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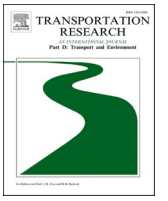

Mitigating child exposure to traffic-related air pollution on the school commute: Views of parents and teachers in England

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ABSTRACT

Children are particularly vulnerable to the adverse health effects of traffic-related air pollution (TRAP) due to their developing physiologies. A survey was distributed to schools in England for completion by parents and teachers. The survey examined perceptions of TRAP on the school commute and assessed views on potential interventions for reducing exposure. 76.7% of parents and 75.8% of teachers were concerned about TRAP at their school. The most common cause for concern was school proximity to a busy road (44.2% parents and 42.5% teachers).

Active travel was the most common measure already undertaken. The biggest obstacles to reducing school TRAP were driving convenience, school proximity to busy roads, and lack of parental support. Parents and teachers considered local authorities most responsible for improving school TRAP. Active travel was a popular and desirable intervention for reducing potential child exposure, and parental education on this and related topics were also desirable.

1. Introduction

Traffic-related air pollution (TRAP) is a key source of urban air pollution (Houngbégnon et al., 2020; Morici et al., 2020). As such, TRAP around schools has gained increasing attention in the media and academic endeavour over recent years due to the severity of consequences of exposure on both the health and development of children. Children are particularly vulnerable to the adverse health effects of TRAP due to their developing respiratory systems (Asri et al., 2021; Beamer, 2019; Goldizen, Sly & Knibbs, 2016; Horak et al., 2002). Children also have a greater metabolic rate than adults, which results in a higher breathing rate, presenting one of the starkest differences between the lungs of children and adults (Salvi, 2007). The greater respiration rate of children also increases airway exposure to inhaled pollutants, and this can also adversely affect lung growth and development. Additionally, the oxidant nature of many air pollutant gases is closely correlated with inflammation in animal and cell studies (Kelly, 2003). In recent years, there has been growing concern about the impact of TRAP on children's health, leading to calls for measures to reduce child exposure, particularly around schools (Dadashova et al., 2023; Sá et al., 2017; Banerjee, 2016).

1.1. Air pollution & schools

A growing number of academic studies have demonstrated the detrimental outcomes of TRAP concentrations in and around the

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school environment and the negative consequences of child exposure to these harmful pollutants. A broad range of research has highlighted the negative effects of air pollution exposure on the internal organs of children (Hamra et al., 2015; Kampa & Castanas, 2008), and their developing cardiovascular, nervous, and respiratory systems (Diener & Mudu, 2021; Adar et al., 2015; Kim, Kabir & Kabir, 2015). Reduced academic ability and concentration levels of schoolchildren are other factors that have been linked to air pollution exposure (Chandra et al., 2022; Grineski, Collins & Adkins, 2020). Further research has demonstrated the adverse effects of air pollution exposure on pre-existing respiratory conditions, such as asthma, and allergies (Beemer et al., 2022).

Schools and the school commute are important contexts for child exposure to TRAP, as school buildings are often located near busy roads with accordingly high levels of traffic. In addition, the openings times of schools coincide with peak morning traffic and many parents drive their children to and from school (Rangel et al., 2022; Whitehouse & Edwards, 2018; Whitehouse & Grigg, 2018). This combination means that many children are potentially exposed to the highest daily societal levels of TRAP every morning on their school commute.

1.2. Mitigation strategies

A systematic review was conducted (Brown, 2023) to identify effective TRAP reduction and mitigation strategies suitable for application to the school commute and at the school gates. The review identified potential mitigation strategies including active travel, rideshare, anti-idling, awareness, and low-emission zones (LEZs), also known when implemented within the vicinity of school buildings as 'school streets' (Thomas, Furlong & Aldred, 2022).

1.2.1. Active travel

Promotion of active travel, such as walking or cycling to school, aims to reduce reliance on motorised transportation, reducing vehicular emissions around schools. Active travel is a relatively low-cost solution, and initiatives can include walking, cycling or scooting, school buses, bike trains, and improved infrastructure such as safe pavements and cycle lanes (Ghimire & Bardaka, 2023). Active travel has many advantages, including improved physical health, reduced traffic congestion, and reductions in air pollution (Wang et al., 2023). However, challenges include ensuring safe routes for children, addressing parental concerns about safety, and accommodating students who live too far from school to walk or cycle (Wilson, Wilson & Krizek, 2007; McDonald, 2005).

1.2.2. Rideshare

Rideshare programs at schools encourage families to share rides with other students to reduce the number of vehicles commuting to and from the school each day. This initiative helps to reduce traffic congestion around school zones, lowering overall vehicle emissions and improving air quality (Si et al., 2022). The benefits of ridesharing include reduced fuel consumption and a lower carbon footprint, as well as fostering a sense of community among parents and students (Jacobson & King, 2009). However, rideshare programs can encounter difficulties such as coordinating schedules between families, ensuring the safety and reliability of shared rides, and overcoming parental preferences for direct control over child transportation (ibid.).

1.2.3. Anti-Idling

Anti-idling policies aim to reduce air pollution around schools by limiting the time vehicles idle while waiting for students. This initiative commonly involves educating drivers about the harmful effects of idling and enforcing regulations to minimise the practice. The primary positive aspect of anti-idling policies is the reduction in emissions of harmful pollutants (Ryan et al., 2013). Additionally, these policies can lead to fuel savings (Gao & Klein, 2011) and decreased noise pollution (Abrams et al., 2019). However, the implementation of anti-idling measures can face challenges such as ensuring consistent enforcement and changing driver behaviours (Ryan et al., 2013).

1.2.4. Awareness

Raising awareness about air pollution involves educating parents, teachers, and the local community about its sources, impacts, and mitigation. This can include organising workshops, distributing informational materials, and integrating air quality topics into the school curriculum. The primary benefit of raising awareness is the empowerment of the community to take proactive steps in reducing pollution, such as adopting rideshare, using public transportation, or active travel to school (Mendoza et al., 2022). Furthermore, informed communities are more likely to support and comply with other pollution-reducing measures (Castell et al., 2021). However, obstacles to raising awareness include varying levels of community engagement, potential resistance to change, and the need for sustained efforts and resources to maintain high levels of awareness and participation (Ramírez et al., 2019).

1.2.5. Low-Emission zones

Low-emission zones (LEZs) include strategies such as 'school streets', which establish LEZs by restricting vehicle access during peak hours, are designed to create a safer and healthier environment for students. These zones not only reduce air pollution but also encourage active travel by making walking and cycling safer and more attractive options. The positives of school streets include the reduction of traffic accidents, improved air quality, and the promotion of healthier lifestyles among students (Thomas, Furlong & Aldred, 2022). Despite these benefits, implementing school streets can face several challenges, including resistance from parents who rely on cars for school drop-offs, the need for effective traffic management plans, and potential pushback from local businesses and residents affected by the restrictions (Smith et al., 2022; Varma, 2021).

1.2.6. Current research context

The current research builds upon the review findings in Brown (2023), using the identified strategies as a basis for enquiry to explore the views and perceptions of key stakeholders in England on TRAP around schools and on the school commute, and the desirability of these measures and interventions for mitigating child exposure. Whilst an international context is desirable, a focus on England offers several advantages, particularly when investigating issues like TRAP near schools. One primary benefit is the ability to produce recommendations within the context of UK-specific legal and regulatory frameworks that influence environmental and public health policies. This specificity also allows for a detailed analysis of local measures, their perceived effectiveness, and the contextual factors influencing their implementation. Such focus ensures the relevance and applicability of research findings and recommendations specifically tailored to local policymakers and stakeholders.

Additionally, concentrating on schools in England helps manage the complexity and scope of the research within practical constraints such as time, budget, and available expertise. Localised data sources provide consistent and high-quality data that benefit accurate analysis. The cultural and behavioural patterns related to commuting and school transportation in the UK, which might differ significantly from other countries, also impact the applicability and relevance of the study outcomes. By maintaining a specific geographic focus, the research can maintain depth over breadth, ensuring thorough investigation and meaningful contributions to the local context. This approach not only enhances the practicality and impact of the research but also sets a robust foundation for future studies, potentially expanding to comparative international analyses based on a solid understanding of the UK scenario.

