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Article

Evaluating Actions to Improve Air Quality at University Hospitals Birmingham NHS Foundation Trust

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Abstract: Air pollution is the single largest environmental risk to human health in the UK, exerting a major healthcare sector burden and exacerbating health and social inequalities. The NHS Long Term Plan commits the healthcare sector to reducing emissions from all sources, however, to date few Acute NHS Trusts have implemented air quality focused sustainability plans. In this case study, we assess potential air quality improvement actions at University Hospitals Birmingham NHS Foundation Trust's, Queen Elizabeth Hospital in Birmingham, UK as a test case for NHS sustainability actions. We generate an evidenced based, prioritized shortlist of actions to mitigate emissions and protect patients, staff, and local communities from air pollution exposure. The project supports adoption of an evidence-based, contextually relevant, approach to air quality management within healthcare provision. The methodology used could be employed by organizations with similar goals to address environmental concerns.

Keywords: air quality; Queen Elizabeth Hospital Birmingham; healthcare evaluation; NHS Long Term Plan

1. Introduction

1.1. Background

The impacts of air pollution on human health are understood at a national public policy level in the UK, with strategic commitments to improving air quality embedded within the NHS Long Term Plan 2019 [1] and UK Clean Air Strategy [2]. The NHS Long Term Plan specifically acknowledges the healthcare burden of air pollution, which has been quantified across different services [3]. Estimates for healthcare service impacts include the chronic non-communicable disease (NCD) [4,5], and acute and emergency care for respiratory and cardiovascular patients [6,7] attributable to air pollution exposure. Air pollution exposure also disproportionately affects vulnerable groups, thereby amplifying existing health inequalities [8–11]. Lower socio-economic status is consistently associated with increased risk of respiratory illness [8,9], higher risk of death due to air pollution related conditions [10], and a greater likelihood of being unaware of behaviors to prevent exposure to air pollution [11]. Children are amongst the most vulnerable group for air quality impacts on respiratory health [9]. The NHS Long Term Plan explicitly acknowledges the need to both address health inequalities and to protect population health; of critical importance to meet the growing demand for healthcare among a population with increasingly complex care needs [1].

NHS services are also a major direct contributor to air pollutant emissions, with healthcare related activities (staff/patients/visitors) estimated to account for ~5% of road traffic in England [3]. The Clean Air Hospital Framework (CAHF) is a self-assessment

tool developed by Global Action Plan and launched in 2019, providing a structured approach towards air quality improvement at hospitals in the UK [12]. However, to date relatively few Acute NHS Trusts in the UK have initiated the CAHF and there is a lack of available published evidence regarding which CAHF actions have been most widely adopted and how effective these have been for improving local air quality. Given the limited evidence base, NHS service providers and leadership teams lack awareness of the most effective actions to adopt to address air quality impacts. There has been significant focus on generating evidence for interventions in other areas, including Air Quality Alert Systems [13–16], Promoting Active Travel [17–19], removal by urban forests [20], Low Emissions Zones [21–24], Cross-Organisational Collaboration [25,26] and Research Communication and Engagement [27,28]. These are typically achieved by changes implemented by local authorities and therefore considered beyond the health sector's control (beyond as a consultee). Changes to UK legislation adopted within the Environment Act 2021 will enable greater collaborative and partnership working, ensuring responsibility is shared across local government structures, and with relevant public bodies, including healthcare providers.

This new regulatory landscape provides scope for an increasingly important role for NHS Trust organisations in providing environmental leadership and management, whilst potentially operationalising a broad range of actions to mitigate emissions. However, there is currently a paucity of participatory research evidence regarding the feasibility of implementing air quality actions within the context of Acute Trusts in the UK.

The Queen Elizabeth Hospital Birmingham (QEHB; ~1200 beds) is one of the largest hospitals in the UK. The hospital is one of a group of hospitals managed by University Hospitals Birmingham NHS Foundation Trust (referred to as UHB or the Trust)

1.2. Setting

The QEHB opened in 2010 and is located adjacent to the University of Birmingham Campus in the suburb of Edgbaston, Birmingham. Birmingham Women's Hospital is also on the same site as the QEHB building, alongside several academic research facilities. The site is served by University station, providing access to cross-city rail services (12 min to Birmingham New Street). University station is currently undergoing redevelopment to increase capacity. The site is also served by multiple bus routes, traffic free cycle routes and pedestrian options including the A38/A34 blue routes to the city centre. There is also a traffic-free route running west from the QEHB to areas of Birmingham such as Woodgate, Weoley Castle, Harborne and Quinton.

Research undertaken within the West Midlands Air Quality Improvement Programme (WM-Air) indicates that modelled annual mean concentrations of nitrogen dioxide (NO_2) and fine Particulate Matter ($PM_{2.5}$) averaged to ward level exceed WHO 2021 Global Air Quality Guidelines for all areas of the West Midlands. Recent data obtained from the Birmingham Air Quality Supersite indicate existing annual average $PM_{2.5}$ concentrations of 8 μgm^{-3} between September 2021–June 2022. The site is not subject to any existing Local Air Quality Management interventions, being located outside the Birmingham Clean Air Zone area, introduced in June 2021 as a targeted action to reduce NO_2 concentrations to a maximum annual average 40 $\mu g/m^3$ in the shortest possible timeframe.

1.3. Study Aims and Research Questions

In this context, the aim of this mixed- methods study was to scope, identify and appraise the effectiveness of proposed actions relevant to air quality across all areas of operational management at the QEHB site. We investigate the following research questions: (1) which actions could improve air quality at QEHB? (2) what are the perceptions and attitudes towards air quality action among Trust staff? (3) which air quality actions are the most feasible and impactful over short/medium and long-term time horizons? (4) which selected air quality actions should therefore be prioritised for future delivery?

This in-depth case study addresses the knowledge gap concerning how to operationalise the CAHF across Acute Trust settings and the wider health sector in the UK.

2. Materials and Methods

This study was undertaken using a four-stage process: (i) scoping; (ii) qualitative assessment; (iii) quantitative assessment; (iv) synthesis and appraisal.

2.1. Scoping and Identification of Air Quality Actions

The first stage of the project was to scope a list of actions that might be likely to achieve one of two goals. The action should either: aim at improvement to local air quality around QEHB by reducing the emissions associated with the hospital's operations, or to protect UHB's patients, staff, and the wider local community from harmful exposure. The actions identified are also appraised on how achievable they are in a given timeframe -thereby capturing the relationship between time to implement and scale of action.

The seven policy areas of the CAHF are categorized in the following domains: Travel, Local Air Quality, Procurement, Communication and Training, Design and Construction, Outreach and Leadership, and Energy. Within these policy areas are a non-exhaustive list of example actions that lead to becoming a 'Clean Air Hospital'. The framework was completed through auditing UHB policy documentation, including UHB's 'Sustainability Strategy' [29], and the action tracker from the Trust's newly formed Sustainability Group. The sources allowed identification of any actions in the CAHF that were not yet being implemented at the QEHB site.

2.2. Data Collection for Qualitative Assessement: Interviews with Subject Area Experts

2.2.1. Participants

Study participants were initially identified through discussions with two members of the Trust's Sustainability Group, followed by snowball sampling [30]. Participants were identified as those who were experts in one or more of the following areas: leading change at UHB, designing sustainability strategy at UHB, the operational specifics of the QEHB, understanding air quality and its impacts on healthcare or public health, or working in engagement and communications to do with air quality and sustainability. A crucial factor was that the interviewees needed to have a breadth of understanding of the Trust as a whole and how changes would interact across the Trust, reflecting a diverse range of working perspectives.

A total of 11 participants were recruited and completed semi-structured interviews between 23 January 2020 and 14 May 2020 (Table 1).

Table 1. Participant information (whilst maintaining the participant's anonymity in line with the consent process and ethical approval).

Participant's Professional Field	Area (s) of Expertise
Strategy and Analysis	Designing sustainability strategy at UHB; the operational specifics of the QEHB
Respiratory Medicine	Air quality and its impacts on healthcare and Public Health
Patient and Public Involvement and Engagement	Working in engagement and communications to do with air quality and sustainability
Medical Physics	Leading change at UHB; the operational specifics of the QEHB
Public Health and Environmental Epidemiology	Understanding air quality and its impacts on healthcare and Public Health; working in engagement and communications to do with air quality and sustainability

Table 1. *Cont.*

Participant's Professional Field	Area (s) of Expertise
Quality Development	Leading change at UHB; designing sustainability strategy at UHB; the operational specifics of the QEHB
Innovation and Trust Leadership	Leading change at UHB; designing sustainability strategy at UHB; the operational specifics of the QEHB
Estates	Leading change at UHB; designing sustainability strategy at UHB; the operational specifics of the QEHB
Operations	leading change at UHB; designing sustainability strategy at UHB; the operational specifics of the QEHB; working in engagement and communications to do with air quality and sustainability
Estates	Working in engagement and communications to do with air quality and sustainability
Finance	Leading change at UHB, designing sustainability strategy at UHB, the operational specifics of the QEHB, working in engagement and communications to do with air quality and sustainability

2.2.2. Procedure

Two Interviews were held remotely whilst the rest were in person. The interviews ranged from 44 min in length to 91 min (average 66 min). All interviews were recorded and then transcribed by the lead author. Interviews were always held in a private space that was convenient for the interviewee and conducted according to [31]. The participant information sheet, a draft consent form and the interview sample questions are included in Appendix A.

