Pupil attainment at KS2 (average point score- the 'expected level' is 27)	27	England 29 Oxfordshire 29
Air pollution, (NO_2) (a score >1 indicates that the levels of pollution exceed national standards of clean air)	0.5	England 0.4 Oxfordshire 0.4



Pupil Postcode Map

Hanwell Fields Primary School, Banbury		
Number of pupils	509	
Ward: Banbury Hardwick		
Ward Profile	**Ward**	**England/County**
Population age (% 0-15)	21%	England 19%
Ethnicity • % White (total) • % next most common ethnic group	 93% 3.5% Asian	 England 86%
% Children living in relative low-income families.	14%	England 18% Oxfordshire 11%
IMD -% living in the 20% most deprived neighbourhoods in England)	0%	England 20%
% obese at year 6	19%	England 20% Oxfordshire 16%
Pupil attainment at KS2 (average point score- the 'expected level' is 27)	27	England 29 Oxfordshire 29
Air pollution, (NO_2) (a score >1 indicates that the levels of pollution exceed national standards of clean air)	0.4	England 0.4 Oxfordshire 0.4



Pupil Postcode Map

St Joseph's Catholic Primary School, Carterton, West Oxfordshire		
Number of pupils	79	
Ward: Carterton North West		
Ward Profile	**Ward**	**England/County**
Population age (% 0-15)	20%	England 19%
Ethnicity • % White (total) • Next most common ethnic group	 >93% Asian	 England 86%
% Children living in relative low-income families.	No data	England 18% Oxfordshire 11%
IMD -% living in the 20% most deprived neighbourhoods in England)	0%	England 20%
% obese at year 6	17%	England 20% Oxfordshire 16%
Pupil attainment at KS2 (average point score- the 'expected level' is 27)	No data	England 29 Oxfordshire 29

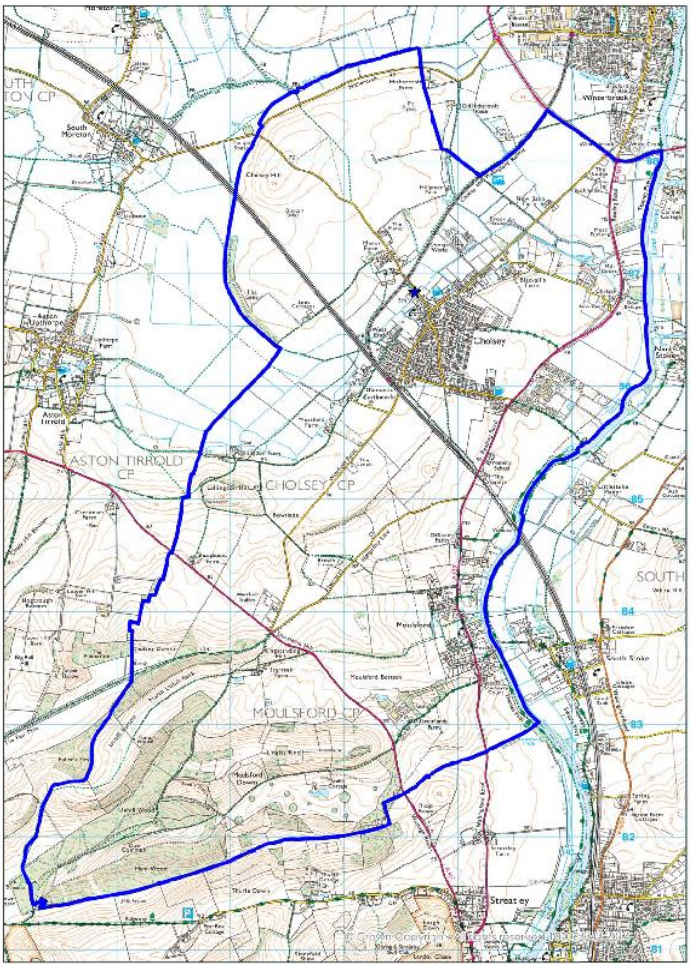
Air pollution, (NO_2) (a score >1 indicates that the levels of pollution exceed national standards of clean air)	No data	England 0.4 Oxfordshire 0.4

Pupil postcode map

Control Schools

Cholsey Primary School, Cholsey, Wallingford		
Number of pupils	290	
Ward: Cholsey and Wallingford South		
Ward Profile (no data available)	**Ward**	**England/County**

Location and Designated Area of Cholsey Primary School



School catchment area

St Mary's Church of England Primary School, Banbury		
Number of pupils	200	
Ward: Banbury Grimsbury and Castle		

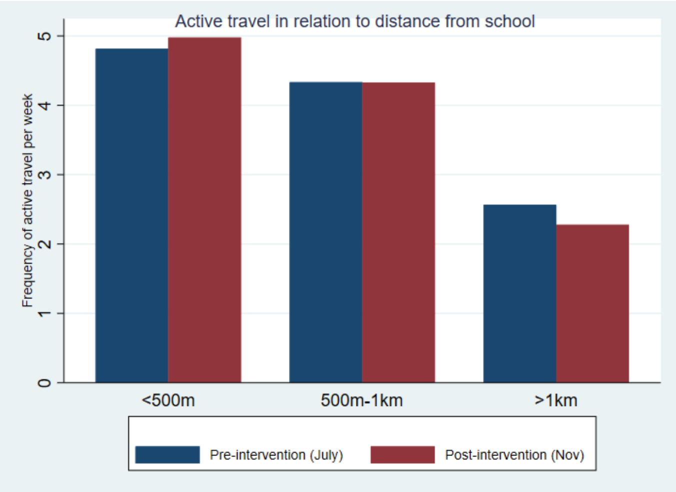
Ward Profile	Ward	England/County
Population age (% 0-15)	20%	England 19%
Ethnicity • % White (total) • % next most common ethnic group	 83% 12% Asian	 England 86%
% Children living in relative low-income families.	17%	England 18% Oxfordshire 11%
IMD -% living in the 20% most deprived neighbourhoods in England)	15%	England 20%
% obese at year 6	23%	England 20% Oxfordshire 16%
Pupil attainment at KS2 (average point score- the 'expected level' is 27)	28	England 29 Oxfordshire 29
Air pollution, (NO_2) (a score >1 indicates that the levels of pollution exceed national standards of clean air)	0.5	England 0.4 Oxfordshire 0.4

Catchment area

APPENDIX 4. SUPPLEMENTARY RESULTS

TRAVEL MODE SUPPLEMENTARY RESULTS

Figure 4. Active travel to and from school, by distance to school (all respondents)



PUPIL HANDS-UP SURVEY RESULTS

Survey data on pupils' reported travel mode to school collected via a 'hands up' survey pre-intervention (July 2021), at all four intervention schools and two control schools. Data were collected for the post-intervention period also (November 2021) and collated by class. The number of classes and hence the number of pupils reporting travel data, varied substantially from pre- to post-intervention at all schools (see Table 2). In effect, this represents a convenience sample of students at each timepoint. In the post-intervention survey, there was a reduction in the percentage of pupils who reported using active travel at two intervention schools and one control school. There was a small increase (1-2%) in reported active travel at one control school.

Table 1. Pupil reported total trips and percentage active travel* total over 5 days, per school.