Despite substantial literature documenting the health impacts of TRAP on children, there is a notable gap in understanding the perceptions and attitudes of parents and teachers regarding this issue. This study aims to fill this gap by surveying these key stakeholders to gather insights into their concerns and perceived barriers to reducing TRAP exposure in school environments. The current research complements existing literature by offering qualitative data on the social and behavioural aspects of TRAP, providing a more holistic understanding of the issue. Specifically, it highlights parent and teacher concerns related to air pollution at school, which is a critical yet sometimes overlooked factor in TRAP studies. By documenting these concerns, the study emphasises the need for targeted interventions in urban planning and school siting.

1.2.7. Study aim

This study aims to identify a set of TRAP exposure reduction and mitigation measures and interventions considered appropriate for the school commute, ratified by key stakeholders. To achieve this aim, a survey was distributed to schools throughout England for completion by parents and teachers. The survey examined perceptions of TRAP around schools and on the school commute, the impact on child health, and views on potential interventions for reducing exposure. This research is novel in its dual focus on the perspectives of both parents and teachers, providing a comprehensive view of community attitudes towards TRAP. By identifying specific concerns and assessing potential interventions, this study offers actionable insights that can guide policy and community efforts, ultimately aiming to reduce children's exposure to harmful pollutants and improve their long-term health outcomes.

2. Materials & methods

2.1. Overview

A survey was delivered to schools in England via their publicly available email contacts to determine what TRAP reduction and mitigation interventions for implementation around schools and the school commute were popular amongst key stakeholders.

2.2. Questionnaire Construction & Ethics consent

The questionnaire was constructed in Qualtrics and comprised three blocks (consent page, demographic questions, and questions about the respondents' attitudes and experiences towards air pollution and associated mitigation interventions) (Appendix A). Demographic data was considered imperative for the questionnaire, as any population's requirements cannot be measured or met without sufficient knowledge of its characteristics (Table 1).

Whilst the questionnaires were entirely anonymous, it is important to know some specifics about those responding, as this would allow the identification of a representative sample population. The procurement of relevant demographic information also enables the differentiation between sub-groups of responders. This segmentation holds the possibility of providing insights that may be missed when only assessing aggregate data.

Table 1
Demographic survey questions.

Number	Question
Q1	What is your age?
Q2	What is the first part of your postcode?
Q3	Please choose one option that best describes your ethnic group or background.
Q4	What is the highest level of education you have completed?
Q5	What best describes your school affiliation?
Q6	How many children do you have?

The second block of the questionnaire addressed air pollution and mitigation interventions and is presented in Table 2.

The questions in the second block related to the respondent's experience of air pollution as an issue in their community and around schools, in addition to identifying their opinions on associated considerations and potential effective measures.

2.3. Pilot

An initial pilot survey run was delivered to members of the Faculty of Environment and Technology (FET) at University of the West of England, Bristol, to determine any design flaws and highlight any possible improvements, inconsistencies and errors in the questionnaire content and logic. A total of 67 responses were procured from the piloting, and minor issues were addressed.

2.4. Distribution

Email addresses for all schools in England were procured via an existing freedom of information request (WDTK, 2020). The original list included 24,921 entries (each referring to an individual school) and, following validation (removal of duplicate and invalid emails), this was reduced to 24,009.

Once all issues were addressed and the content and logic of the questionnaire were sound, it was distributed using the Qualtrics survey distribution feature. Distribution of the questionnaire spanned three months (April to July 2021).

2.5. Data Cleaning & analysis

The survey acquired 1441 responses which were sorted into 862 (59.82 %) parents (including family members and carers) and 579 teachers (including head teachers, school staff and support staff). Fig. 1 shows the composition of the respondents by percentage. The teacher response category is composed of 284 (49.05 %) teachers, 85 (14.68 %) teaching assistants and 210 (36.27 %) who identified themselves as 'other school staff'.

The survey received a greater number of parent respondents than teacher respondents (862:579, respectively). This is likely due to the distribution method, with schools as the survey gatekeepers.

1441 respondents completed all demographic questions, and 1424 progressed to the first air pollution question (Q7). 778 parents and 493 teachers, totalling 1271 participants, completed the entire questionnaire, resulting in a completion rate of 88.20 %. All response data were cleaned and analysed using Microsoft Excel (Version 2306).

2.5.1. Representativeness

A Jarque-Bera (JB) goodness-of-fit test was used to determine if the age data matched a normal distribution (Appendix B). The p-value for parents was greater than 0.05, so the null hypothesis was not rejected. The p-value for teachers was less than 0.05, so the data can be described as normally distributed. Most parents were aged 35–44 ($\overline{x} = 41.86$), and most teachers were aged 45–54 ($\overline{x} = 45.71$).

The normality of the number of respondents' children was determined (Appendix C). The p-value for parents and teachers was less than 0.05, so the data can be described as normally distributed for both groups. Most parents (n = 481, 55.80 %, $\overline{x} = 1.97$) and teachers (n = 212, 36.61 %, $\overline{x} = 1.54$) specified 2 children. The respondent ethnicity was broadly representative of the population (Table 3).

The respondents were distributed throughout England (Appendix D). The respondents were well-educated, with the greatest proportions of each group holding at least a bachelor's degree (44.4 % and 56.0 % of parents and teachers, respectively) and with an average of two children. There were no notable regional variations.

3. Results & Discussion

3.1. Air pollution concerns (Q7, Q8)

Q7 How concerned are you about the effects of air pollution on pupils' school health?

Fig. 2 shows the percentage responses to Q7. The majority of parents' (76.7 %) and teachers' (75.8 %) indicated that they were very or fairly concerned about air pollution at their school.

Table 2
Air pollution survey questions.

Number	Question
Q7	How concerned are you about the effects of air pollution on pupils' school health?
Q8	Why are you concerned (select all that apply)?
Q8	Why are you unconcerned (select all that apply)?
Q9	What has your school/community/council/other done to improve school air quality?
Q10a	What measures do you think would be effective for improving air quality at school?
Q10b	What would be the most effective measure for improving air quality at school?
Q11a	What are the biggest obstacles to improving air quality and/or reducing car use at school?
Q11b	What is the biggest obstacle to improving air quality at school?
Q12	Who do you consider to be the most important for supporting efforts to improve school air quality?

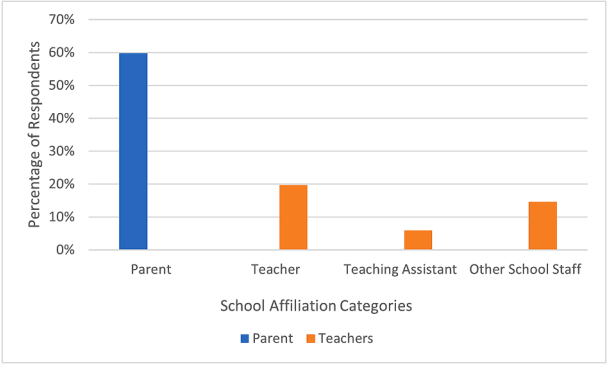

Fig. 1. Respondent percentages by stated affiliation.

Table 3
Comparison of stated respondent ethnicity and UK population.

Specified Ethnicity	Percentage of UK Population (ONS, 2018)	Parent Respondents	Teacher Respondents
White	86 %	756 (87.7 %)	528 (91.2 %)
Mixed	2.2 %	25 (2.9 %)	14 (2.4 %)
Black	3.3 %	15 (1.7 %)	10 (1.7 %)
Asian	10 %	36 (4.2 %)	16 (2.8 %)
Arab	0.6 %	3 (0.4 %)	1 (0.2 %)
Another ethnic group	1 %	7 (0.8 %)	3 (0.5 %)
Preferred not to answer	N/A	20 (2.3 %)	7 (1.2 %)

More respondents were concerned than not, and there was little observable difference between parent and teacher responses. Most respondents stated they were fairly concerned (Parents, 40.37 %; Teachers, 45.42 %). Whilst more teachers than parents expressed that they were fairly concerned, numbers were comparable between both groups.

Q8 Why are you concerned?

The respondents who had expressed concerns (i.e. selected 'very' or 'fairly' in response to Q7) were then prompted to clarify their reasons by selecting from a list of options (Fig. 3).