The structure of the CAHF was used to discuss policy areas linked to QEHB air quality impacts. The use of this framework ensured a broad range of topic areas were discussed providing a system-wide perspective.

2.2.3. Analysis

The software package NVivo was used for thematic analysis of the resultant text files. These were coded into two categories of nodes; the first category based on the policy areas and the second coded by distinct potential actions for trust. This generated a list of 79 different actions for further quantitative evaluation and analysis. Nodes were also used to code barriers to specific actions for use in later analysis.

2.3. Data Collection for Quantitative Assessment

2.3.1. Participant Recruitment

The list of 79 distinct actions identified in Section 2.2.3 were then evaluated numerically through a survey sent out to a larger group of people in December 2020.

Survey participants were subject area experts in one or more of the areas of importance for the project (Section 2.2.1), including those recommended by participants during interview discussions.

Of the 30 invited participants, 21 survey responses were received (response rate 70%) with 2 of these incomplete (with answers for 39% and 82% of questions respectively).

2.3.2. Data Collection

The survey included data capture for potential air quality actions identified from qualitative interviews in terms of predicted impact, perceived achievability and expected timeframe. Qualtrics, a web-based survey tool, was used to design and host the survey as shown by the sample question in Figure 1.

Please select an option to describe the following action in terms of its potential impact, how easy it will be to implement, and what time frame we should be working within.

	Describe the extent to which the following action will improve our local air quality or enable us to protect people from local air pollution?						How easy will it be to implement this action?						What timeframe in years would you put this action in for it to achieve its potential?			
	Not at all	Insignificant	Moderate	Significant	Extreme	No Idea	Impossible	Difficult	Moderate	Achievable	Easy	No Idea	1	5	10	No Idea
Create a sustainability in healthcare management module with the education department to disseminate knowledge and raise awareness.	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Figure 1. Survey question format, including Likert scale (Impact and Achievability dimensions) and timeframe for action (short/medium/long).

This format was replicated for all 79 actions identified in Interviews using the following questions:

- 'Describe the extent to which the following action will improve our local air quality or enable us to protect people from local air pollution?' Answers are on a Likert scale with six options:
    1. Not at all
    2. Insignificant
    3. Moderate
    4. Significant
    5. Extreme
    6. No Idea
- 'How easy will it be to implement the action?' With answers the Likert options:
    1. Impossible
    2. Difficult
    3. Moderate
    4. Achievable
    5. Easy
    6. No Idea
- 'what time frame they would expect the action required to achieve its potential' With answers from:
    1. 1 Year
    2. 5 Years
    3. 10 Years

The survey question order was randomised both within each policy area section and also the order of policy area sections. The policy areas were re-structured for the survey along with the nodes used for coding the Interview Data. The new policy areas are shown in in Figure 2. This randomisation controls for the inevitable variation in attention levels that comes with taking a survey of this length-average length of time to completion was 38 min.

In transition from the action scoping (i–ii) to the evaluation stage (ii–iii) of the project, the survey was split into blocks of questions altered from the policy areas of the CAHF, this is shown in in Figure 2. Some CAHF policy areas had far more actions identified for the trust than others. The assignment of actions to blocks is laid out in Appendix B.

Figure 2. The blocks of questions in the survey. These were derived from thematic analysis of the interview data. The number of questions in each block is visible. These are the number of actions derived.

2.3.3. Analysis

There was a very low rate of 'No Idea' responses to any actions. When it came to handling scores these responses were assigned a null value and not included in the averages. The full list of actions in the survey are contained in Appendix B.

To partially control for levels of optimism and pessimism across respondents, the scores were adjusted according to a respondent's average score in each dimension across all 74 actions and the spread of each respondent's scores.

The following manipulation was used to control for respondents interpretation of the Likert Scale:

$$x_{adj} = \frac{x_{unadj} - \mu}{\sigma}, \tag{1}$$

where x_{adj} and x_{unadj} are the adjusted and unadjusted scores respectively; μ is the mean score within that dimension for that participant and σ is the standard deviation of the participant's responses within that dimension.

Having adjusted for some of the heterogeneity in participant's responses, the mean was then taken of the adjusted scores for achievability and impact for each action across all participants responses.

Using the median of timeframe responses the actions were grouped into short run and long run and only compared within these groups to control for the perceived difference in achievability and impact of a long run action versus a short run action.

2.4. Combining Interview and Survey Data

In the Section 3 a mixed methods matrix [32] is presented. To show the complex array of information otherwise only presentable in the long and extended Sections 3 and 4 that precedes it. The synthesis of evidence was undertaken in a subjective fashion by the researcher who used methods of critical appraisal to offer up a fair assessment of the sum of evidence gathered and make recommendations based on this. The ranking of the mixed methods matrix was undertaken by ordering according to the impact score predicted from the survey. This ranking can be adjusted by taking a weighted average of the impact and achievability scores based on the decision maker's appetite for risk.

3. Results

Below are the findings from the survey presented in successive figures with impact score plotted against achievability in each, these comparative figures are split by timeframe and policy area. With each subsection having the long- and short-term figures for that policy area. The qualitative evidence for certain actions is laid out beneath each figure. The first subsection is a comparison between policy areas for each timeframe.

3.1. Comparison of Policy Areas in Short and Long Run

In Figure 3 the key policy areas, where actions are highest impact in the short-term, are those within strategy and policy on travel. Energy is likely to be high impact but the achievability on average is much lower. The other policy areas do not stand out significantly in terms of impact. In general, the same trend of actions becoming less achievable as impact increases can be seen.
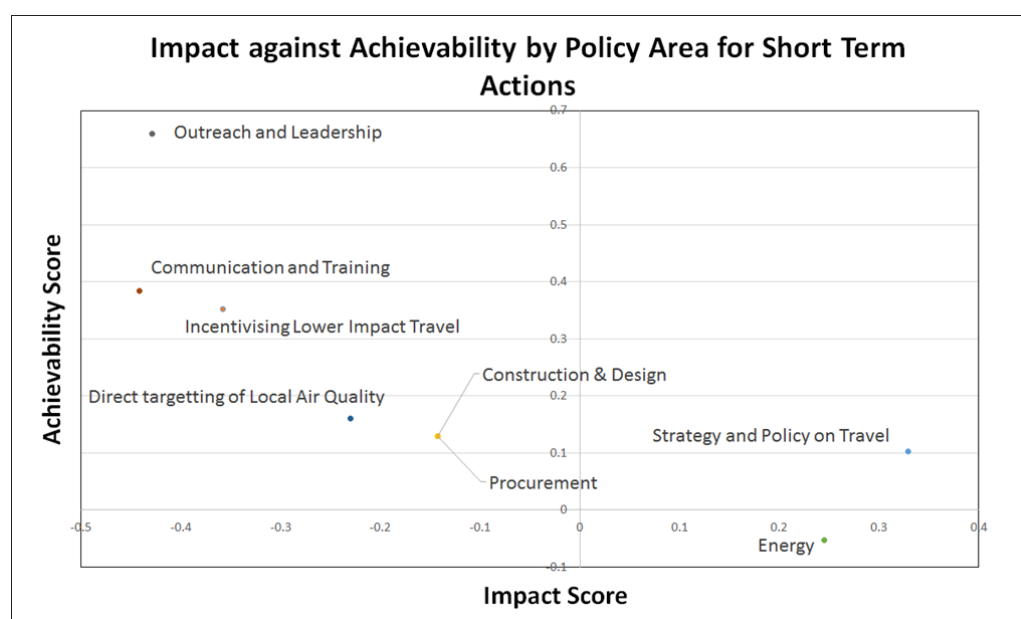
Figure 3. Plots the policy areas average scores for Impact and achievability for short term actions. Strategy and Policy on Travel is a stand out area with high impact.