School	Pre intervention	Post intervention
Sandhills	271 (85%)	925 (81%)
Tyndale	194 (78%)	757 (79%)
Hanwell Fields	1210 (59%)	2053 (45%)
St Joseph's	439 (68%)	No data
Cholsey -control	1343 (78%)	1065 (80%)
St Mary's - control	876 (68%)	517 (64%)

*Active modes include walking; cycling, scootering; park and stride

VEHICLE MONITORING

A review of the whole-day traffic pre-intervention showed 'morning 'drop off' and afternoon 'pick up' periods correspond to the peak traffic count peaks times, across weekdays at all locations except that near Carterton Primary School, a control location on a main road into the town and where the 'commuter peak at 5-6pm was higher.

Data were captured for between three and nine days (pre-intervention) and five and eight weekdays (post-intervention). Data were excluded if it was known that the school was closed to pupils (e.g., inset day). There was considerable variation in the counts by site, and pre-intervention counts were somewhat higher at control sites compared to intervention schools. Only three days' worth of data were captured at all three control sites pre-intervention, compared to at least eight days at intervention sites.

An increase in car counts at Tyndale school (intervention) at drop-off post-intervention is an unexplained outlier; and few vehicles were recorded at St Mary's school (control) due to the sensor location on a quiet side road with no through traffic.

Average counts for the school drop off ('AM') and pick up ('PM') periods combined, for all schools are shown in Figure 6.

Figure 6. Car counts pre and post installation of the Park and Stride route, by location ('c' denotes control location).

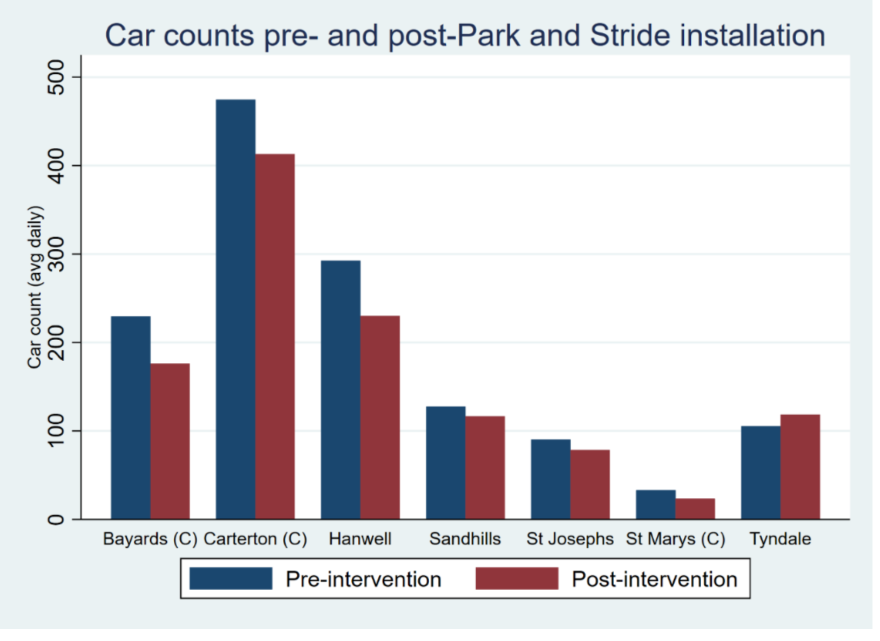


Figure 7. Percentage change in number of vehicles from pre-post, by location ('c' denotes control location)

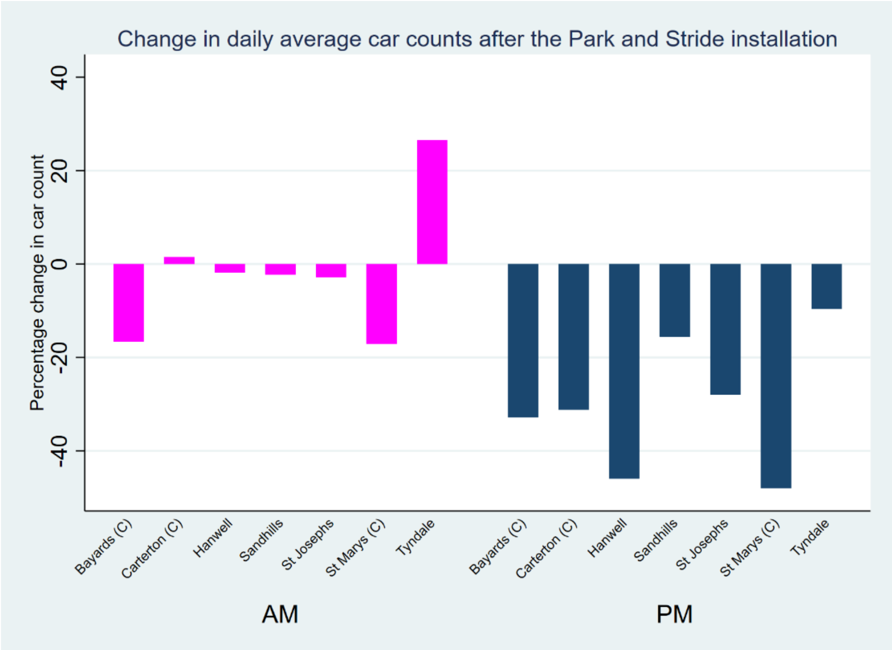
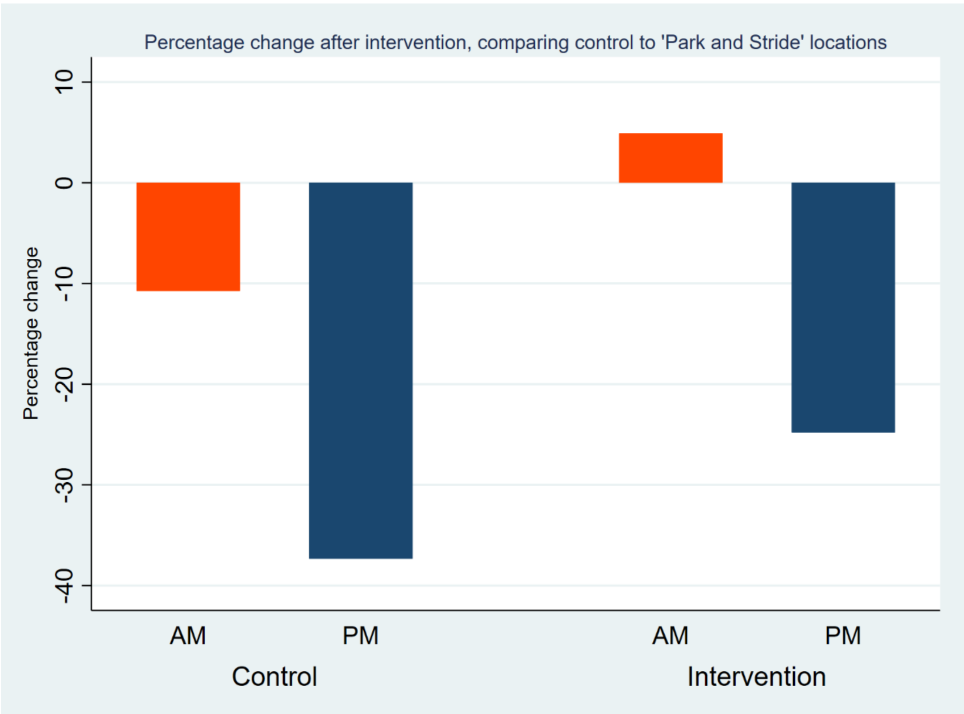


Figure 8. Change in average daily car count post-intervention, comparing intervention to control locations.