School proximity to a busy road was the greatest cause for concern for parents (44.2 %) and teachers (42.5 %). Secondary concerns included idling outside the school (Parents, 40.0 %; Teachers, 32.3 %), general concerns due to media coverage of air pollution (Parents, 33.1 %; Teachers, 32.3 %), and congestion at the school (Parents, 30.7 %; Teachers, 25.7 %). These findings are supported in the literature, with the majority of parents exhibiting general concerns regarding child health as a consequence of air pollution exposure (Cobbold et al., 2022), particularly when in close proximity to busy roads (Liao et al., 2015; Stevens, Cullinan & Colvile, 2004).

Teachers appeared to be more aware of increasing levels of respiratory illnesses among children at their school and monitored levels of air pollution. This may be because teachers are more able to observe trends, such as year-on-year increases in respiratory conditions in the classroom (see Hinton & Kirk, 2015). This also highlights an area in which parents could be better informed about poor air quality at their school, both in terms of concentration and health impact.

For those responses under 'other', the provided statements were coded by theme (some statements included more than one topic

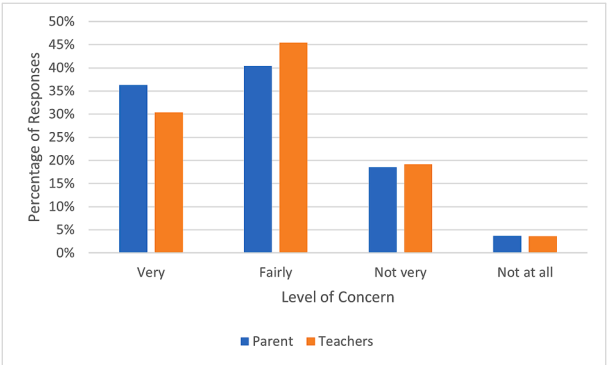

Fig. 2. Percentage responses for the level of concern for the effects of air pollution on the health of schoolchildren.

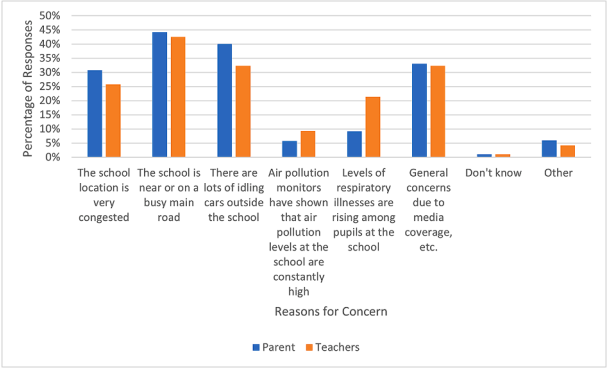

Fig. 3. Percentage responses for reasons for concern regarding air pollution's effects on schoolchildren's health.

and some could be categorised into the options presented in the main question) to show general sentiment (Fig. 4). General concerns were high for both parents and teachers (35.29 % and 30.43 %, respectively). Concerns regarding morbidity, including child health, development, allergies, and asthma were also high among parents (33.33 %), whilst school location was of greatest importance to teachers (39.13 %).

Broader concerns included general awareness, concerns due to media coverage, sustainability and idling at schools, and these were high for both parents and teachers, which is consistent with previous responses. General concerns also included those who expressed unease regarding the implementation of low-traffic neighbourhoods (LTNs). This was a recurrent cause for concern, which the respondents maintained has caused traffic to reroute past their children's schools. Whilst the list is not exhaustive, each of the following statements is from respondents in different postal out codes:

Parent: "Clean air zone in centre of town has moved the traffic to the school recently.".

Parent: "The LTN has produced increased traffic around the school with idling vehicles all day on 2 roads surrounding the school."

Parent: "A new LTN scheme has been introduced in Kings Heath, Birmingham. Oddly, it has closed off a lot of quiet suburban roads which always had low footfall and the consequence is significantly increased traffic on the roads with [*sic.*] are more heavily populated. The local high street which is near my daughter's school now has constant idling traffic. Likewise, the only main park in our area has basically become a car park. There are constantly lines of traffic alongside it which means it is not a safe area for them to play. The local council has ignored the negative impact of this LTN and appear to plough on regardless. My 8-year-old daughter who has never had any health problems, has developed very worrying respiratory issues which I can only feasibly attribute to the impact the LTN has had."

Parent: "A new LTN in Ealing is displacing the traffic towards our school.".

Parent: "An LTN has been placed meaning all traffic is now channelled past this school and two nearby primary schools. Their journey to school is also negatively impacted by LTN."

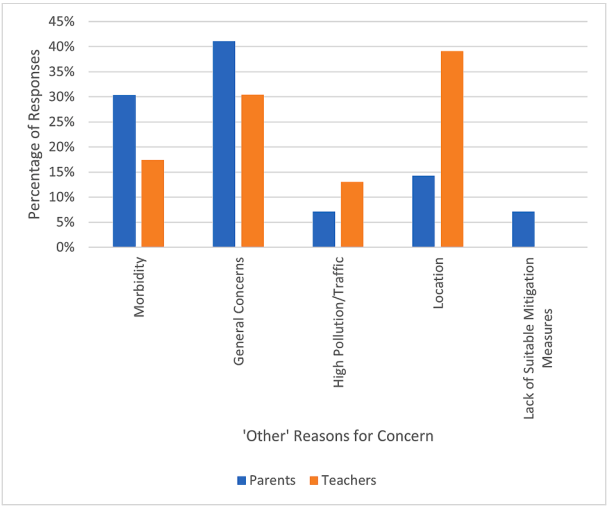

Fig. 4. Percentages of categorised coded responses for 'other' reasons for concern regarding air pollution's effects on schoolchildren's health.

The concerns surrounding schemes such as Low-Traffic Neighbourhoods (LTNs) appear consistent. Each maintains that the poor planning of LTNs has resulted in traffic becoming re-routed past their school, leading to greater congestion and air pollution in the area. It must also be considered that those who were satisfied with LTNs in their areas did not feel the need to express their approval although in any case, no positive comments about LTNs were provided.

Although teacher responses in the 'other' category are comparatively few, one teacher highlights LTNs as an issue, which is consistent with previous comments on the subject:

> Teacher: "The imposition of LTNs by the council has increased both congestion and air pollution in our area. Traffic is slower and idling for longer periods. Absolute insanity!"

Among teacher responses for 'other' concerns, the most common concerns were associated with asthma and health, which was also the second most popular reason for concern among parents. Some teachers expressed concern for their own health:

Teacher: "Have experience of asthma in my family.".

Teacher: "Concerned for my own respiratory health as I work there.".

Other teachers expressed concerns for child health:

> Teacher: "The school is away from the main road but many of the children live directly off a main road and many travel to school by car despite living very nearby. Asthma in school in [*sic.*] on the increase."
>
> Teacher: "Air pollution is an issue amongst both children and adults, I personally suffer from Asthma and notice it more in the workplace. This correlation must mean that there are high levels of pollution at/around school which will be affecting the children's health."

These comments each link morbidity to road and traffic proximity in their school areas. Concerns about school location in this regard (proximity to main roads, airports, or industry) were the most common response among teachers and were more than twice that of parents. However, more parents than teachers highlighted a lack of suitable interventions in place to mitigate against air pollution, including:

Parent: "Poor quality active travel links to enable car free travel.".

> Parent: "The school cut down all of the established trees which makes the problem a lot worse."

The disparity between parents and teachers regarding interventions may also be indicative of a lack of communication between the groups.

3.2. Lack of concern (Q8)

Q8 Why are you unconcerned?

Respondents who did not express concern were presented with an alternative follow-up question and prompted to clarify their reasons (Fig. 5).

For those parents and teachers who were not very or not at all concerned, the most common reasons were the rural location of the school (9.1 % and 9.5 %, respectively), little nearby traffic (9.1 % and 9.8 %, respectively), or that active travel was common among pupils (7.5 % and 7.3 %, respectively). Reasons for the lack of concern among parents regarding air pollution are debated in the literature, although common reasons cited include a lack of awareness (Sunyer et al., 2017; Stafford & Brain, 2015) or a greater set of concerns taking priority, such as family or financial matters (Stafford & Brain, 2022; Rashid et al., 2021).