Figure 4 shows that Communication and Training, and Outreach and Leadership are significant outliers in the long term. The rest of the policy areas in Figure 5 are not so significantly set apart. Strategy and Policy on Travel is the only other area that appears to offer some potentially high impact scores. Figures 3 and 4 both indicate that Energy, Construction and Design, and Direct Targeting of Local Air Quality are policy areas that are unlikely to offer actions with high impact for their achievability score because these areas would require large investments in infrastructure by the trust and alterations to the Private Finance Initiative (PFI) contracts in place at the Queen Elizabeth Hospital site. As a result, these barriers push down the achievability of any action in this space despite the chance that the impacts of such actions could be significant. This is the synthesis of discussion with many interview participants that also indicated these changes would be hard to bring about.
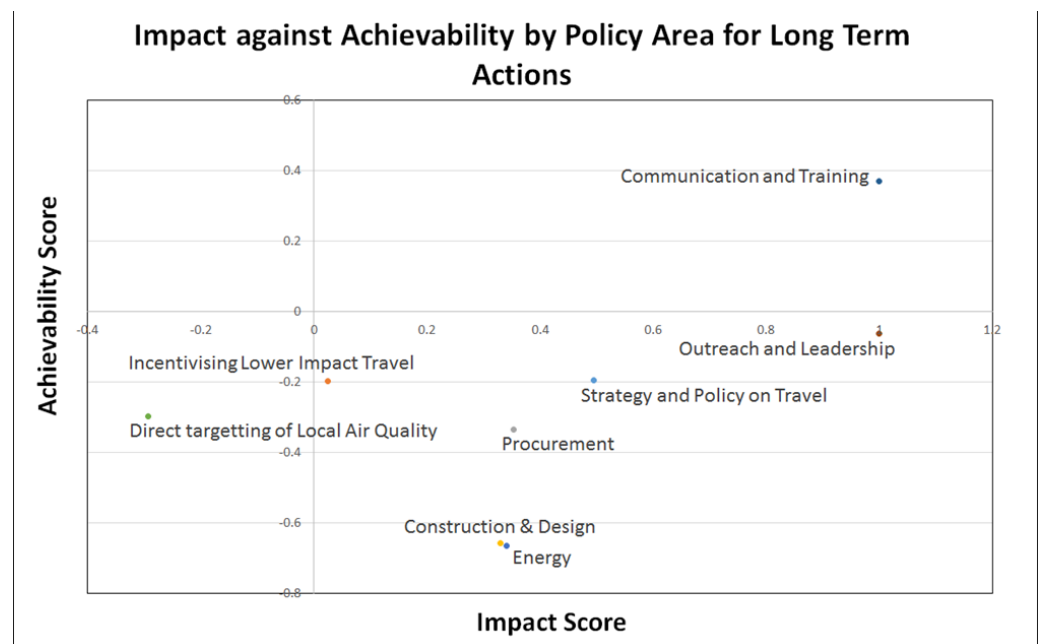
Figure 4. Plots the policy areas average scores for Impact and achievability for long term actions. Communication and Training, Outreach and Leadership and Strategy and Policy are stand out areas with high impact.
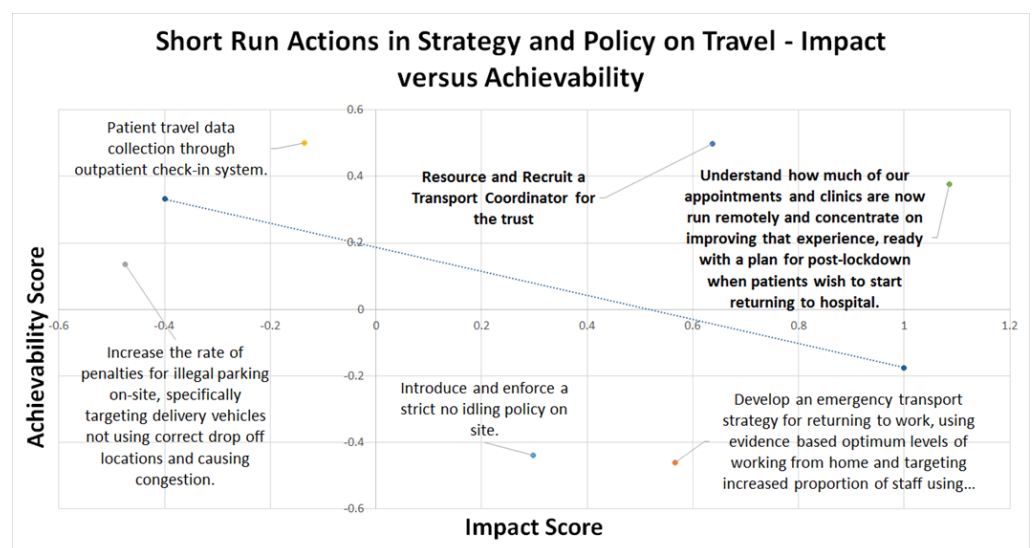
Figure 5. The same trend line in this figure is constant across all of the following figures. It shows the average ratio of impact to achievability grouped by timeframe across all actions featured in our survey. The plots are populated with actions and their average adjusted scores. The position of an action relative to the trendline gives a view of how they compare against the overall average ratio of scores in that time frame. Their position is comparable against the other actions in the plot as well, and those in other plots for the same timeframe.

3.2. Strategy and Policy on Travel

In the comparison of policy areas above it is evident that Strategy and Policy on Travel is the area with the most potential for impact in short run actions. Transport is a key area for the trust to implement changes directly, without significant dependency on external stakeholders. Although it includes complexity in terms of influencing behavioural change

it is also an area with some of the lowest financial resource requirements and can be acted on independently to other policy areas

The illustrative trendline in Figure 5 showing the average ratio of Impact to Achievability (for short term actions) is replicated for each policy area. These lines show the average ratio of Impact to Achievability scores across all short run actions and long run actions, with different lines for the two time frames. Short run actions that are above where the average score would be for their achievability are good options because they offer a good return in terms of impact generated for of effort invested. that might be needed to achieve them. This is purely comparative against the other actions put to participants in the survey.

Two other actions were highly ranked across all short run actions. The first: '**Developing an emergency transport strategy for returning to work [in the post-COVID-19 pandemic context], using evidence based optimum levels of working from home and targeting increased proportion of staff using sustainable transport (incl. buses and trains)**' was ranked third highest in terms of impact. This is already underway at the trust and will largely be dependent upon the first ranked action regarding the restructuring of patient activity and how much of this is required to be in person.

The interview process suggested that UHB does not have data on how patients travel to and from the QEHB. Whilst the above diagram shows the action: '**patient travel data collection through outpatient check in system**' is low impact. This information would be extremely valuable for measuring impact of other actions so clearly this is required to inform and measure progress in other areas. This could be achieved with a simple question at admission and check-in, for both inpatients and outpatients respectively, and it would offer a huge amount of insight and inform strategy going forward. There was one trade-off identified when discussing implementing this action and that was concern about the other information that the organisation may also want to gather. This was raised by several interviewees who pointed out that other issues, particularly other research projects, would highly value the same opportunity. It is not within the scope of this research to evaluate the actions identified against actions that don't bear any consequence on the issue of air quality and pollution associated with the Trust

This leads on to the two key actions in this timeframe of the policy area. The first action is: '**Understand how much of our appointments and clinics are now run remotely and concentrate on improving that experience, ready with a plan for post-lockdown when patients wish to start returning to hospital**.'

This action was ranked highest for both impact alone and average of impact and achievability in the survey responses. The goal of the action is to reduce the long-term numbers of patients attending physical appointments at the QEHB. If the experience, efficiency, safety and quality, or clinical effectiveness, of these consultations can be improved whilst appointments are held remotely to the point where people are satisfied with their appointments being by video or telephone, then we can reduce the number of people attending hospital as fewer patients will request in person appointments.

Remote consultations were discussed in considerable depth in three participant interviews which took place prior to the first national lockdown in England in March 2020. The last interviewee, as a senior leader in the trust, had been briefed that a large proportion of trust activity, all outpatient care and most pre-op and post-op consultation, was going to move to being held remotely, or otherwise be cancelled. The other two interviews were held at earlier dates and the subject of the use of remote appointments was a strategic aim of the organisation as part of a long-term programme with a structured and controlled roll out of the technologies planned. One of the participants stated:

> " . . . *the plan would be that, on a pathway, the patient wouldn't need to go to see the GP, but would come in straight for diagnostic, and then straight to see the clinician for counselling and discussions around how we're going to deal with their health care needs after having the diagnostics. So possibly take two to three appointments out of the system for each patient that comes through those pathways. So that's a fairly big one.*"

When this participant was interviewed, it was not a common belief that COVID-19 was going to be a significant outbreak anywhere let alone have the impact it did. What happened to hospital activity was a drop in patient and staff travel that no one had expected at the time. Had the COVID-19 pandemic not occurred the proposed action would have been about promoting the use of digital technologies on patient pathways to reduce patient journeys to the hospital. With the benefit of hindsight, we have refocused the action, to being one that concentrates on making the continuance of as much remote consultation and activity as possible by making it as effective, safe, and satisfactory as possible. The resultant changes in behaviour due to the pandemic have accelerated several of these long term strategic programmes, generating urgency reflected in the time frame selected by survey respondents.