APPENDIX 5. AIR QUALITY ASSESSMENT – DETAILED METHODS AND RESULTS.

METHODS

The level of nitrogen dioxide (NO_2) in ambient air close to seven primary schools (four intervention and three control locations) was measured pre and post active travel intervention. NO_2 is a by-product of fossil fuel combustion. Its main source(s) in the urban environment are road transport tail pipe emissions and residential and commercial sector central heating systems (natural gas and fuel oil fired boilers).

NO_2 was measured for a baseline pre-intervention period (from the 8th to 22nd of July 2021) and in a follow-up post-intervention period (from the 1st November to 10th of December 2021). Measurements were made using Alphasense Ltd. Electronic Diffusion Tubes[2]. These low-cost electrochemical sensors provided measurements of NO_2, temperature and relative humidity at a 1-minute resolution. They offer benefits over traditional Palmes type diffusion tube methods, being able to characterise the short-term fluctuations in pollutant levels associated with the active travel interventions focussing on school drop-off and pick-up times.

The baseline data collection period was limited due to imminent school holidays. Although two weeks of data capture was considered sufficient at baseline as per the protocol, additional data collected over the follow-up period are included in the analysis to provide more robust outcomes. Sensors were located at all intervention and control locations, within 10-20m of the school gates or the road leading to the school gate and typically on the nearest lamppost to the main school entrance. The school entrances and air quality sensors were located on B-roads or unclassified roads with the exception of St Mary's School in Banbury. St Mary's is located adjacent to the A361 - the sensor being located within ~5m of the road edge. The two other control locations are also noteworthy being with ~100m and ~150m of a busy dual carriage way.

AIR QUALITY SENSOR DATA PROCESSING

The reliability and uncertainty associated with low-cost air quality sensor data is a known issue for many devices at this end of the sensor market. This reflects that (1) the technology is relatively new in the air quality domain and best practice approaches are not in place, (2) electrochemical NO_2 sensors are sensitive to a range of environmental factors e.g., temperature and relative humidity which interfere with the sensor, and (3) a lack of maturity in the technology and marketplace which manifests as sensor users / customers being poorly prepared to handle the data quality issues that can be experienced. Because of these issues it is normal to apply post processing techniques to raw sensor datasets to improve their quality.

For the Oxfordshire Schools Park and Stride Project a derivative of the method developed by Bush et al, 2021[3], has been employed. This method has been shown to perform well in reducing the uncertainty in sensor measurements from similar sensors. It has been adapted accordingly for this project. The approach compartmentalises the sensor uncertainty into (1) the sensor baseline offset and its variation over time and (2) interferences from temperature and relative humidity. The method uses a specialist penalised least square regression approach to identify the time varying sensor offset and correct for this relative to a city (Oxford)

[2] https://help.aqgateway.com/downloads/Air_Quality_Monitoring_with_your_Electronic_Diffusion_Tube_-_Getting_Started_-_V1.01.pdf

[3] Bush, T., Papaioannou, N., Leach, F., Pope, F. D., Singh, A., Thomas, G. N., Stacey, B., and Bartington, S.: Machine learning techniques to improve the field performance of low-cost air quality sensors, Atmos. Meas. Tech., 15, 3261–3278, https://doi.org/10.5194/amt-15-3261-2022, 2022. Accessed online 21/09/2022: https://amt.copernicus.org/articles/15/3261/2022/

background. Subsequently, a machine learning algorithm is used to correct interferences from temperature and relative humidity.

The machine learning correction model was trained using data collected from each of the sensors used in the main study. Prior to field deployment at schools, a preliminary study co-exposed the sensor units alongside reference instrumentation at the Oxford City Council, Oxford High St automatic monitoring station. This intercomparison took place throughout April, May and June 2021. The data collected were used to train a Random Forest regression correction model, configured specifically for the sensor units used in the main study.

Following correction for sensor offsets and interferences from environmental parameters, the air quality datasets were analysed with standard methods to illustrate the air quality conditions before and after the active travel interventions and to highlight evidence for change.

RESULTS

In the following sections we present evidence on the general levels of NO_2 measured at the study schools, those levels measured under baseline, intervention conditions and observed changes that may be attributable to active travel measures or other external factors.

Note that, the air quality data presented as an *indicator* of the likely air quality. The sensor data are not approved for demonstration of compliance with legal limits and thresholds. To avoid misinterpretation, direct comparison with national or European legal limits / thresholds is not presented. However, where appropriate and supportive of the project aims comparisons are made with relevant guide values recommended by the WHO[4].

GENERAL LEVELS OF AIR QUALITY CLOSE TO STUDY SCHOOLS

Supplementary Figure 1 illustrates the range in daily mean NO_2 concentrations observed at each school over the duration of the study. Data are presented in the form of boxplots showing seven key statistical metrics of the measured concentrations at each location; the minimum concentration value (lower whisker), maximum (upper whisker), median (horizontal bar), mean (green dot), 25th percentile (lower box bound), 75th percentile (upper box bound) and the interquartile range (IQR and the difference between upper and lower box bounds).

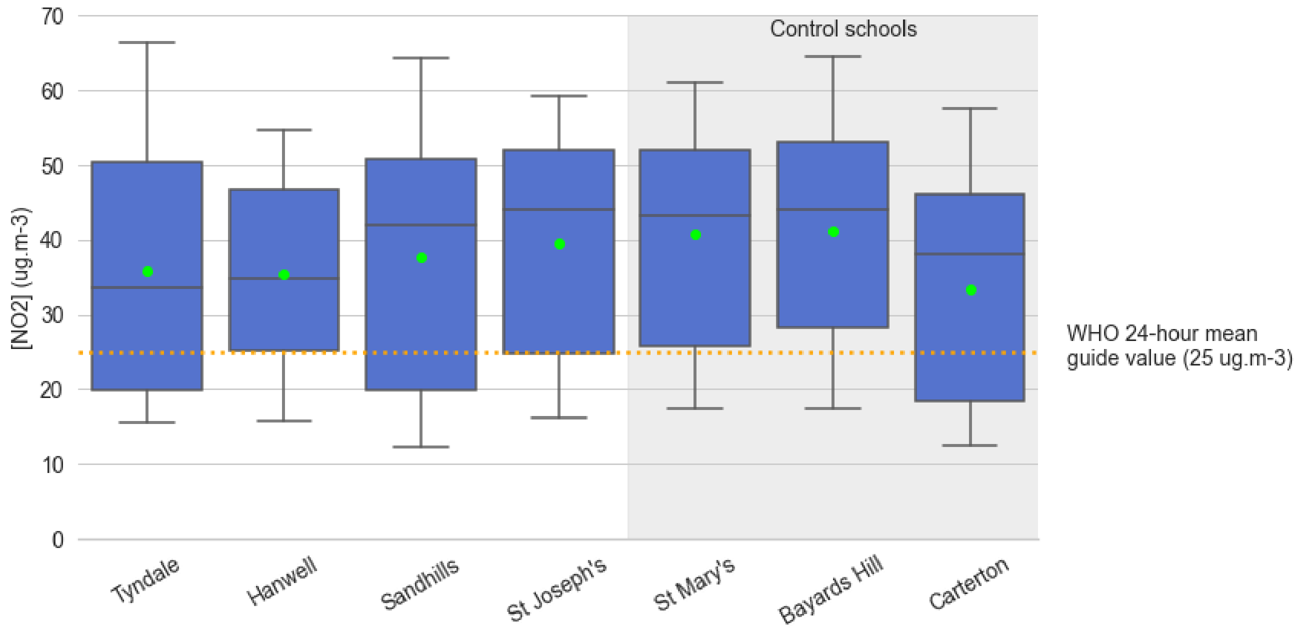
Supplementary Figure 1 shows that daily mean NO_2 concentrations across all schools is broadly similar, both in terms of the extremes observed (the whiskers shown) and the spread of concentrations observed (the IQR / boxes). Daily mean concentrations in the 20-55 $\mu g/m^3$ range are shown to be typical, although there is evidence of more extreme conditions (~12-65 $\mu g/m^3$).