School location presented the most popular reasoning for lack of concern. Schools in rural areas or away from busy roads appear to provide little concern to parents and teachers. This is supported by those who listed responses under 'other'. The provided statements were coded by theme (some statements spanned more than one topic) to show general sentiment (Fig. 6).

The most popular reason for lack of concern for both parents and teachers was that they did not consider it an issue at their school (46.67 % and 40 %, respectively). Strong uptake of active travel among pupils was also a popular reason for the lack of concern. More

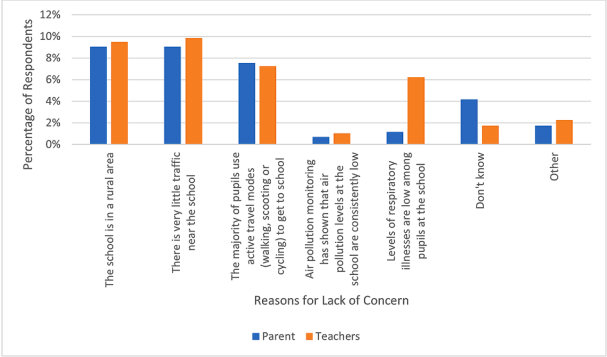

Fig. 5. Percentages of categorised coded responses for a lack of concern regarding air pollution's effects on schoolchildren's health.

teachers than parents expressed that air pollution monitoring showed low levels, and many more teachers than parents indicated that levels of respiratory illness were low among their school pupils. Mirroring the previous responses, many more teachers than parents appear to have a grasp of respiratory illness numbers among pupils. More parents than teachers indicated that they did not know why they were not concerned.

Parental concerns regarding mode shifts were also presented in the survey data. For example, concerns surrounding child safety and travel distance on the school commute were highlighted. The latter, in this case, presents additional issues regarding school catchment areas and pupil selection. Currently, catchment areas in England are commonly determined by local authorities based on factors including geographical boundaries, population density and demographics, and proximity to the school, although this varies among different regions and for different school types. Should catchments be determined via a structured and consistent methodology that requires residency within a particular area active travel distances would present as less of an issue. A far narrower inequality between the performance of schools would be necessary for this to be effective. Concerns for child safety as a barrier to active travel can also be addressed with effective information sharing and targeted initiatives. For example, walking buses or active travel partners and groups (Mackett et al., 2003; 2005). Whilst concerns for safety and distance could also be addressed with initiatives such as ridesharing, for these to be effective, awareness and collaboration are still necessary.

A deficit of effective information sharing and communication was also made apparent in the survey results. For example, an awareness of respiratory illness among teachers, but not parents, is indicative of this disparity of knowledge. Conversely, parents appeared more aware of congestion and idling outside schools. These collective experiences are worthy of cross-sharing, particularly as they could provide the foundation to build effective traffic reduction strategies and TRAP exposure mitigation. Other aspects of the findings support this, such as measures including improved cycle and scooter parking and green infrastructure at school. In both instances, teachers were aware that these measures were in place at their schools, but parents were not, indicating that more communication is required. In addition, there was a persisting sentiment, more so among parents but also among teachers, that parents both require and desire further education on these topics.

3.3. Interventions (Q9, Q10)

Q9 What has your school/community/council/other done to improve school air quality?

Respondents were then asked, 'What has your school/community/council/other done to improve school air quality?' and permitted to select multiple options. The promotion of active travel was the most common measure already undertaken at schools for parents and teachers (21.6 % and 17.8 % respectively), which was considered one of the most effective measures when prompted to select only one (7.3 % and 7.5 % respectively), followed by parent awareness (6.9 % and 6.7 % respectively) Fig. 7 shows the most popular measures.

For those responses under 'other', the provided statements were coded by theme (some statements included more than one topic) to show general sentiment (Fig. 8). Teachers stated more school site interventions than parents (44.44 % and 26.42 % of responses to the question, respectively) whilst more parents than teachers maintained that either nothing had been done or what had been done was insufficient or ineffective (47.17 % and 11.11 %, respectively).

These responses support the findings of the main question. Local policy interventions (including greening, parking zones, and road closures) and school site interventions (including parking restrictions, staggered collections, and School Streets) appear to be better known by teachers than by parents. The number of parents also supports this compared to teachers who stated 'nothing', although ~ 1/4 of responses (exclusively from parents) in this category also included statements maintaining that measures had been taken but were tokenistic or ineffective, including:

> "School has asked parents not to pull up and congest the small dead-end road at the school entrance during pick-up and drop of times. School has asked parents to park in proper parking spaces nearby and walk a short way to the school gates. Parents ignore requests."

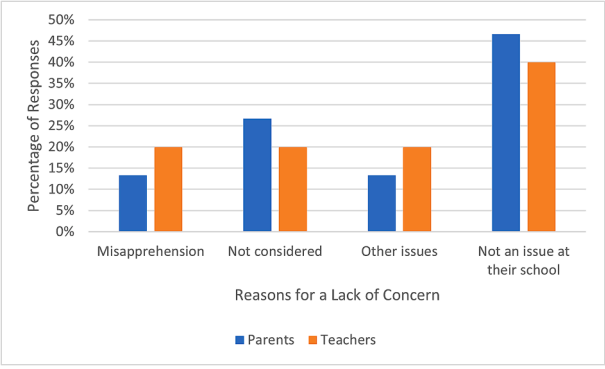

Fig. 6. Percentages of categorised coded responses under 'other' reasons for lack of concern regarding air pollution's effects on school-children's health.

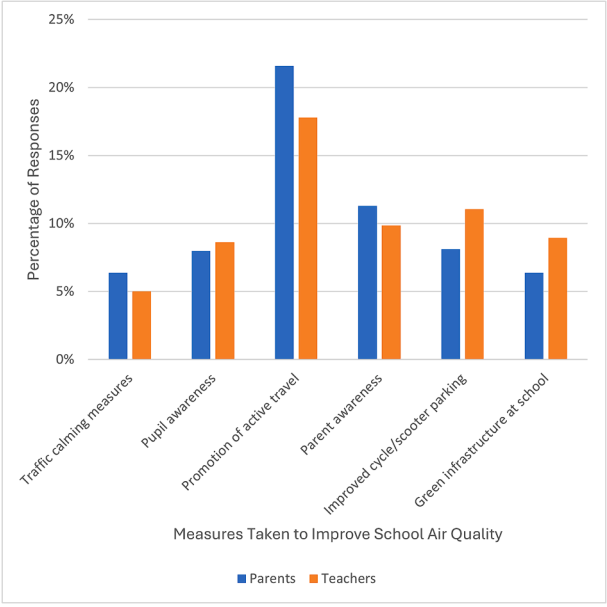

Fig. 7. Percentage of responses for interventions taken to improve school air quality.

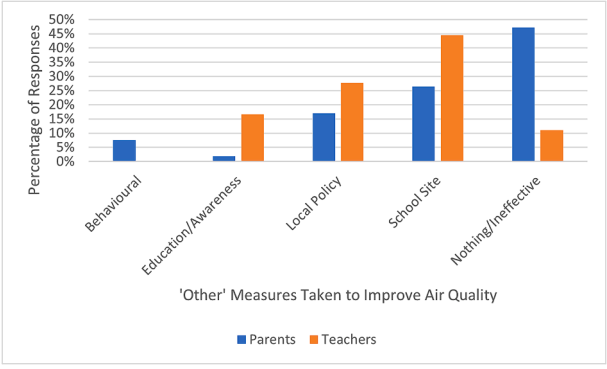

Fig. 8. Percentages of categorised coded responses for 'other' interventions to improve school air quality.

"They try but many people don't really listen and can be out there for 20 mins or more 5 days a week twice a day."
"The school is meant to be part of a local scheme to reduce cars around school. It doesn't work. On any given day there are loads of cars very close to school and on a wet day 10–30 cars can be idling very nearby."

Prompted to choose the most effective measure from those selected, the highest response from parents was the closure of school roads during congregative times (69.2 %), although the promotion of active travel remained high for parents and teachers (47.3 % and 39.9 % respectively).

Q10 What measures do you think would be effective for improving air quality at school?

Fig. 9 shows the responses to the question, 'What measures do you think would be effective for improving air quality at school?'. The most popular measures among parents and teachers included the promotion of active travel (7.29 % and 7.45 %, respectively) and parent awareness (6.91 % and 6.67 %, respectively).