Our findings suggest the trust needs to establish how remote consultations can be delivered amongst the specialties and ensure that this is done safely and efficiently. These findings suggest the use of video consultation wherever possible. If telephone is the only possible technology then testing and imaging need to be completed ahead of consultation so that all information is available for the clinician to discuss on the first call. Not all consultations can remain remote when they no longer need to, and the focus turns to addressing the backlog instead of reducing transmission of the COVID-19 virus. But the proposed action is to establish a strategic and precise plan that maximises the amount of future consultations that will be held remotely so as to reduce the impact on air quality of patient and staff travel for in-person attendances. This is likely the highest priority action from our short-term actions based on its survey score and the evidence from interviews. Prior to COVID-19, a massive barrier existed around the successful adoption of video consultation technology.

The action of: **'Resource and Recruit a Transport Coordinator for the trust'** was ranked second highest for both impact alone and the average of impact and achievability. In the interviews it was made clear that resourcing new positions in the trust needs to add significant value to justify the cost. Participants suggest that transport was potentially a more tangible and focussed area for a job role than simply sustainability. Additionally, it was felt that positions and roles across the trust needed to appoint subject area experts and that sustainability in an organisation as complex as UHB would be too broad an area for a single role or even a small team to cover. Instead, targeting specific themes such as transport and energy which are key to the improvement of air quality and environmental sustainability would likely generate a more significant impact. There is evidence from [33], a study with interviews of 60 'mobility managers' from Belgium, that a similar role as this action proposes, can effectively reduce use of single occupancy vehicles and move staff groups to lower impact travel choices.

There were a number of potential areas to focus upon in this role as identified by interviewees. One aspect raised by a participant was to work towards normalizing active travel

> *'I have been working with some other trusts around their cycle parking facilities, some folks, you know, it's normalizing it, making it feel normal and that you're welcome to arrive by active means that you are given higher priority, that you have safe, secure cycle parking near to the entrance to the hospital.'*

Generating an organisational culture of acceptance for active travel for staff, patients and visitors could provide a significant impact upon traffic.Interviews also showed there is a clear lack of existing knowledge within UHB on the multitude of options available for sustainable travel. A participant, who is a respiratory clinician, talks about their own knowledge and conversations with colleagues:

> *'I didn't know about this, where the cycle lanes were, and people that talk to me when we have casual conversations about, you know, you don't live very far, you could cycle in, going: what and just get knocked off my bike. There aren't any cycle lanes. So that's the perception.'*

Many interviewees indicated the Trust should raise awareness of active travel options, which requires protected time within a designated staff role.

Another participant raised the possibility that the transport coordinator could focus on removing the need for travel altogether. This work is already underway in terms of reviewing patient pathways and removing unnecessary patient journeys. This was also raised by two interviewees who suggested de-centralising care offered by the trust away from the main hospital site closer to where people live in their communities, or adopting entirely digital approaches with virtual reviews and video consultations.

Our findings suggest that UHB should resource and recruit at least one coordinator, alongside some effective measurement systems to assess the impact of this role.

Across all the actions proposed in the survey, the two top scores for impact in Figure 6 were also ranked in the top five for impact at 3rd and 4th. The highest impact was considered to be: **Step up working with UoB, W&Cs and combined authority on Bus and transport links to hospital**. This would include the University of Birmingham (UOB) and Birmingham Women's and Children's NHSFT (BWC), the goal of this would be to target Transport for West Midlands and the combined authority to improve the frequency and coverage of public transport servicing the campus. Interview participants asserted that currently a significant number of staff and patients would find it prohibitively slow and costly to attend/commute to the QEHB because bus services do not run at convenient times, take too long and cost too much. These factors were all mentioned in multiple different interviews. One participant was able to offer some personal insight into their experience of commuting to the hospital by bus:
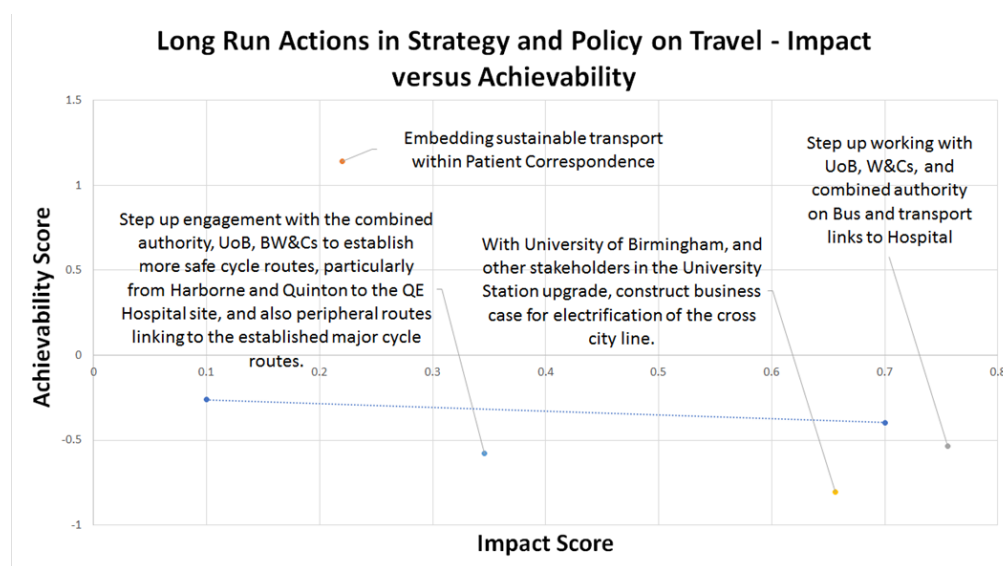
Figure 6. Survey results for Long Run Actions in Strategy and Policy on Travel and includes the trendline for all long run actions across the survey.

'But, they seem to be weirdly discouraging people from taking that bus as a route to get to work because it's a really strange thing . . . you'd expect a bus service provided to get you into the QEHB, would think about having lots of buses around the period of eight o'clock to nine to get people in work. But for some reason, inexplicably, this bus service, the one bus service that gets you from Mosley into the QEHB has this inexplicable 50 min pause where no buses run. So between 08.00 a.m. and 08.53 a.m., there is no bus that gets you into the QEHB. So you're either extremely early or very late into work.'

This general theme of a lack of joined up thinking around where people are going for what times and why, and consideration of providing alternatives rather than servicing current demand, is thematic across interviews of the personal experiences of many of the staff at the QEHB. Amongst the more general population of staff from the combined UHB,

UoB, and BWC travel survey from 2018, 20% of respondents said the first thing that would make them consider taking public transport was a more frequent service, whilst 26% of respondents answered a more reliable service. The three organisations' combined efforts seem likely to have a greater impact if this is coordinated approach is achievable.

The action ranked 4th overall for impact in the long run is another case for inter-organisational collaboration: **'With University of Birmingham, and other stakeholders in the University Station upgrade, construct a business case for electrification of the cross-city line.'** The motivation for this is that the current NO_2 pollutant concentrations at railway stations, such as Birmingham New Street, which many staff and patients coming to the QEHB must pass through, are recognised to exceed EU Public Health Standards due to a reliance upon a diesel rail fleet operating in an enclosed environment [34]. The organisations named in the action have already successfully collaborated to orchestrate Network Rail's ongoing redevelopment of University station. The above action is to take this a step further to reduce emissions associated with diesel trains with potential benefits for public health [35,36].

This action which identifies the role of joint working with external stakeholders is similar to the previous action in its clarity of the outcome but not so clear on the mechanism of how to make it happen. However, this acknowledges the need to undertake cross-organisational work to achieve high impact, although achievability scores reflect this is not an area over which the trust is able to lead. The challenge of deliverability was reflected by responses of many interview participants, who fed back to the effect of: 'Yes, it would be great, but hard to achieve.' However, multiple participants asserted that the trust should always be forthcoming with regards to collaborating, including identifying relevant lead organisations.

All of the actions shown in Figures 3 and 4 scored comparatively highly on impact. The only aspect that sets any of them apart is the achievability of the action to: **'Embed sustainable transport within patient correspondence'**. This action is considered by survey participants to be extremely achievable, with the highest achievability to impact ratio across all policy areas for its timeframe. This is largely due to its ease of implementation rather than impact. The idea is that communication with patients should prioritise public transport routes, and safe active travel routes, when describing how to arrive at appointments rather than simply telling patients where parking facilities are on site.