The similarity in the distribution of concentrations at each school is notable and an indicator of the similar locations having been selected for the study. The control schools which were not the recipients of active travel measures are generally representative of the four 'intervention' schools.

Despite the similarity in concentration distribution exhibited by each school, it is noticeable that the three schools closest to a major emission source - St Mary's School (control school), Sandhills School (intervention) and roadside location approximate to Bayard's Hill school, observed the highest individual daily mean concentrations and average daily mean concentrations over the duration of the study.

[4] https://www.who.int/publications/i/item/9789240034228?ua=1

Supplementary Figure 1. *Boxplot showing the frequency distribution of the 24-hour mean NO_2 concentration at each school over the duration of the study (pre and post intervention periods combined)*



Supplementary Figure 1 also presents the WHO guide value for daily mean NO_2 (as the orange, horizontal dashed line). This threshold value may be compared with the measured average daily mean concentration at each school, e.g., the green dots shown in each box plot (the median being presented as the black horizontal bar). Using this symbology Supplementary Figure 1 shows that average NO_2 levels over the duration of the study were greater than the WHO's daily mean guide value. This is confirmed by the median values which are less susceptible to extrema and outliers; the median values at each school are also more than the WHO guide values.

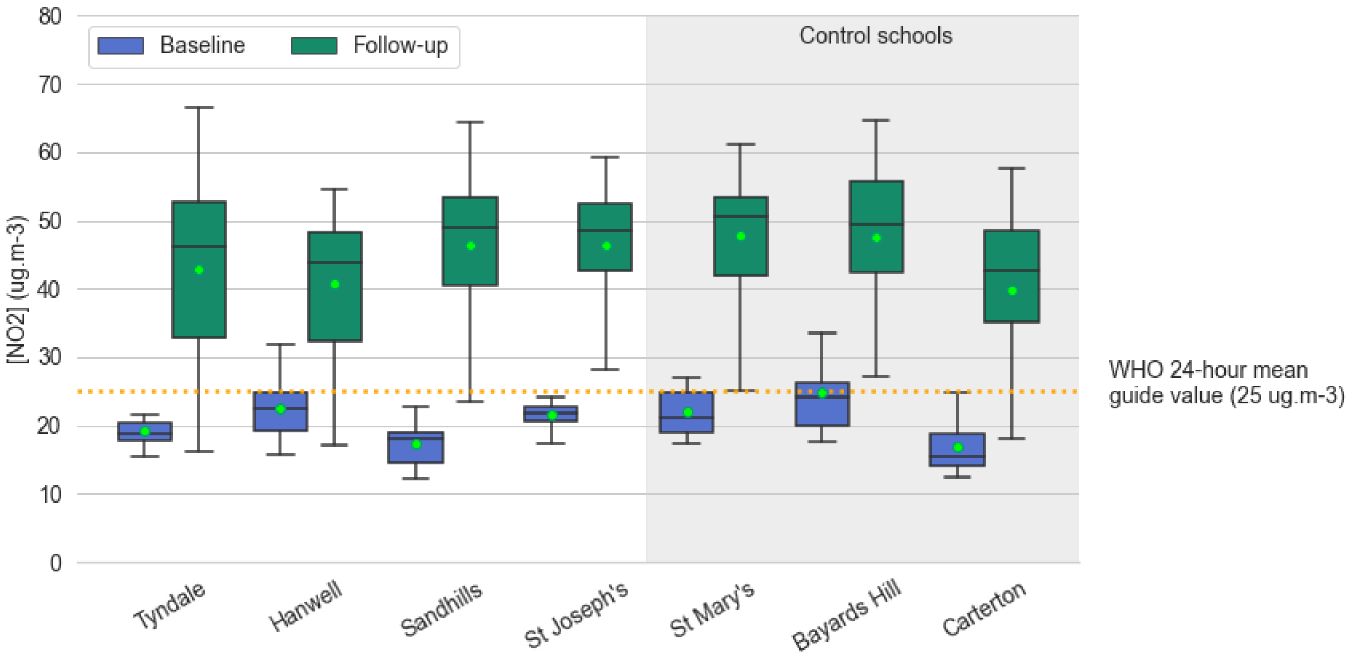
There were no occasions when measured 1-hour mean concentrations were above the WHO short-term (1-hour) guide value of 200 $\mu g/m^3$.

DIFFERENCES IN AIR QUALITY BASELINE VS FOLLOW-UP

Supplementary Figure 2 illustrates the range in concentration observed during (1) the baseline scenario - 8th to 22nd of July 2021 (blue boxplots), and (2) the follow-up, post intervention - 1st November to 10th December 2021 (green boxplots).

Despite similarities in the observed range in concentrations exhibited in Supplementary Figures 1 and 2, the most marked feature of fig. 2 is the differential in measured NO_2 in the baseline vs. the follow-up period. In the latter the mean NO_2 concentration is ~20-25 $\mu g/m^3$ higher than in the baseline period. This increase is replicated in median values and is accompanied by an increase in the range and variance in the daily mean concentrations – see whisker and IQR components of both baseline and follow-up boxplots.

Supplementary Figure 2. *Boxplot showing the frequency distribution of the 24-hour mean NO_2 concentration at each school for baseline and intervention periods individually*

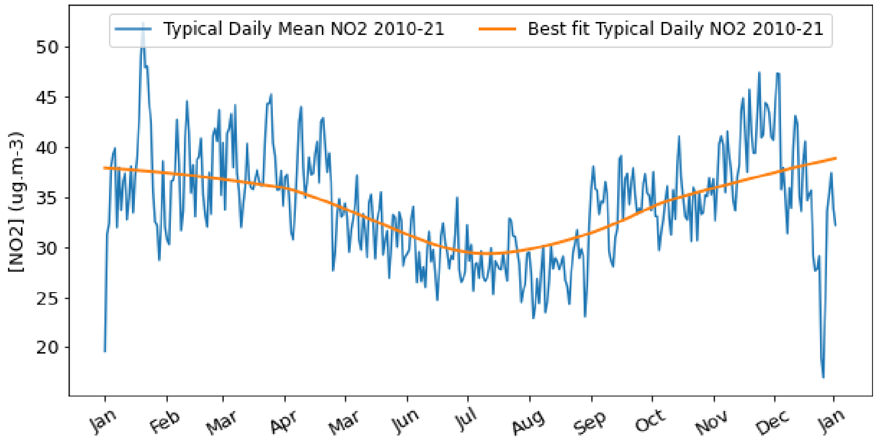


The variation in concentrations shown presented methodological challenges for the identification changes in air quality arising from the introduction of active travel measures. To further inform our approach, Supplementary Figures 3 and 4 present a reality check on the main features of Supplementary Figure 2.