Active travel is a popular measure due to its relatively low cost and ease of implementation. Parent awareness is also a popular measure stated by both parents (7.29 %) and teachers (7.45 %). Whilst the groups are mainly in agreement in their responses, teachers have relatively lower response rates than those of parents and appear to be school-based interventions, such as improved cycle and scooter parking and green infrastructure at school. Teachers are more likely to be aware than parents of each of these due to their time spent at the school, but this may be indicative of an opportunity for better communication between schools and parents to encourage greater uptake of active travel. The lack of communication is also supported by the greater number of parents than teachers who responded 'nothing' or 'don't know', which could point to a lack of communication between schools and parents regarding measures they are taking.

There appears to be greater disagreement for the promotion of car sharing, which more teachers than parents desire. This attitude

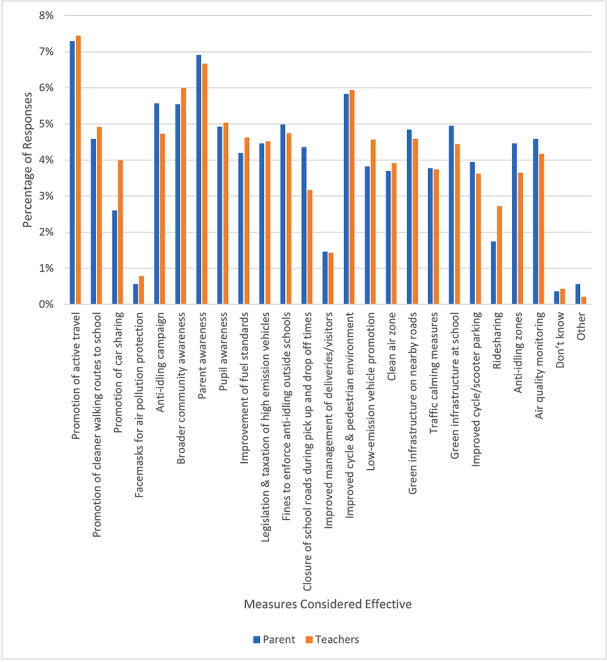

Fig. 9. Percentages of responses for measures considered to be effective for school air quality improvement.

may be apprehension due to the nature of the intervention in that parents rather than teachers would primarily undertake it. Conversely, a similar disparity exists with the closure of school roads during drop-off and pick-up times, which is favoured more by parents than teachers.

For those responses under 'other', the provided statements were coded by theme (some statements included more than one topic) to show general sentiment (Fig. 10). Both parents and teachers had comparatively high expectations for active travel (30.77 % and 22.22 %, respectively).

The sentiments in the responses to the main question are broadly supported in the 'other' category (those coded 'unknown' were either unclear or the respondent stated they did not know). Active travel remains a popular measure for both groups. The school commute measures (including improved routes, better public transport, and school buses) were also popular among parents, which may be due to the parent experience of the school commute. School site measures (including staggered collections, greening, improved monitoring, closure of School Streets, and parking restrictions) were also only highlighted by parents, which may also be due to the perceived workload and cost of these measures among teachers. The following parent statements support this attitude:

> "Closure of through travel past the school site during pick-up and drop-off times to be enforced by number plate recognition camera evidence."

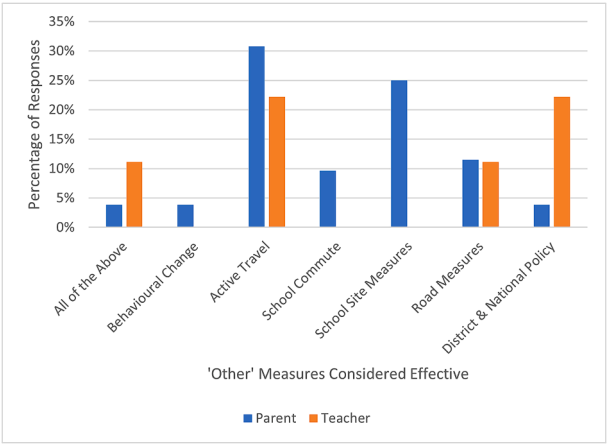

Fig. 10. Percentages of categorised coded responses under 'other' measures considered to be effective for school air quality improvement.

"School Streets and encouraging teachers and school staff to walk & cycle to school."

Conversely, teachers were more in favour of district and national policy measures (including banning fossil fuel cars, government incentives and the location of schools away from sources of pollution) than parents.

The respondents were then prompted to select one measure they thought would be most effective from those they had already chosen (Fig. 11). The promotion of active travel remained high for parents and teachers (47.29 % and 39.92 % respectively). However, this was second to the most popular response from parents, who indicated that the closure of school roads during pick-up and drop-off times was the most preferable, and this measure was more than twice as prevalent among parents than teachers (69.19 % and 24.86 % respectively).

These responses are consistent with the results from the previous question, placing a renewed emphasis on the promotion of active travel (Parents, 14.15; Teachers, 17.79 %), and the closure of school roads at pick-up and drop-off times (Parents, 14.85 %, Teachers, 7.94 %); although the latter remains increasingly more popular among parents, but is the second most popular response for teachers after active travel.

3.4. Obstacles (Q11)

Q11 What are the biggest obstacles to improving air quality and/or reducing car use at school?

The respondents were asked, 'What are the biggest obstacles for improving air quality at school?' and were permitted to select multiple options (Fig. 12).

The biggest obstacles chosen by parents and teachers for the improvement of air at school were the convenience of driving (17.3 % and 17.4 %, respectively), the school's proximity to busy roads (12.8 % and 12.2 %, respectively), and a lack of parental support (11.5 % and 11.1 %, respectively). When prompted by the follow-up question to select just one option, the single biggest obstacle based on these choices was the convenience of driving (27.8 % and 28.2 %, respectively) and the school's proximity to busy roads (24.9 % and 24.5 %, respectively). The convenience of driving is also highlighted in the literature as an issue that must be addressed, given its commonality as a reason for persistent car use among parents (Varaden et al., 2021; Nikitas, Wang & Knamiller, 2019; Ahern et al., 2017; Mehdizadeh et al., 2017) and commuters (Jayaraman et al., 2020; Kang et al., 2019; Buehler, Götschi & Winters, 2016).

For those responses under 'other', the provided statements were coded by theme (some statements included more than one topic) to show general sentiment (Fig. 13). Comparatively more accord existed between parents and teachers regarding the biggest obstacles to

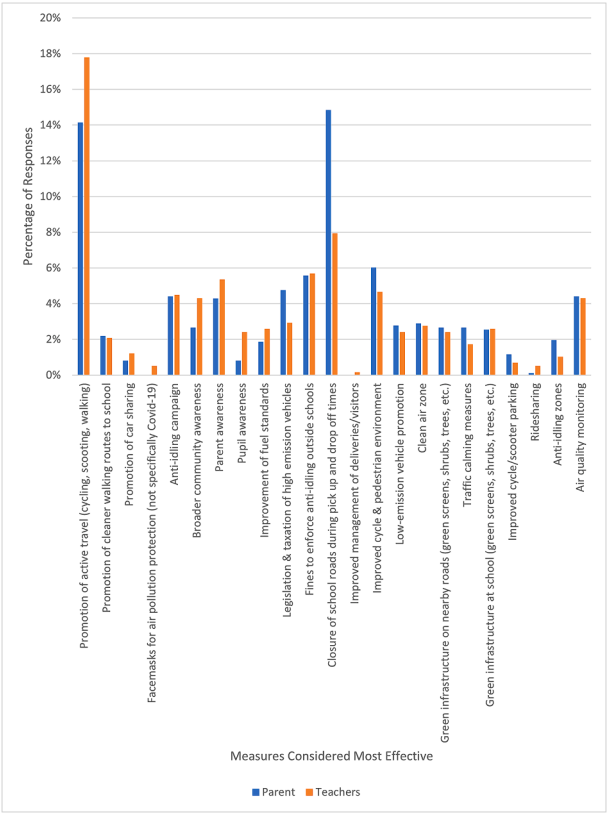

Fig. 11. Measures considered to be the most effective for the improvement of school air quality.