A common theme amongst barriers discussed in interviews related to the potential for an action to be a tick box exercise that has no real arising impact. This was raised to suggestions to implement a sustainability section in the trust induction day, which all new employees must attend. The reason an action might be considered a 'tick box' exercise is that it's simple and easy to implement and therefore all actions should therefore be considered in terms of both impact and achievability.

Through discussion in interview the route for implementing this was generally agreed to be a phased approach. Initially the trust can just replace the current map on the back of physical letters with a map more tailored towards active travel and public transport. This is unlikely to be very successful because evidence indicates 'nudging' is most successful when tailored and 'smart' [37] by targeted personalisation. There is currently work going on around this at the trust:

> *'But at the moment the way patients receive information in their patient letter, it feels predominantly focused around accessing car parking and not actually public transport. Again, we're just currently moving through switching from paper correspondence with patients to electronic correspondence and we're hoping to kind of rejig the patient letter there so that we can actually embed links so that you could say, if you want to access the QEHB site by public transport, how would you go about doing it?'*

The participant suggested the first step would be to provide a simple link to Google maps; an action which is low cost and straightforward to implement.

3.3. Incentivising Lower Impact Travel

This policy area is different to the above in that it is focussed on facilitating and guiding staff and patients to use active or sustainable transport choices to access the QEHB site. Whilst strategy and policy on travel is about actions at an organisational level, the below set of actions refer to indirect actions the trust can take to enable individuals to take sustainable travel choices for wider benefit.

Key to understanding these potential actions is to consider them in context of current UHB provision in this area. The trust does not currently hold routine data on patient and visitor travel modes but does undertake a biennial staff travel survey. The staff travel survey published before the COVID-19 pandemic in 2018 had 1022 responses, indicating 8% modal share for cycling to work and 60% private car use respectively. Of 618 car users, over one third (35%, n = 215) had a journey time of <30 min. These 'Short Journeys' of under 10 miles [38] are those trips which could be most be efficiently and reasonably replaced by active travel. Research indicates that walking for journeys of ~1 mile and cycling up to 10 miles is feasible, and with appropriate urban/sub-urban infrastructure provision could be quicker than the equivalent journey by car.

In Figure 7, some of the actions lie below the average ratio line of Impact to achievability scores. One action, that has further evidence arising from interviews to support its low impact score, is '**putting in a park and ride service from Longbridge**'. There is already a park and ride service in place from the Edgbaston cricket ground, located approximately X miles from UHB and utilising this venue's extensive parking capacity that is largely unused during the week. However, this facility is not widely used and the suggested reason for this from respondents is the inconvenience of added steps in a journey. With one participant stating: 'people do have an issue with even relying on a bus because they see it as more inconvenience'. This suggests that actions and the solutions should focus on journeys that are as simple as possible, with an emphasis on active travel and better coverage and convenience of public transport.

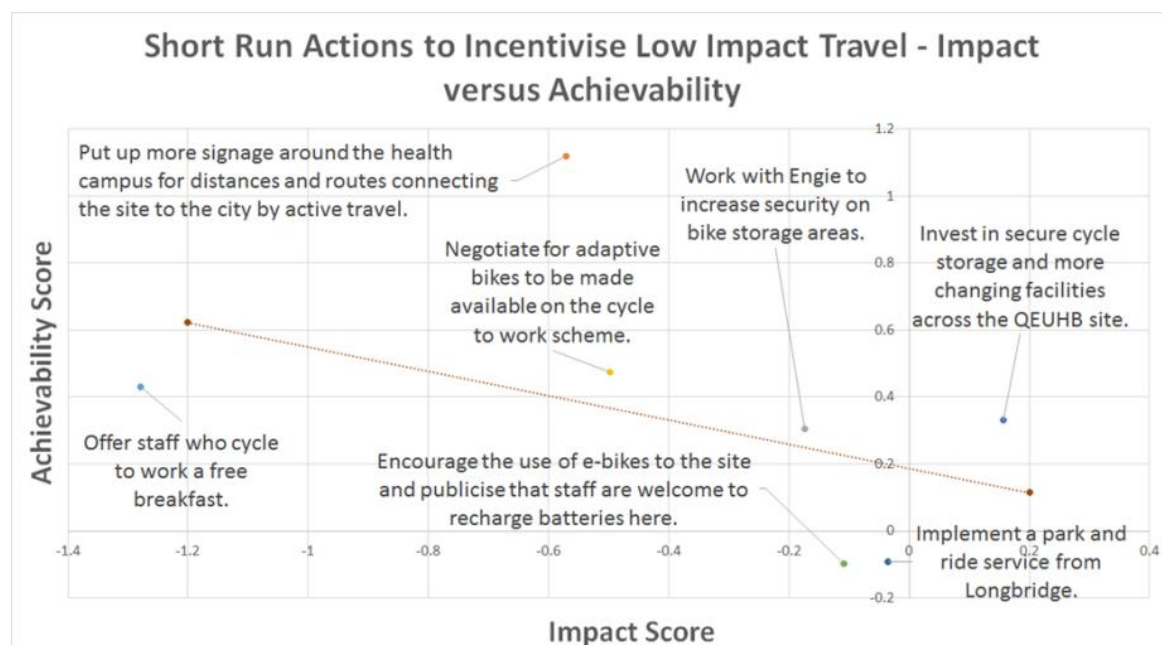**Figure 7.** Survey results for short term actions to incentivize low impact travel. The trendline for all short run actions is in place for comparison across all policy areas.

A key message from people interviewed who cycled to work was that whilst there was plenty of cycle storage this wasn't secure enough. They didn't feel confident that their bikes would be safe parked throughout the day whilst staff were at work. This result is

reflected by the fact that the highest impact score within this policy area is to: **'invest in secure cycle storage and more changing facilities'**, one participant said the following:

> *'I think we could have better facilities, more of them and more secure facilities, for cycling and they would be used, and that would help to increase sustainable travel. I don't think we do very well.'*

> . . .

> *'But again, while we've still got an issue with security that's a really big problem that needs to be dealt with. It's affecting our staff already. One person down here just got a new bike through the cycle to work scheme. It got stolen within a week.'*

The trust has a programme offering free D-locks (the most secure portable type of bike lock) to employees to help keep bikes safe, however many of those we interviewed who were already cyclists were not aware of this offer and were not sure that D locks provided sufficient security. Two participants, who were keen cycle commuters and working in the heritage building at the QEHB site, indicated there were two secure cycle sheds but only one in active use because a second padlock for the same key couldn't be sourced. This shows the practical barriers to use of existing cycle storage and suggests additional investment in secure facilities is required. One participant observed the following:

> *'I think that is indicative of the issue that you're facing here in that any move towards improvement is just going to be fraught with just massive bureaucracy at times. It can be paralyzing . . . '*

Additionally security by the contractor on site was considered under the action: '**Working with Engie to increase bike storage security**'. This scored as less impactful than improving the facilities for storage and in general would prove more costly as UHB would have to employ staff rather than have a bike shed with a lock on the door.

The action: '**Put up more signage around the health campus for distances and routes connecting the site to the city by active travel.'** is ranked 2nd for Achievability and 4th highest for average score of Impact and Achievability. Largely because it is seen as an extremely easy action to implement rather than being one that is going to provide the 'modal shift', a term used by one participant, required in travel behaviour and choice of transport.

Most studies evaluate improvements to cycle infrastructure alongside wayfinding signage so it's not possible to isolate the impact of the signage in isolation [39–41]. However, this is a relatively low cost and easy to implement action.

The aim of **'installation of electric vehicle (EV) charging points in car parking across the trust site'** is to enable staff and patients to choose to travel to the hospital in an EV rather than an internal combustion engine vehicle (ICEV). Many survey participants were supportive of this action (Figure 8). A large proportion of local housing does not have access to off-road parking and therefore household charging facilities. Interviewees stated that if they could charge their EV at work, it could enable them to purchase one instead of a petrol or a diesel car. Several interview participants also suggested the real impact of few members of staff using EVs is unlikely to be significant compared to other actions. UHB should therefore facilitate growing infrastructure for EVs in line with the growth in demand for infrastructure amongst staff.