Supplementary Figure 3 presents a time series of the average daily mean NO_2 concentration measured in Oxford 2010-2021. This time series has been derived from three Oxford city centre reference measurement stations which operated over this period. The stations used were Oxford Town Hall, Oxford High Street and Oxford St Ebbes. Their locations are classified as traffic orientated (Town Hall and High Street) and urban background (Oxford St Ebbes). Hourly mean NO_2 data have been processed over this period to calculate the average daily mean NO_2 concentration for each day in a standard calendar year. Fig. 3 shows a clear annual seasonal cycle in NO_2 concentrations. The nadir in the summer months coincides with the low concentrations observed during the baseline study period and the autumnal zenith with the higher concentrations found during the follow-up period. The drivers for the seasonal cycle include increased convective mixing and dilution in the ground-level layer in the summer months and increased vehicle and central heating during the winter months resulting greater local direct and indirect NO_2 emissions.

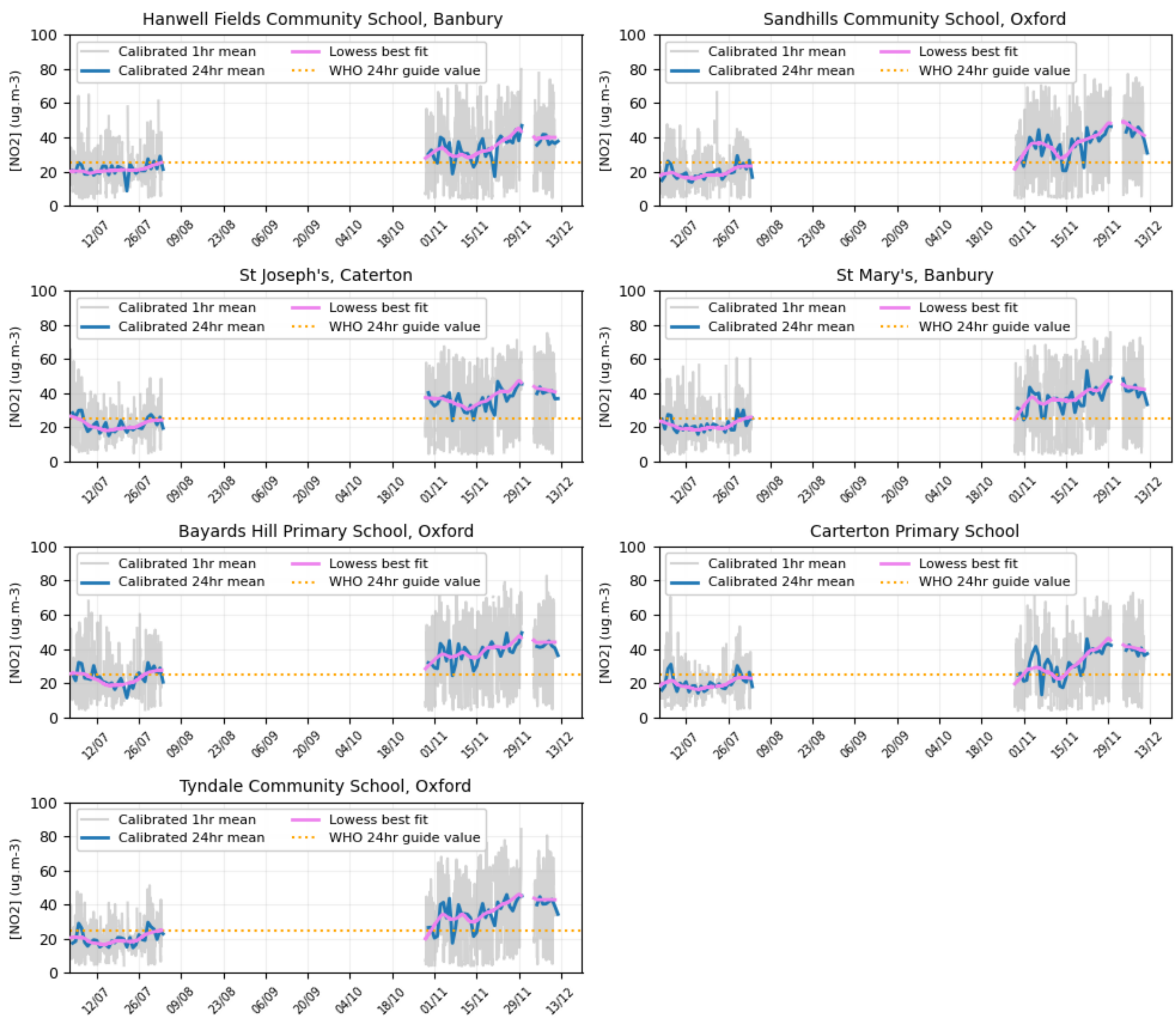
Supplementary Figure 4 presents a time series of sensor observations at each school for the duration of the study. A timeseries for the daily mean NO_2 (blue line) and 1-hour mean NO_2 (grey line) are presented alongside a smoothed daily mean NO_2 concentration derived using a LOWESS regression best fit approach. Fig. 4 indicates that taken within the context of the annual cycle in NO_2 (illustrated in Fig. 3), the concentration differentials shown in the boxplots presented in Supplementary Figure 2 are comparable, certainly of the same order of magnitude when taking siting of measurements into account. It is unlikely also that the increase is attributable to a drift in the sensor baseline as the QA/QC procedures used to pre-process the datasets make allowances for drift.

Supplementary Figure 3. Time series of typical (average) daily mean NO_2 concentration observed by Oxford city centre reference instrumentation 2010 2021.



Typical Daily Mean NO2 2010-21
Best fit Typical Daily NO2 2010-21
[NO2] (ug.m-3)
50
45
40
35
30
25
20
Jan
Feb
Mar
Apr
Mar
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

Supplementary Figure 4*. Time series of calibrated NO_2 sensor observations at each school over the duration of the study illustrating seasonal trend in NO_2 across Oxfordshire.*



CHANGES IN AIR QUALITY ARISING FROM WAYFINDING ROUTES

Results in sections 2.1 and 2.2 above encourage confidence in the reliability of the measured air quality data. At the very least these data offer an internally consistent and comparable indicative assessment of NO_2 levels. Observed levels of NO_2 broadly align with expectations given the locations chosen for sampling. However, challenges are presented for the identification of changes in air quality arising from active travel measures because of the seasonal trends observed. The method used to identify changes in air quality concentrations is outlined below.

To compensate for the seasonal trends in NO_2, the concentrations measured in the hours adjacent to drop-off and pick-up hours were used as a seasonally local datum for normal conditions at drop-off and pick-up time in the absence of active travel measures. An analysis of the diurnal cycle in NO_2 at each school informed this approach. This showed that NO_2 concentrations measured in the baseline at drop-off and pick-up were broadly the same (on same part of the diurnal curve). Any departure from this state in the follow-up period could therefore be taken as a marker for a change in concentration arising from active travel measures relative to the local datum. NO_2 diurnal cycle plots supporting this approach are presented in Annex A (see Figures D1 to

D3). Supplementary Table 1 below, summarises the definition of drop-off, pick-up and adjacent hours used. The concentration delta (change) arising from active travel measures was calculated for the baseline and follow-up scenarios as shown in the equation (1) below.

$$\Delta C = C_{(drop\text{-}off\ /\ pick\text{-}up)} - C_{(drop\text{-}off\ /\ pick\text{-}up\ adjacent\ hours)} \qquad (1)$$

Where;

ΔC	Is the concentration delta (change) in NO_2 during drop-off or pick-up hours relative to the hours adjacent.
$C_{(drop\text{-}off\ /\ pick\text{-}up)}$	Is the NO_2 concentration measured in drop-off or pick-up hour.
$C_{(drop\text{-}off\ /\ pick\text{-}up\ adjacent\ hours)}$	Is the NO_2 concentration measured in drop-off or pick-up hour.