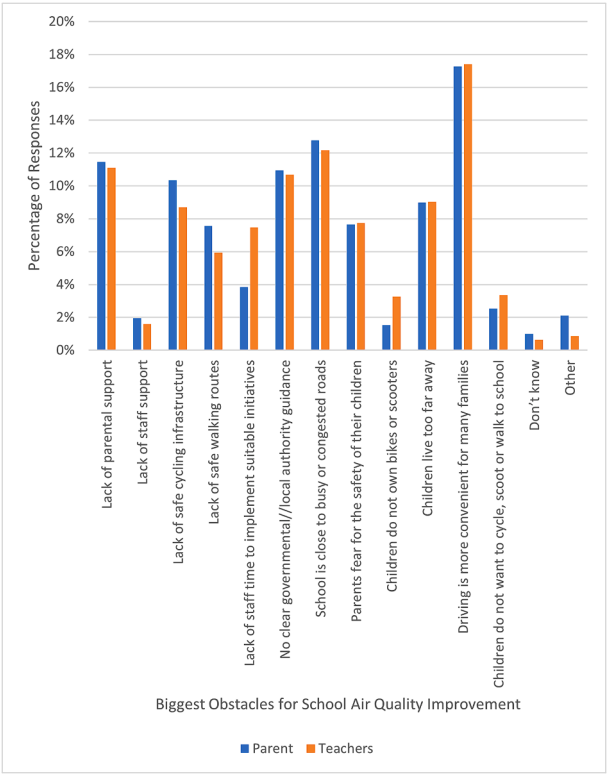

Fig. 12. The biggest obstacles for the improvement of school air quality and the reduction of car use.

the improvement of air quality, with attitudes (26.1 % and 29.2 %, respectively), followed by school issues (18.8 % and 20.8 %, respectively) the most popular.

Responses coded under 'attitudes' (including the necessity of driving, parents driving, the perception of driving, and priorities) were broadly consistent with the perception of the convenience of driving, coupled with having to work:

> Parent: "Parents often have to get straight to work after school run so there isn't time to walk."
> Parent: "Parents have to get to work after school drop-off. Time spent walking 15 mins back home on top of the commute, is more time out of the working day, or running further late to work, which just is not acceptable to businesses every day."

Others maintained that parental attitudes were an issue:

> Parent: "Example: I arranged a playdate recently. I asked the mother if we should walk or cycle – she said they would take the car (said location is 10 min walk away). This is what we are dealing with!!! (Exasperated tone)"
> Teacher: "As with anything, some parents are very onboard and travel actively as much as possible. Other parents need cars for onward journeys to work (although a little less so with working from home). And other parents appear to only consider their

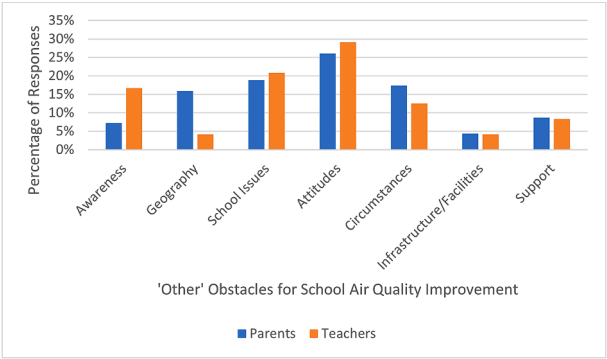

Fig. 13. Categories for coded responses under 'other' biggest obstacles for improving school air quality and reducing car use.

own convenience. Children are very supportive of active travel (as shown in recent hands up survey when they were asked how they did travel and how they would prefer to travel). Getting parents who are able to make changes on board is key to reducing car traffic around the school. Additionally active travel alternatives need to be improved to encourage them, e.g., safe cycling routes (there are no complete routes available), improved pedestrian crossings, improved railway bridge crossings etc."

The desire for guidance was also apparent, with one parent stating:

Parent: "So far it seems to be that is not a very high priority for our school, or it is not particularly on their radar. They are a great school – could be that they just don't have the time/resources. A regional champion would be great – could visit each school with a pre prepared plan/pack."

School issues were also a popular theme and included idling, a lack of active travel, and parent drop-offs, and are consistent with the previously stated needs of working parents:

Parent: "Multiple children going to multiple schools mean that a car must be used for many parents. Another big one not represented here anywhere is Taxis. They do not shut off their engine when they are picking up and dropping off children at schools."
Parent: "Working parents often have to drop to school in order to get to work."

An apparent disparity in awareness existed within the groups, with parents maintaining:

Parent: "Parents seem unaware of the issues caused by pollution and idling."
Parent: "Parents aren't aware of the detrimental effects of idling their cars."
Parent: "Lack of parent awareness of the risks of poor air quality."

These positions are consistent with previous responses regarding a lack of awareness and the requirement for further information and communication between affected groups. The responses also emphasise the school's proximity to main roads and the convenience of driving as the biggest obstacles, with a lack of parental support, no clear authority guidance, and children living too far away from school as secondary issues.

The respondents were then prompted to state the single biggest obstacle for the improvement of school air quality (Fig. 14) based on the responses they provided in the previous question. Agreement persisted between parents and teachers, each stating that driving is more convenient for most families (27.75 % and 28.22 % of responses to the question, respectively) and the school is too close to busy or main roads (24.87 % and 24.50 % of responses to the question, respectively). For both parents and teachers, a lack of parental

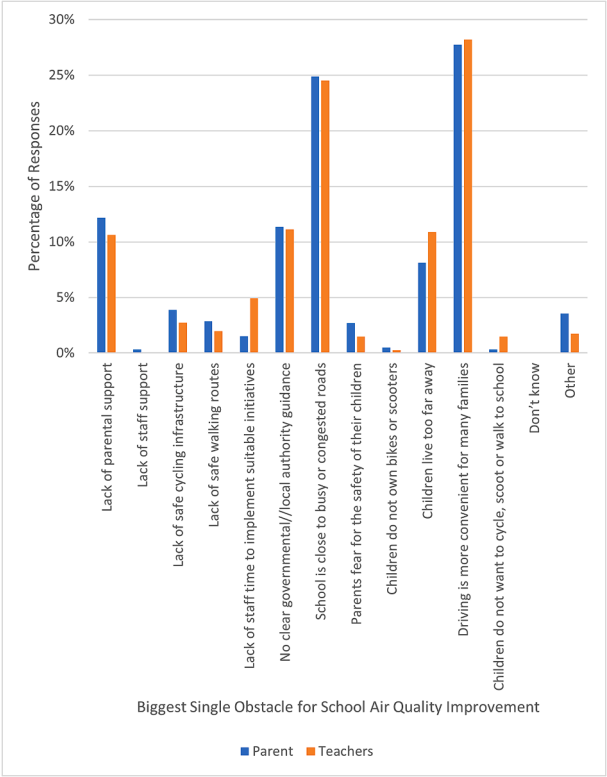

Fig. 14. The biggest stated obstacle to improving school air quality.

support (12.18 % and 10.64 % of responses to the question, respectively), no clear authority guidance (11.34 % and 11.14 % of responses to the question, respectively) and children living too far away (8.12 % and 10.89 % of responses to the question, respectively) were also popular responses.

The responses here support those of the previous question, emphasising the school's proximity to main roads and the convenience of driving as the biggest obstacles, with a lack of parental support, no clear authority guidance, and children living too far away from school as secondary issues.

3.5. Responsibility (Q12)

Q12 Who do you consider to be the most important for supporting efforts to improve school air quality?

The respondents were then asked, 'Who do you consider to be the most important for supporting efforts to improve air quality at schools?' (Fig. 15). Both parents and teachers stated that local authorities (43.1 % and 38.5 %, respectively), national government (23.3 % and 27.5 %, respectively), and parents (18.1 % and 17.4 %, respectively) were the most responsible parties for the improvement of school air quality.

These views are also supported in the literature, with attitudes maintaining that national and local government failures are responsible for persistent air pollution (Dyer, 2020; Sofia et al., 2020).

Neither parents nor teachers considered the local community (7.9 % and 10.0 %, respectively), schools and staff (4.4 % and 4.2 %, respectively) or campaign groups (1.0 % and 1.6 % of responses to the question, respectively) responsible.