The survey response to the action of: '**Create pricing equity for staff and patients between public transport and driving**' was ranked 24th for Impact, 23rd for Achievability and 30th for an average score of the two dimensions out of 36 short-term actions. It was the expectation, based on the thematic analysis of interview data, that this action would be seen as an essential and easy first step; therefore, it is likely that participants who only responded to the survey only felt very differently about this action.
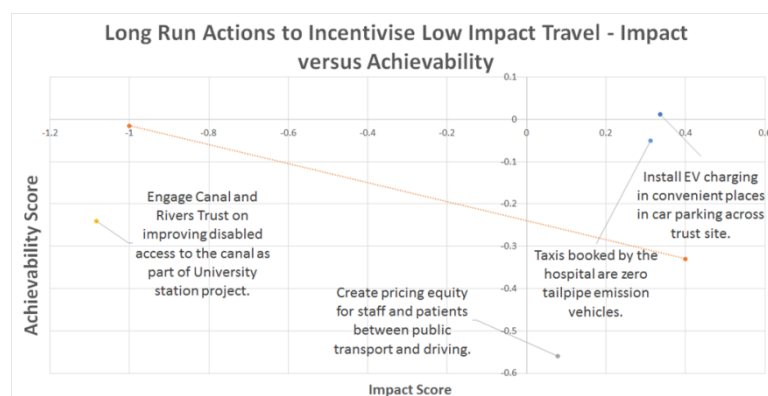
Figure 8. Long run actions for incentivizing low impact travel, in terms of impact versus achievability with the long run trendline for comparison across policy areas.

Multiple interview participants asserted that it is currently far more costly to get the train or bus to work at QEHB everyday than it is to drive and park. This action could involve either subsidising staff public transport fares for, increase the price of hospital car parking, or a combination of these two factors to provide an economic incentive for modal shift. The 2018 UHB staff travel survey indicated that for 215 respondents who drive to work, over half (55%, n = 118) would choose travel by bus or train as the next most viable alternative and of these 41% (n = 89) would be most likely to start taking the train or bus based on a financial incentive, such as greater discounts on tickets or an interest free loan. Public transport occupancy levels decreased substantively during the COVID-19 pandemic and remain below pre-pandemic levels following the lifting of national public health restrictions in February 2022 [42]. The use of financial incentives could be an important tool to incentivise a return to public transport for those who transitioned to Single Occupancy Vehicle commuting during pandemic restrictions. Four interviews highlighted the need for price parity between car and public transport modes:

'the price of a permit is still cheaper than the cost of a travel permit ticket on the railway or the bus. At the very least we should aim for parity, if not making car parking more expensive . . . it is actually less than a bus permit. It can't be right that it's cheaper to park than to come by public transport.'

A key barrier identified for implementing these changes was concern regarding staff recruitment and retention, notably consultants/highly skilled staff who are in high demand.

'[X] said to me about the car parking, that [they] didn't want all the consultants to go work for a different hospital because they couldn't park their cars.'

Another participant noted:

'It's not particularly easy to nudge people out of their cars. To a certain extent you have to force it. And the fact that we've reduced the number of car parking permits, we've started to tier staff as to their importance and whether they get a parking permit or not, is beginning to bring some of that enforcement, but once you start enforcing things, then we have the downside of that we lose staff goodwill and we can't really afford that at the moment.'

This raises the valid point that making it more difficult or costly for people to commute by car may change where they are willing to work. One participant stated that a common reason for leaving the organisation, was that parking on site was too difficult. The member of staff mentioned an anecdote about speaking to three physically fit and able-bodied military nurses who lived within a few miles of the trust but were not able to park on site. The participant observed that people consider it a right to be able to drive to their work.

At an organisational level such concerns are likely to limit feasibility of further restrictions to car parking provision. However, opportunities remain for ensuring alternative options are more affordable and attractive as an alternative sustainable transport offer.

3.4. Procurement

Cargo Bikes were discussed by a couple of interviewees, who were judged to have expertise on the matter. A member of staff interviewed, who is a senior manager in estates for the trust was doubtful about what role these could fulfill:

'I think the potential is a bit limited. And also a lot of the goods tend to be too bulky. Post tends to come into this site, there's a post room, so it's delivered there and distributed just on foot. So there's no vehicles really used, so I think it'd be limited.'

This is a valuable point, that couriers on bikes may not be useful intra-hospital given that most transport around the site is undertaken on foot by the portering staff. However, it is evident that potential scope the use of cargo bikes is not widely realised at UHB Given that another interviewee discussed the case of another major secondary care centre with similar services and layout to the QEHB successfully implementing this action inter-hospital, UHB could therefore commit resource to exploring viability of this option to reduce vehicle dependent deliveries to the site (Figures 9 and 10).

Figure 9. Impact and achievability of the short run actions on Procurement, with accompanying short run trendline across all short run actions.

Procurement is a key area that survey respondents indicated had potential for significant impact in the longer term.

The action: '**Trust builds sustainability into its procurement network with points given in tender processes for use of low emission and low impact supply chains.**' ranked 1st for Impact and 3rd for its average score of impact and achievability out of the long-term actions in the survey. This is already a part of the trust's Sustainability launched in 2019, which includes three key 'How to . . . ' actions to achieve the policy aim of 'The sustainable purchasing of goods and services.' [29] These actions are: to firstly gain an understanding of the carbon footprint of the trust's procurement from which to measure improvements. Secondly: 'Include in our tender processes eligibility and evaluation criteria that take into account environmental issues, sustainability, local economic and social value factors as appropriate.' And finally, 'Work in partnership with our suppliers to support our sustainability priorities.' It is likely that if the trust can achieve these actions then targeted sustainability requirements within tender processes will provide an incentive for suppliers to improve their own practices. However, metrics are more widely available for assessing carbon emissions and measures to compare and assess air quality impacts would be more challenging to access.
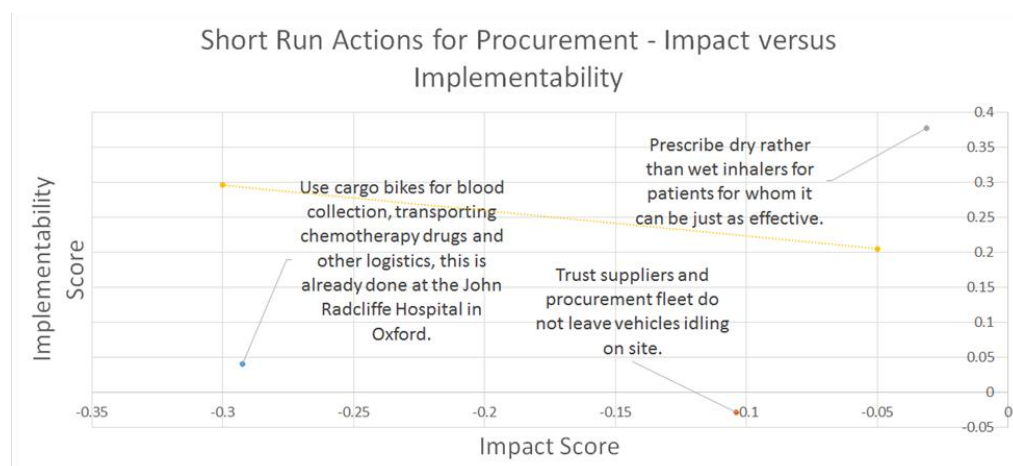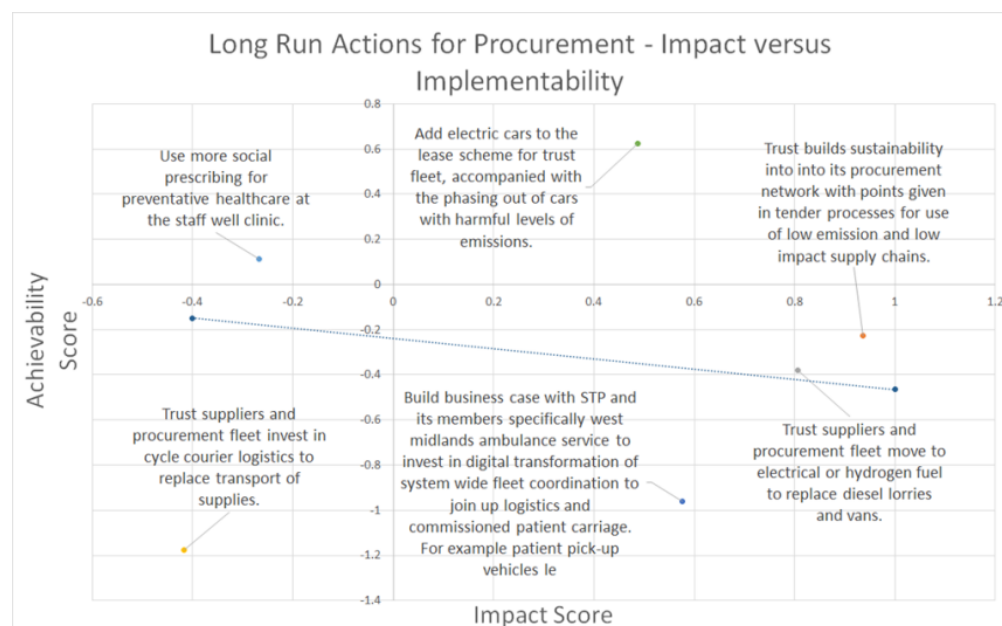
Figure 10. Impact and achievability of the long run action on Procurement, with accompanying long run trendline across all long run actions.