Supplementary *Table 1 Constituent hours of drop-off, pick-up and drop-off / pick-up adjacent hour*

	Constituent hours (hour starting)
Drop-off hour	08:00
Drop-off adjacent hours	07:00, 09:00
Pick-up hour	15:00
Pick-up adjacent hours	14:00, 16:00

Supplementary Figures 5a-d provide an illustration of the output of this analysis, again using boxplots to present the frequency distribution of daily mean NO_2 measured at each school during the drop-off /pick-up hours and adjacent hours of the baseline / follow-up scenarios. Weekend days have been excluded from this analysis.

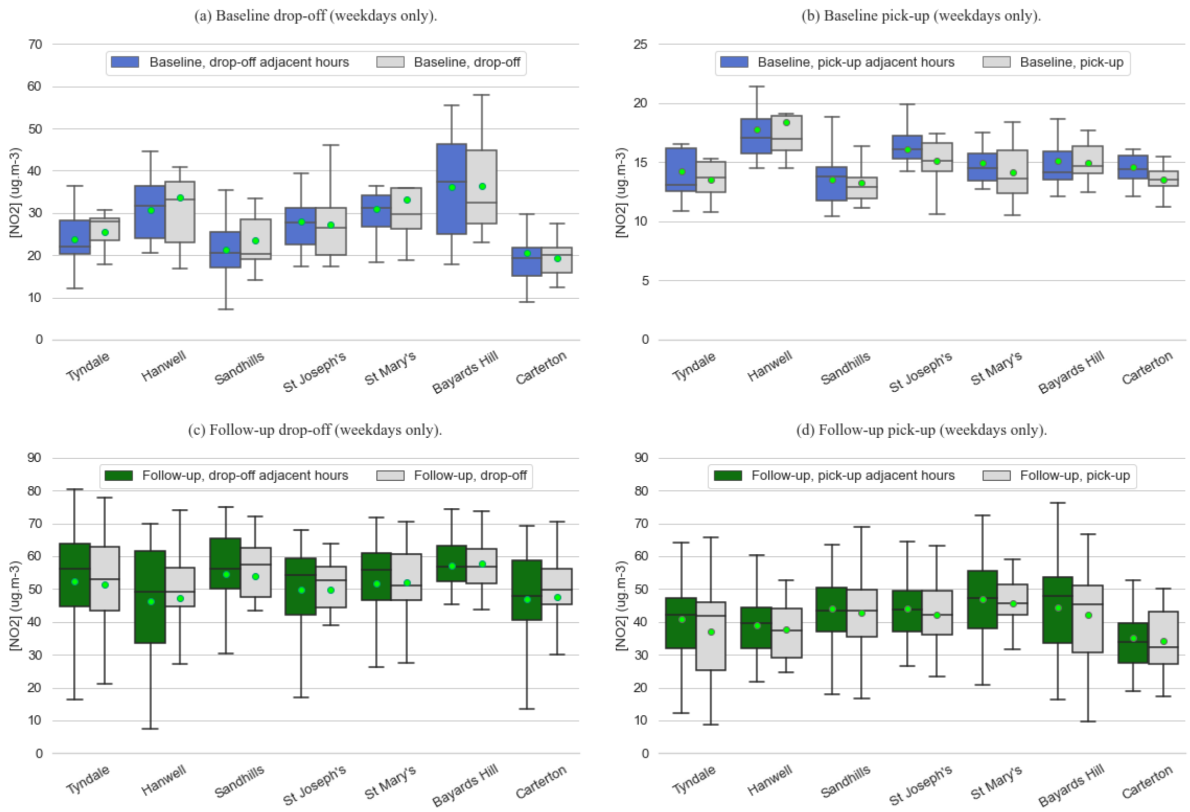
A visual inspection of Supplementary Figures 5a-d offers some *qualitative* evidence for a positive impact arising from active travel measures. Comparing Supplementary Figures 5a and 5c (drop-off hour and drop-off adjacent hours in the baseline and follow-up scenarios), mean values at drop-off in the baseline tend to be higher than those in drop-off adjacent hours, whereas at follow-up, mean values are generally lower than those in the drop-off adjacent hours. This feature is also observed for median values at some locations, but the relationship is generally weaker. Similar relationships are not discernible in the pick-up datasets.

A Student's T-test[5] was used to test for statistical significance in the difference in the mean concentrations observed at drop-off and drop-off adjacent times. Student's T at P=0.90 and P=0.95 did not indicate significance in the difference mean values measured at drop-off and drop-off adjacent hours in the baseline

[5] Student. (1908). The probable error of a mean. *Biometrika*, 1–25.

and follow-up scenarios. Therefore, no statistical significance is associated with visual interpretation presented above. This observation is reflected in the pick-up datasets also.

Supplementary Figure 5a-d *Frequency distribution of daily mean NO_2 concentrations measured at drop-off/pick-up and drop-off/pick-up adjacent hours in the baseline and follow-up scenarios*



ANNEX A MEASURED 1-HOUR DIURNAL NO_2 CONCENTRATIONS

Figure D1

Diurnal variation in 1-hour mean NO2 at Wayfinding sensor locations, 2021.