For those responses under 'other', the provided statements were coded by theme (some statements included more than one topic) to show general sentiment (Fig. 16). Among parents and teachers, there was broad agreement that everyone (55.56 % and 66.67 %, respectively) and national authorities (16.67 % and 33.33 %, respectively) were most important.

The outcome of the responses listed under 'other' indicates that the majority of these respondents believe that everyone has a responsibility, although the provided statements may indicate that further guidance is still desired:

Parents: "All of the above but it needs national leadership and funding."
Parents "Both local authorities and the schools themselves would need to work together."

3.6. Summary

The sample was broadly representative of the population. School proximity to main roads was of great concern, and conversely, those who were unconcerned about air pollution were predominantly from rural areas. The convenience of driving was viewed as a key obstacle to the improvement of school air quality, and both teachers and parents considered local authorities to be of key importance in actioning change. Active travel was a popular intervention for reducing potential child exposure to TRAP, and parental education on this and related topics were also desirable.

There was general agreement between parents and teachers regarding the most important parties for supporting air pollution improvement, and both considered local authorities and the national government to be most important, followed by parents.

3.7. Recommendations

Based on the survey findings a series of recommendations were produced for authorities and stakeholders for the reduction of TRAP around schools and on the school commute. Each recommendation is subject to context, including geography and the specific requirements of the school.

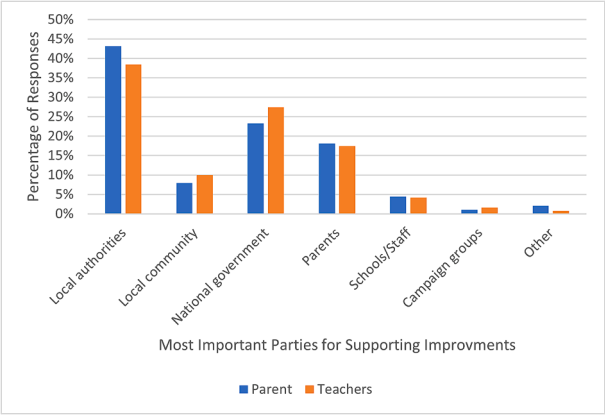

Fig. 15. Parties considered to be the most important for supporting air pollution improvement efforts.

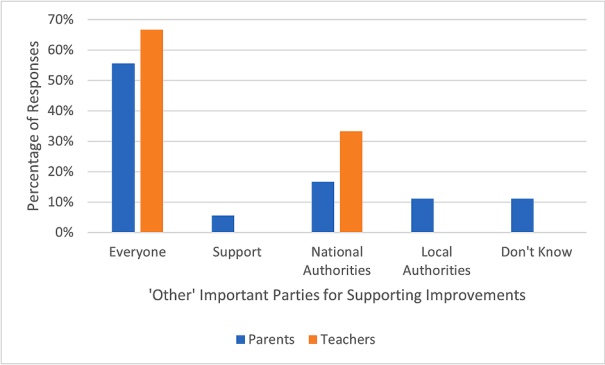

Fig. 16. Categories for coded responses under 'other' parties are considered the most important for supporting air pollution improvement efforts.

3.7.1. National level

3.7.1.1. Legislation. Legislation has many benefits, including creating a set of clearly defined and workable goals rather than relying on other inducements, such as market-based incentives, that may be slow to become effective or to work at all (De Vries & Hanley, 2016). In addition, meaningful legislation can set a standard for public expectation (Héroux et al., 2015). Strong legislation should ensure that wherever possible new school sites are located away from major pollution sources like busy roads and industrial areas. Strict enforcement of pollution limits and existing anti-idling laws is essential to make these measures effective.

3.7.1.2. Behavioural change. Enhancement of anti-idling laws around schools should be supported with public campaigns that encourage behavioural changes. Educational programs about the benefits of reduced car use should be integrated into the school curriculum. Anti-idling laws already exist, but stricter enforcement could promote behavioural change. 'Nudge' behaviours, such as signs at schools encouraging parents to turn their engines off when waiting to collect children, may be effective (Capraro et al., 2019) but can be further supported by legislation and penalties for non-compliance.

3.7.1.3. Subsidies. Legislation and campaigns for behavioural change may be ineffective if people are not provided with desirable practical alternatives. Government subsidies should be provided for eco-friendly transport options like electric cars and bicycles to encourage parents and schools to shift from using polluting vehicles. These subsidies are justifiable by the money they will save through the mitigation of environmental damage and negative health impacts, each of which will be abated by the reduction of polluting vehicle use.

3.7.2. Local authority

3.7.2.1. Traffic management & LEZs. Low Emission Zones (LEZs) should be implemented around schools during peak times to cut down on child exposure to pollutants. Drop-off and collection points can be moved beyond the zonal boundary to minimise potential child exposure to pollutants at the school gates. In addition, the introduction of LEZs around schools at congregative times may also discourage the use of cars when combined with active travel campaigns. Schools should be supported in setting up these zones effectively and traffic management measures considered to reduce overall vehicle emissions near schools.

The Safe Routes to School (SRTS) program in the United States provides an important reference point for successful and effective traffic management near schools. Initially launched in 2005 as a federal program, SRTS aims to make walking and cycling safer and more accessible for children commuting to school. The initiative provides funding to states and local communities for infrastructure improvements such as pedestrian crossings, sidewalks, and bike lanes, as well as for educational campaigns. The SRTS program successfully reduced traffic-related injuries in school zones by 44 %, while also increasing the number of students walking or biking to school (McDonald et al., 2014).

The effectiveness of SRTS lies in its integrated approach to traffic management, which includes physical changes like speed bumps and pedestrian-friendly street designs in combination with community engagement initiatives. These efforts include educating drivers about speed limits in school zones and encouraging carpooling and ridesharing. Such measures have created safer school environments while reducing both traffic congestion and air pollution. Incorporating similar measures, such as establishing Low Emission Zones (LEZs) and pedestrianising areas around schools during peak hours, could be highly effective in reducing traffic-related air pollution and promoting safer commutes for children in the UK (Stewart, Moudon & Claybrooke, 2014).

3.7.2.2. Behavioural interventions. Active travel should be encouraged through improved infrastructure and public transport options for schoolchildren. Awareness programs can be combined with practical interventions to enhance their effectiveness. These should be targeted at schoolchildren as a vulnerable group and can include educational and information programmes that can encourage them to make improved and informed choices using national advice tailored to the local environment.

3.7.3. Teacher/Parent

3.7.3.1. Awareness & communication. Increased communication between local authorities, schools, and parents can foster a collaborative approach to reducing TRAP. Use varied engagement strategies to gauge attitudes towards active travel and address any concerns through targeted informational campaigns. For teachers who may be reluctant to undertake new and integrated strategies due to the possibility of increased workloads, the benefits of increased levels of active travel should be fully explained in the context of the literature, including healthier, happier, more relaxed children with improved concentration and better behaviour in class (Fyhri et al., 2022).

It is important to engage parents, teachers, and local communities through awareness campaigns that promote the health benefits of walking and biking while highlighting the environmental impact of car-based school commutes. By involving parents and educating them about the dangers of TRAP to their children's health, behavioural changes, such as adopting carpooling and ridesharing programs, can be encouraged. This community-centric approach helps build a long-term commitment to reducing vehicle emissions and improving air quality around schools (Stewart, Moudon & Claybrooke, 2014).

Incorporating a similar focus on communication and awareness in the UK, particularly through targeted campaigns about the health risks of TRAP and the benefits of active travel, could enhance parent and community engagement. This, in turn, can drive further support for policies like anti-idling zones and car-free school streets, increasing their effectiveness at reducing child exposure to harmful pollutants (McDonald et al., 2014).

3.7.3.2. Active travel. Schools should be encouraged to facilitate active travel by providing necessary amenities like bike racks and safe routes. Engagement should take place with local government to improve infrastructure, making active travel a safer and more attractive option for families. For those concerned about child safety on the school commute, walking buses can be effective for encouraging active travel among children (Smith et al., 2015). This success is not limited to urban environments. Rural schools have benefited from tailored strategies, such as 'walking school buses,' where groups of children walk to school under adult supervision. These initiatives encourage a culture of active travel while addressing parental concerns about safety. Similar initiatives could benefit from adopting active travel models that combine infrastructure improvements with behavioural interventions, encouraging more pupils to walk or bike to school (McDonald et al., 2014). This should involve working with local governments, schools, and parents to identify barriers to active travel and implement sustainable solutions. Working with local traffic authorities to redesign roadways, create safe bike paths, and install traffic calming measures like speed bumps and reduced speed zones around schools are all ways to ensure stakeholder engagement is effective (McDonald et al., 2014).