There is the additional challenge for interaction between local and national handling of NHS procurement for certain goods and services. One interviewee noted that NHS England [1] and other NHS governing bodies are pursuing sustainability from the national level and the proactive organisations, such as UHB, could use this, alongside their own improvements, to try and lead change across regions where they can exert an influence. This interviewee told us about the trust's forming the Birmingham Hospitals Alliance procurement group with Birmingham Women's and Children's and the Royal Orthopedic Hospital NHS trusts, which has provided greater influence over procurement processes:

> '*So we have a very significant voice in the West Midlands procurement network in a way that, you think UHB was before, but actually we weren't . . . So we've increased our voice and so there are things we can influence and I think it's, it's coming at a time that the national level is also incredibly interested in sustainability as well. So I think our bigger voice and the national level also recognizes that value for money is very important, but we can also use our purchasing power in a slightly different way. The STP, for example, did quite a bit of work around the social value policy, drawing on some of the learning from local authorities that perhaps do this and their suppliers tend to be more local than the NHS, so sometimes it's slightly different. But we did quite a bit of work just to kind of start to understand what good looks like across all our partners for procurement for social value.*'

There was a wider consensus amongst those interviewees who were working on strategy or were members of the board of directors that this approach was now approved as a trust strategy which would undergo implementation, however there were no tangible examples provided with regard to air quality benefits.

The two actions: '**Add electric cars to the lease scheme for trust fleet, accompanied with the phasing out of cars with harmful levels of emissions. '/' Trust suppliers and procurement fleets move to electrical or hydrogen fuel to replace diesel lorries and vans**.' both scored highly as long-term procurement actions. The second is ranked 2nd in Achievability and 2nd for average of Impact and Achievability. The first has already begun in part, with one director in interviews outlining that the fleet will be replaced by hybrid and then EVs once appropriate charging infrastructure has been installed. EVs will not eliminate PM emissions (due to brake, tyre and road surface wear [43]), however they are an effective way of reducing tailpipe emissions of NO_2 compared to ICEV vehicles. When

used in conjunction with the use of cargo bikes (for freight movement), decarbonisation of the trust's procurement fleet would be a significant local air quality improvement measure, although, as suggested by survey findings, this it is likely to be a long-run action due to costs involved.

Specific concerns were also raised regarding the role of the trust in investing in sustainability actions: one director put it in the following terms:

> '*Our primary purpose as an organization is to deliver healthcare, safe, high quality, effective healthcare to patients. So that needs to be our primary focus. To do that you need to have money. So that is secondary and then you're kind of into the tertiary elements, which is how we do that? I think sustainability sits in that kind of tertiary element of how we do it. How do we do this effectively? How do we do this in a sustainable way? How do we do this with minimum waste? All those kinds of things. If we minimize the waste that should mean that we've got more money to spend elsewhere within the system. It all fits together. But if you're asking for a hierarchy. The hierarchy needs to be: high quality, safe, patient care to start off with, to do that you need money, below that you need the whole implementation area.*'

The importance of prioritisation was a universal theme amongst interviewees, suggesting it is critical to understanding why sustainability is yet to be embedded within healthcare provision. The statement outlines that the primary focus of a hospital is to keep sick people alive, and to do this the hospital needs to use money in an effective way to achieve this primary goal. If its ability to deliver healthcare is jeopardised because of alternative investment decisions—such as fleet upgrades—then the trust has failed in its primary purpose. However, following introduction of the NHS Green Plan and legally binding net zero commitments for healthcare services, this position is likely to shift, with emerging recognition of the role for trusts in maintaining and promoting health of people and the planet [1]. This point does illustrate a fundamental barrier to delivering change and an example of a wicked problem which requires a systems approach [44]

3.5. Energy

The policy area of energy did not provide a large number of actions from the scoping exercise, As can be seen in Figure 11 there were only 6 actions identified across both timeframes. This made it the policy area with the second least actions scoped after construction and design, which was omitted from further analysis. Of the six actions related to energy, two actions targeted solar power generation on the QEHB site, one targeted installation of low NO_x boilers and one aimed at installing a ground/air source heat pump. Interviewees indicated that these actions are of high potential impact for air quality but likely to be subject to numerous deliverability constraints, due to the third-party provider arrangements for building and maintaining trust estates and facilities; reflected in the low scores for achievability.

One short run action from the energy policy area was to: **'Implement 'power down' periods of IT equipment trust wide to lower energy usage, e.g., automatic shutdown on all non-essential machines.' (shown in Figure 11) which was** ranked 5th highest overall for impact Interviewees frequently raised the fact that there are numerous computers that are left on all the time and only restart automatically every so often for software updates. A policy to support this action would need to consider which computer hardware is required to be kept powered and these could be controlled by an automated system. Other considerations raised in interviews were the need to be able to opt out from automatic shut-down, for instance if running Research and Development, Informatics, or IT procedures overnight).
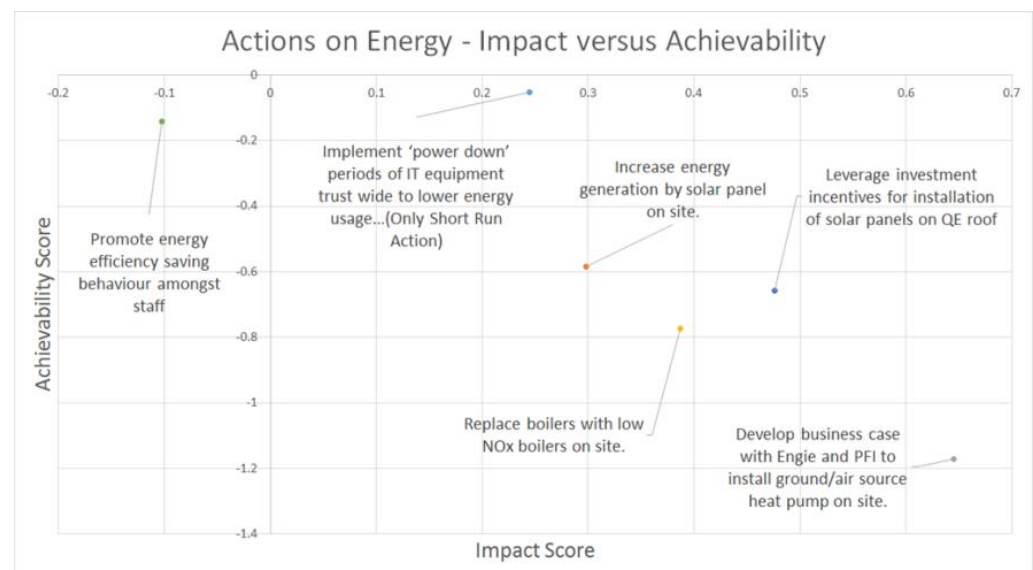
Figure 11. Actions across long run and short run time frames, assessed for impact and achievability.

3.6. Communication and Training

The scores given to short-run actions in the communication and training domain were consistently low in terms of impact. For actions scored as highly achievable, the action's survey scores still achieved a ratio of achievability to impact that placed them below the average ratio trendline. These actions included: 'Add messaging around behaviour change to pay slips promoting active travel and sustainability' and 'Use posters and e-posters on electronic check-in to convey information on Health Impact of Air Pollution and how to protect yourself'.

In almost every interview respondents indicated a frustration in the process for driving behaviour change. There was the earlier example of the nurses who lived within a mile of the hospital and were frustrated by how hard it was to park at the hospital, the context for which was a discussion on the difficulty of initiating behaviour change. In the same conversation the participant discussed the CAHF action for including a sustainability section in the Trust induction; for which the participant considered that information retention would be low and negated or contradicted by conversations with long-term employees and observations following employment commencement. The formative period in the first few weeks within an organisation is when new employees' understanding of the organisational culture are established and where their sense of which behaviours were acceptable are formed. This interviewee felt that sustainability information on payslips was more likely than trust induction to have an impact on staff behaviour. No further methods to motivate staff behaviour change were considered likely to be effective.

Almost all Interviewees noted that actions related to communication were low impact and ineffective. This also included those actions relating to provision of information to patients.