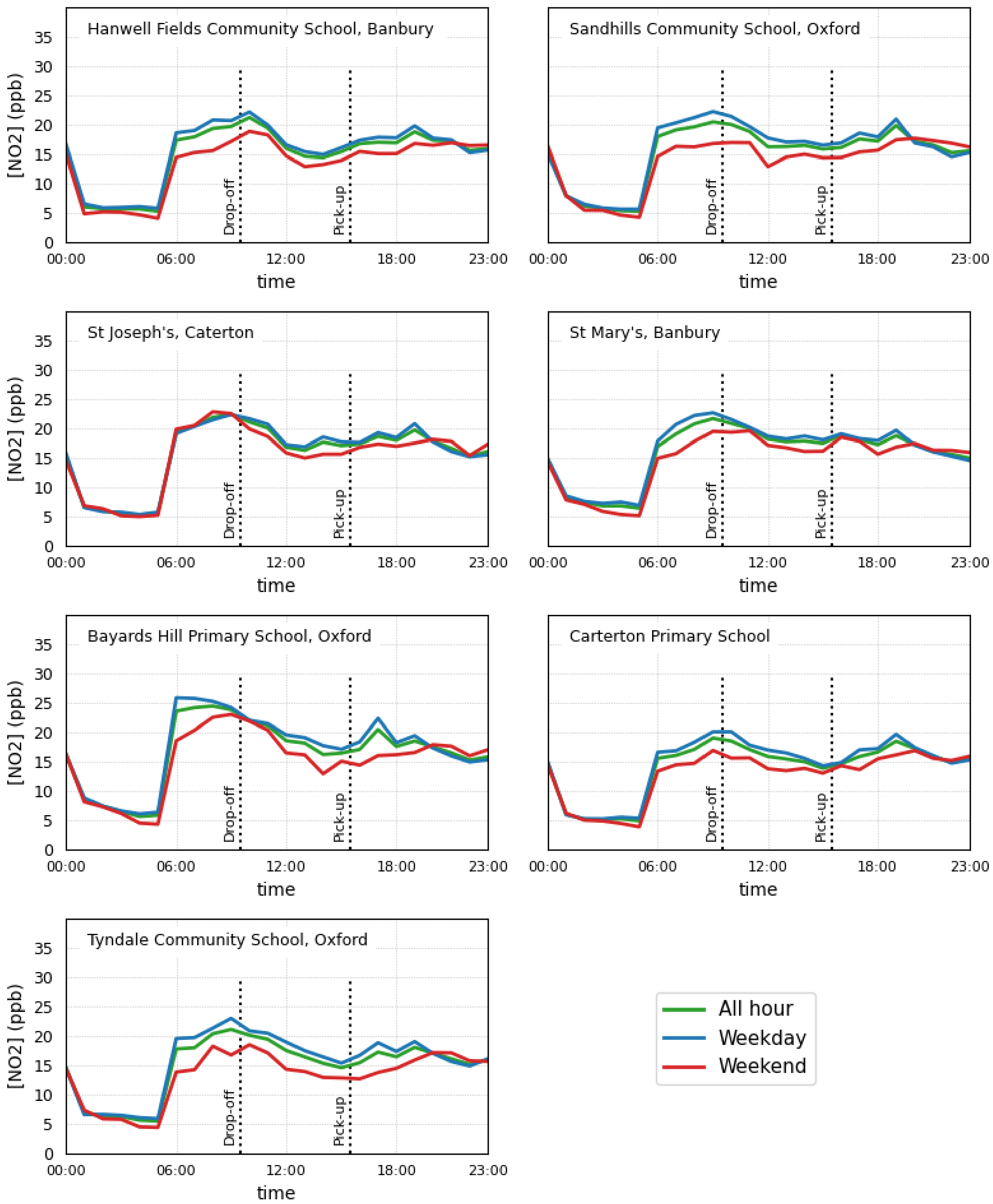


Figure D2

Diurnal variation in 1-hour mean NO2 at Wayfinding sensor locations, Baseline 2021.

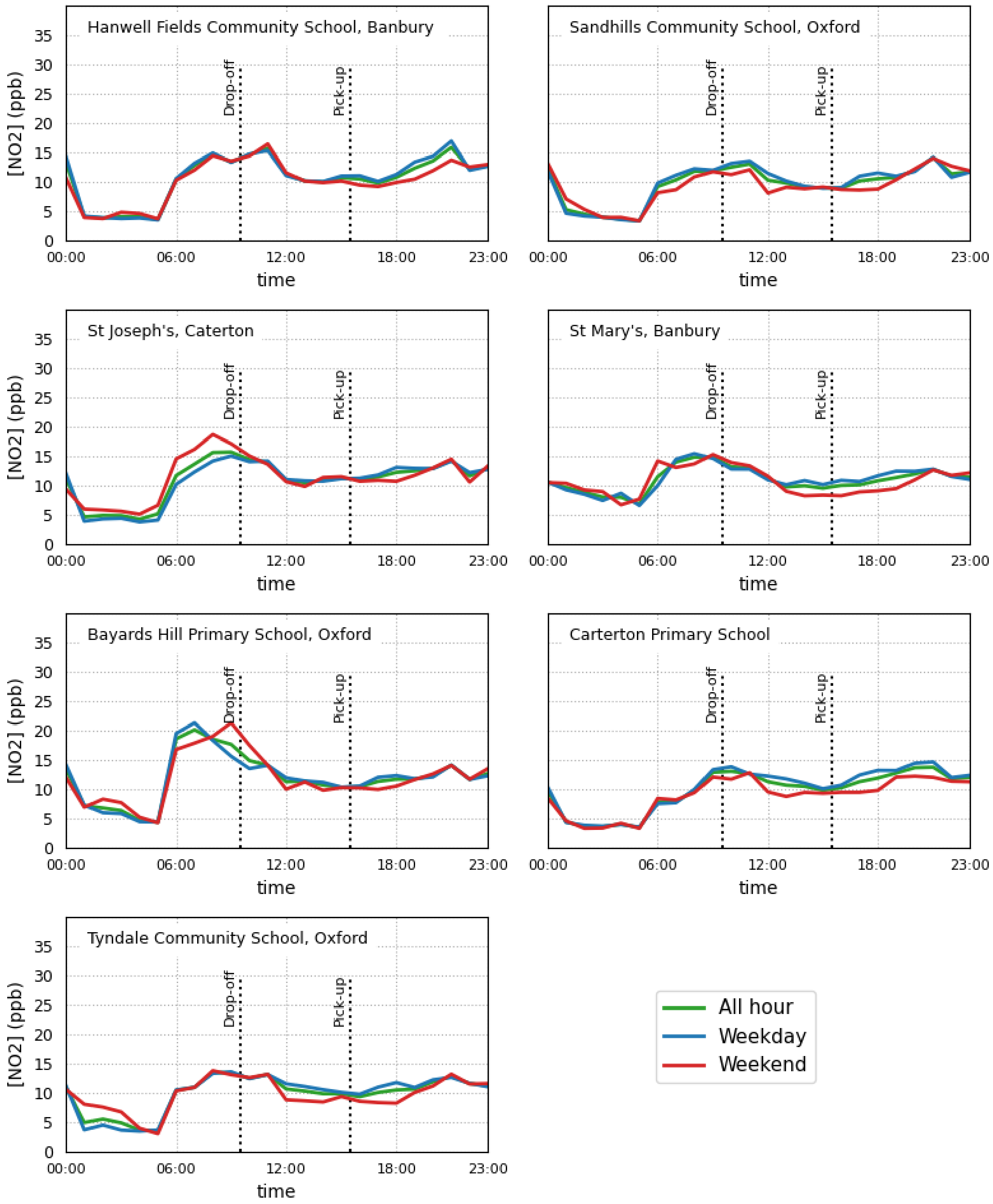
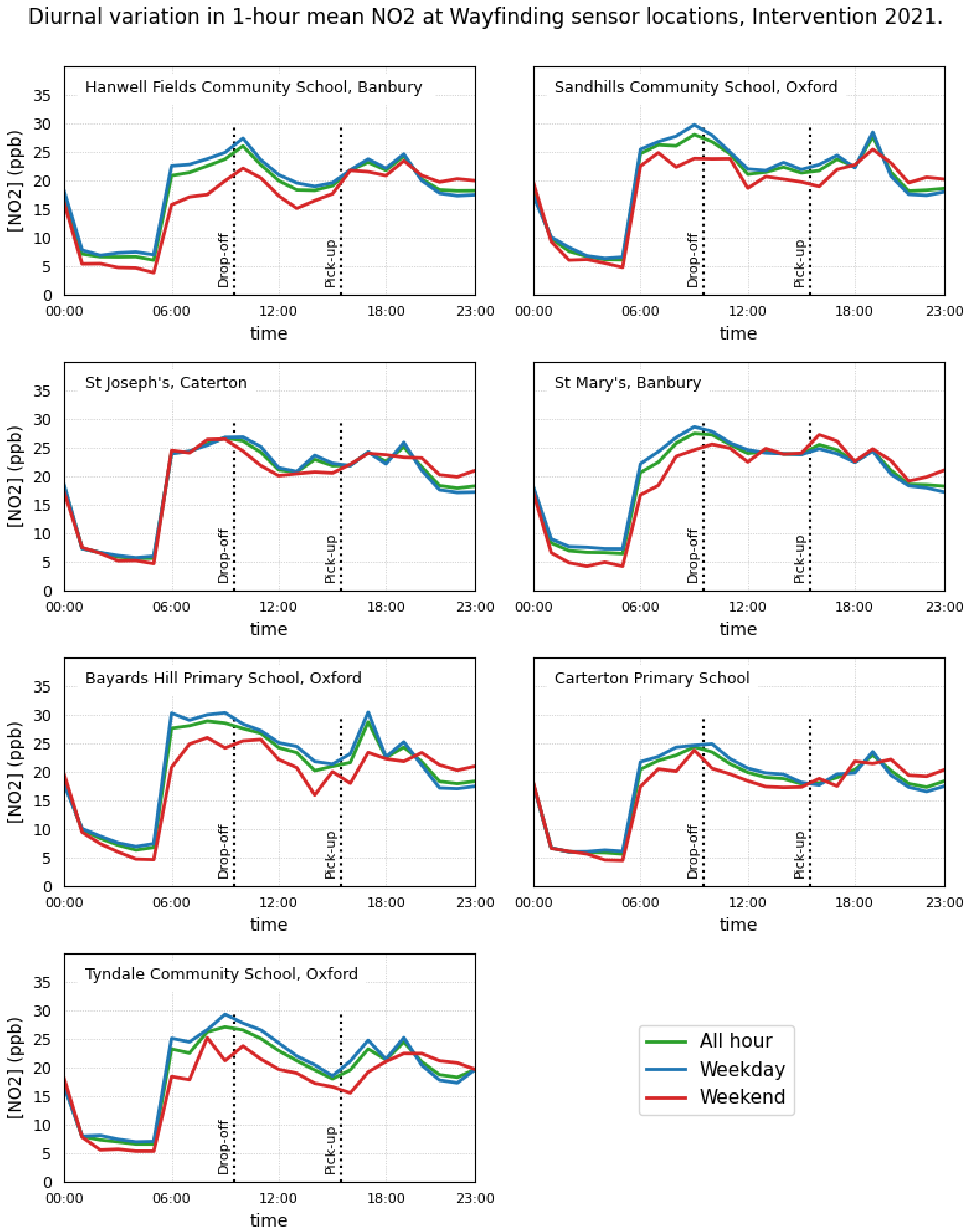