3.7.3.3. Rideshare. Promotion of ridesharing schemes among parents can reduce the number of vehicles during the school commute. Ensuring these schemes are well-organised and meet safety standards to encourage widespread adoption is essential. For rideshare schemes to be successful and have longevity, it is important that the child is introduced to the other family prior to the lift sharing and that all parties, parents, and children are happy with the arrangement (Jain, Johnson & Rose, 2020). Children must also be clear on what is expected of them during the trip in terms of their behaviour. For example, some drivers will not allow eating in their car, and the children must understand not to distract the driver and wear a seatbelt (Zhang et al., 2015).

3.7.3.4. Anti-Idling. Strengthening of enforcement of anti-idling zones around schools and education of parents about the health risks associated with idling can encourage compliance. Whilst not as effective as other measures for the reduction of TRAP on the school commute, anti-idling zones around schools can send an important message to parents and the public regarding expected behaviour and safeguarding child health.

The effectiveness of self-interest cues has been highlighted as effective for encouraging positive environmental behaviour and can be beneficial for promoting anti-idling compliance. Messages to promote the anti-idling campaign should accordingly be centred on cues for financial loss and child health interests (Van De Vyver et al., 2018).

3.8. Limitations & recommendations for future research

A key limitation is the possibility of self-selection bias, as individuals already concerned about air pollution may be more likely to participate, potentially skewing the results towards a more negative perception of the issue. Conversely, those less interested or unconcerned about school air pollution may be underrepresented, possibly compromising the development of comprehensive solutions.

Additionally, whilst internet use is now commonplace and widespread (particularly with the use of smartphone access) the possibility exists that the sample may be skewed towards relatively affluent populations due to the use of an online survey. To mitigate this issue gatekeepers were encouraged to share the survey with parents, teachers and other related groups via other channels (newsletters, bulletin boards and similar), and the survey was optimised for smartphone use. However, these steps could not guarantee that the survey reached those without internet access and similar future research should consider additional methods of offline distribution.

Furthermore, the categorisation of respondents as parents or teachers may not accurately represent their perspectives, as some may answer based on both roles. However, teachers will still respond from a position of knowledge authority regardless of their position as parents, and parents are likely to be equally experienced in the pragmatics of child school travel. A Delphi approach for intervention co-design in future research could offer additional perspectives from key stakeholders and help assess intervention suitability, particularly in mitigating child exposure to TRAP.

While this study provides detailed insights specific to England and the UK, it inherently limits the generalisability of the findings to other geographic contexts. Different countries may exhibit varied environmental conditions, regulatory frameworks, and cultural attitudes towards transportation and schooling, which could influence the effectiveness of TRAP mitigation strategies. Future research should consider expanding the scope to include comparative international studies. This could help to validate the applicability of the UK-based findings and enable a global perspective on the effectiveness of different interventions. These potential studies could help in developing more universally applicable strategies, fostering broader improvements in public health and environmental policies worldwide.

The appeal of active travel makes this an important area for future research. However, active travel is not always practical for parents and children who may live in remote or rural locations, or those who reside far from their school. For these people it may not be possible to travel substantial distances on foot or by bicycle to attend school. A limitation of the current study is that due to measures taken to ensure the anonymity of its respondents, there is no way to accurately determine perceptions related to pollution based on an urban and rural divide. Future studies based on the current research should address this to provide insights into any differences in attitudes between these groups.

Concerns were raised in the survey regarding Low Traffic Neighbourhoods (LTNs). Since this study was conducted research in this area continues to grow and future investigations should build upon this ongoing work. The effects on air pollution have been assessed in the literature, including evaluations made on the impact of LTNs on NO_2 and traffic flows. Findings suggest that LTNs can potentially reduce air pollution and traffic, without generating an increase in traffic volumes or air pollution in surrounding streets (Yang et al., 2022). Research has also countered media claims that LTNs have affected delivery of emergency services, finding that their impact has been minimal. For example, an extensive analysis involving the fire services showed no significant delays in 72 LTNs. Ambulance trusts have not reported delays due to LTNs and have acknowledged their health benefits (Goodman et al., 2021). Additional research on LTNs has identified impacts including the reduction of traffic volume and the promotion of active travel (Aldred & Goodman, 2021). LTNs were associated with increased walking and possibly reduced car driving, with improved perceptions of the local cycling environment. This is especially notable in emergency LTNs, which are low-cost and rapidly implemented. Over time, the effects on cycling, walking, and driving were observed to increase, especially in LTNs which included complementary measures like cycle tracks and junction improvements. The impact of LTNs on the local environment also extends beyond traffic and air quality. Evidence suggests that LTNs encourage more walking and cycling, with significant physical and mental health benefits (Zhang & Cheng, 2023). Additionally, studies have shown a reduction in street crime in areas with LTNs (Goodman, Laverty & Aldred, 2021), and local businesses have benefited from increased foot traffic (Kariuki-Cobbett, Morley & Worthy, 2023).

Overall, the evidence points to the effectiveness of LTNs in reducing traffic volume, promoting active travel, and positively impacting the local environment. Future research could further explore these areas, especially in assessing long-term impacts and the broader effects on regions beyond the immediate vicinity of LTNs. Regional assessments of deprivation and public opinion within and outside LTN boundaries regarding intervention efficacy should also be conducted to inform future research on these measures' effectiveness. Future research should further investigate the benefits of LTNs in reducing traffic volume and air pollution and highlight the broader benefits of LTNs to the participating neighbourhoods and broader areas.

3.9. Conclusion

The current study investigated interventions for reducing and mitigating exposure to TRAP on the school commute. The outcome of the investigation has provided the basis of recommendations for policymakers, teachers, and parents. The implications of these recommendations focus on reducing car use and traffic on the school commute as the most effective method of mitigating child exposure to harmful pollutants on their daily journeys.

The findings of this study highlight several critical concerns from both parents and teachers regarding traffic-related air pollution (TRAP) and its detrimental effects on children's health, particularly during the school commute. The majority of respondents expressed strong concern about the proximity of schools to busy roads and the rising levels of respiratory illnesses among children. School zones with frequent idling and congested traffic were also identified as major sources of air pollution, exacerbating health risks for students. These findings emphasise the need for targeted interventions to mitigate TRAP exposure, particularly during peak traffic hours.

Active travel initiatives emerged as one of the most popular and effective measures for reducing TRAP, supported by both respondent groups. The preference for this solution highlights its relatively low-cost implementation and the additional benefits it offers, such as improved physical health, reduced congestion, and enhanced student concentration in class. However, concerns over safety and the convenience of driving remain substantial barriers to its broader adoption. These concerns were critical in shaping the policy recommendations, which call for increased infrastructure improvements, such as safe cycling and pedestrian routes, along with enhanced communication efforts between schools, parents, and local authorities.

The study's findings also underscore the importance of community involvement and government action in tackling air pollution around schools. Both parents and teachers identified local authorities and the national government as key players in driving change, indicating a strong desire for regulatory interventions such as low-emission zones (LEZs), stricter anti-idling laws, and the strategic siting of schools away from major pollution sources. These insights were directly incorporated into the recommendations, advocating for legislative action, increased enforcement, and government subsidies for eco-friendly transport options.

The findings of this study provide valuable insights into the views of parents and teachers on TRAP and attitudes towards measures for reducing child exposure on the school commute. These insights can inform the development of policies and interventions to promote active travel and reduce car use around schools, improve child health and reduce their exposure to harmful pollutants. This study contributes to the growing body of evidence on TRAP and its impact on child health, and to provide practical recommendations

for reducing exposure and promoting healthy environments around schools.

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CRediT authorship contribution statement

Louis Brown: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Enda Hayes:** Supervision. **Jo Barnes:** Supervision.

Declaration of competing interest

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

Data availability

The data that has been used is confidential.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trd.2024.104454.

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