Figure D3



Diurnal variation in 1-hour mean NO2 at Wayfinding sensor locations, Intervention 2021.
Hanwell Fields Community School, Banbury
Sandhills Community School, Oxford
St Joseph's, Caterton
St Mary's, Banbury
Bayards Hill Primary School, Oxford
Carterton Primary School
Tyndale Community School, Oxford
[NO2] (ppb)
time
Drop-off
Pick-up
00:00
06:00
12:00
18:00
23:00
All hour
Weekday
Weekend

APPENDIX 6. LESSONS LEARNED

Project element	Lessons learned description	Time period identified	Implications	Recommendations
Site Selection: Difficult to find schools where Wayfinding could be a feasible intervention given the environment	Schools with recognised traffic and congestion issues have often tried in the past to change travel behaviour. Those which continue to have issues frequently don't have easily identifiable park and stride sites or in some cases, any feasible walking/cycling routes which is why the problem remains. Sites were not feasible due to factors such as lack of footpaths for walking, lack of parking for cars within walking distance etc, lack of access to car parking locations.	Design	The number of schools and choice of schools to include as intervention sites was limited to those feasible and engaged.	Better data collection on school travel and centralised repository for this?
Site Selection: Promotion and roll out of alternative Active travel interventions	The roll out of school streets over the same time period made selection of schools more difficult as some schools with potentially good options for walking were already ear marked for a school street	Design	The number of schools and choice of schools to include as intervention sites was limited to those feasible and engaged.	Again, coordinated workspace would help to manage projects with significant overlap
Site Selection: Lack of data on baseline active travel	Choice of intervention schools (and control locations) was made more difficult without having easy access to baseline active travel data. Although this data was available elsewhere it was not accessible through the WOW travel tracker (due to COVID low	Design	The number of schools and choice of schools to include as intervention sites was limited to those feasible and engaged.	

	response). We were reliant on schools engaging and identifying a problem at the site.			
Site Selection: lack of engagement from schools	This was a recognised risk, especially with COVID but the mitigation was assumed we could work around lack of engagement and present a light-touch approach. However, there was always a risk that schools would back out	Design	The number of schools and choice of schools to include as intervention sites was limited to those feasible and engaged.	Better early engagement by project lead with local physical activity leads who know the schools. Also, more close working with travel plans team.
Design: Initial view of 'park and stride was just from car parks - these are sometimes limited	Position of the wayfinding programme was initially as a park and stride scheme. Working through this project it is often as useful to use wayfinding from residential areas even where no defined parking is available.	Development		Widen consideration of the approach to residential areas. Requires data on pupil postcodes of residence
Design: local planning not conducive to active travel interventions	Some sites had limited options due to local planning and development issues that are not conducive to creating walking and cycling routes.	Development		
Delivery: Low parental engagement	May have been easier in non-COVID times when able to meet parents outside school and get their input/thoughts or set up in person meetings at the school	Development		Need to have a plan for delivering with limited parental engagement and still delivering something worthwhile.

Delivery: Supplier delays	Difficulties with suppliers meeting deadlines for delivery and installation - this led to delays in implementing and subsequently evaluating the intervention.	Implementation		
Design: enhancing the behaviour change aspects of the intervention	Greater emphasis on behaviour change may have enabled a greater take up of active travel using the Wayfinding routes however, lack of parent and school engagement hampered the ability of the OCC team to design and implement such behaviour change resources to accompany the installation. In hindsight a more 'stepped' approach, to build in additional behaviour change activities to promote the wayfinding routes and signs over time is likely a more realistic and effective approach. This will allow the council to support school-led initiatives to generate greater behaviour change. More firm commitment and engagement from schools may well be required in order to optimise the potential benefits from the Wayfinding project	Implementation		
Implementation: School engagement	Installation and 'go-live' should be school led. This requires really good school engagement and commitment. This has been a challenge when schools have been managing COVID over the term. The final 6 months of this project should focus on supporting schools to engage	Implementation		

	with their wayfinding routes and ideas to build up use of the installed routes.			
	Taking a multi-faceted approach to collecting outcome data has been valuable because there are inevitable challenges in gathering survey data from parents or children. Objectives measures e.g., vehicle counts, are less nuanced and so also have some limitations. Collecting a range of measures, particularly for a small pilot, is valuable. Though qualitative data is likely to be very valuable, we have experienced significant challenges in collecting this due to COVID in schools and lack of ability to meet face to face.	Evaluation		
	Data collection and evaluation over the short-term is necessary to understand any immediate changes. Over the longer term, evaluation is necessary, however other factors (other interventions, changes in the environment, policy, COVID etc will impact this longer-term evaluation.	Evaluation		