In the case of asking if clinicians should be trained how to communicate with patients on issues around air quality to prevent harm, several interviewees also pointed out that the trust largely provides secondary specialist care to patients who are severely unwell and that essentially the organisational role does not include disease prevention. These participants observed that the majority of UHB patients will not be impacted by lifestyle change. A Respiratory consultant gave the example: if you have a COPD patient who is registered with the specialist Respiratory Medicine service, then the likelihood of the patient choosing to get here by walking isn't going to be possible but also isn't likely to make a difference to them if they did. This barrier was more of a discussion point around proposals to implement a greater extent of preventive medicine and social prescribing by the trust, as promoted in the CAHF tool. A recurrent interview theme was that communications actions

were more relevant in primary compared to secondary care; with the latter restricted to promotion of lifestyle changes which target exercise and diet as a mechanism for chronic disease management.

The action **'Create a sustainability in healthcare management module with the education department to disseminate knowledge and raise awareness.' was the only action within communications considered likely to have an impact; ranked 4th for achievability, with an average score** for Impact and Achievability. A broader set of actions was connected to this area, including building key performance indicators on Sustainability and Air Pollution into our trust's performance assurance structure. The goal of this action is to embed the aims of the Trust's sustainability strategy and the ICS within operational management's priorities for managing the hospital on a daily basis. To achieve this, staff need to be informed and understand the ways in which the organisation's activities impact these indicators and how changes are likely to impact performance, considering the complex system of the QEHB [45]. It is also hard to trust management of this performance measure to be devolved and handled in the more dynamic way that is needed for such experimentation and change to be resilient in a complex system [46]. To allow the dynamic management of these issues then the trust may need to train and enable staff to recognise where change will be beneficial and lead on this at a department level. Our findings also suggest that this may be achieved achieve using existing Continuing Profesional Development (CPD) at the trust. This approach was considered to be more effective and impactful than mandatory training due to the voluntary and pro-active elements of this approach.

3.7. Outreach and Leadership

In the long term, the scores for outreach and leadership are much more positive in terms of impact, as shown in Figure 12.
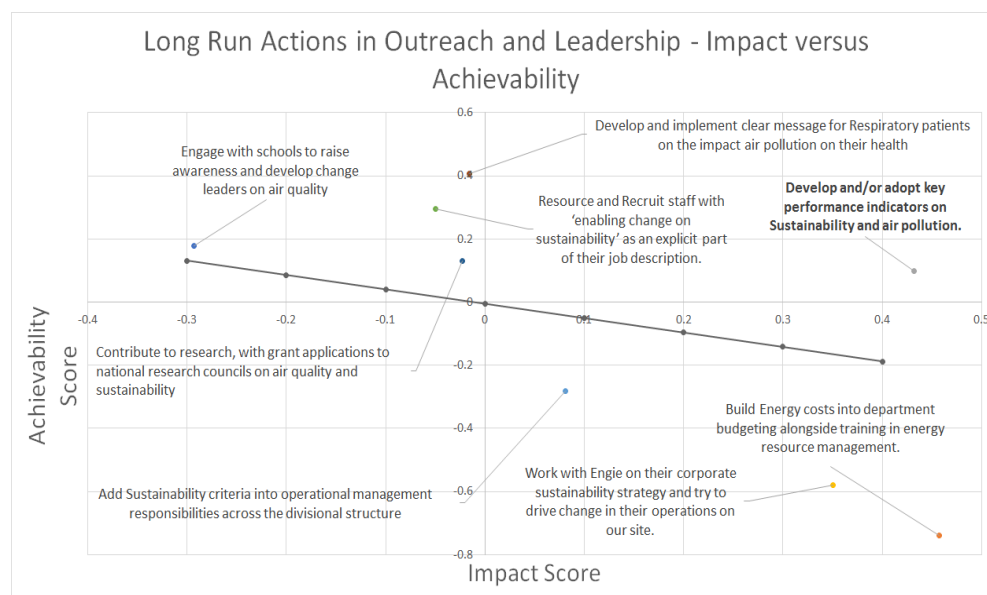
Figure 12. Shows the Long run actions for Outreach and Leadership, with relationship between impact and achievability.

The targeting of clinical messaging for respiratory patients, which was discussed previously in the communication section, was one of these actions. Investment in becoming a research hub supporting grant applications on air quality and sustainability also scored highly. This action is based on the documented positive externalities that occur in hospitals where clinical research is a focus, with evidence indicating these trusts to perform better in measures of patient outcomes and patient experience [47,48].

The final action that scored well for impact and achievability was recruiting staff with sustainability as the focus of their job role. This action was discussed at all interviews with mixed responses. It tended to be participants with specialist knowledge and a focus on environmental sustainability who wanted to see this. Whereas the generalists and experts in UHB and the QEHB, those with experience in leading change in the organisation more generally, were more cautious. This discussion included reference to the advantages of specialisation based on the organisational structure rather than sustainability, including preferences for a transport coordinator role. A persuasive case was made by in one participant who had previously had 'ownership' of sustainability at the trust, who explained a high level of resource had been used trying to find relevant information and that strategic decisions had been taken by other teams of which the staff member remained unaware (such as a switch to a renewable energy supplier). The participant also favoured a model whereby individuals from across the organisation adopt responsibility for relevant issues within their area of expertise instead of compartmentalising 'sustainability' away from those with operational knowledge.

The standout action in this policy domain is to: **'Develop and/or adopt key performance indicators on Sustainability and air pollution.'** The survey score for this action is high impact and above average in terms of relative achievability, ranking 5th overall. In support of this action one participant stated:

> *'In every area of our clinical activity and our financial activity we are reporting against mandatory data requirements. If you can't measure something in the NHS, you just can't say anything about it.'*

Whilst another participant was even more candid:

> *'Whatever they are tested on, so however they show that they do their job well, they'll do whatever they're measured on, but they aren't measured on sustainability . . . If they were measured on it they would do it, I think . . . when you set a measure, people will try to get the best number of that measure and if they can achieve that by not actually doing anything useful for sustainability they will. If they can achieve that by cheating, they'll do it. But on the other hand they'll still do some good things . . . '*

Enabling staff to understand and apply mechanisms which will improve sustainability and air quality Key Performance Indicators is likely to achieve tangible benefits. There is no existing evidence which suggests implementation of KPIs with a focus on environmental sustainability from healthcare are effective. However, evidence from manufacturing [49], and food production [50] sectors suggest that such an approach is effective for measuring whole life cycle impacts of products procured and could be transferred to the healthcare sector.

3.8. Final Recommendations Table

The interview and survey findings were synthesised to produce a priority shortlist of recommended actions presented in Table 2 as a Mixed Methods Matrix [32]. These actions are those assessed as being most urgent and high impact. In the matrix, 'All positive' in the column labelled 'Interview consensus' means that the action was discussed with every interviewee and all interviewees were supportive. Where the entry is 'Majority Positive', either the action was not discussed with all participants, or it was not universally supported as being significant. In addition, any barriers, or trade-offs identified within the study are stated. The actions are ordered by holistic appraisal (from high to low), based upon all of the data collected in our study.

Table 2. Shortlist of recommended actions arising from data synthesis. (ordered by the average of Adjusted Impact and Achievability scores.

Rank	Actions	Survey Score		Interview Consensus	Barriers /Trade-Offs
		Impact	Achievability		
1	Quantify Hospital Activity run remotely, then undertake improvement of quality and efficiency of these services for post-lockdown to prevent return to business as usual	1.09	0.38	All positive	IT Video Consultation Capacity
2	Create the Transport Coordinator Role	0.64	0.50	All positive	Cost
3	Develop an emergency transport plan for returning to work. Establish real optimum levels of home working and target sustainable transport use to establish new habits	0.57	−0.46	All positive	Staff Health Impacts/ productivity concerns
4	Implement 'power down' periods of IT equipment trust wide overnight	0.24	−0.05	Majority Positive	None
5	Build sustainability into procurement processes rewarding low emission and low impact supply chains	0.94	−0.22	All positive	Cost/ Complexity/ national policies on procurement
6	Convert fleet to electrical or hydrogen fuel to replace diesel lorries and vans	0.81	−0.38	All Positive	Cost
7	Put up more directions and information around the health campus for active travel	−0.57	1.11	All positive	None
8	Gradually install EV charging in convenient places in car parking across the trust site	0.47	−0.15	Majority Positive	Car parking capacity/current low demand
9	Create pricing equity between public transport and driving for staff and patients	0.08	−0.56	Majority Positive	Concern over staff dissatisfaction at cost of parking
10	Review logistics fleet to assess capacity of cycle courier logistics	−0.29	0.04	No	Lack of Knowledge about capability/capacity
11	Collect Patient and visitor travel data through check-in systems	−0.13	0.50	Majority Positive	Opportunity cost of not collecting other data for other purposes
12	Embed sustainable transport within Patient Correspondence	0.22	1.14	Majority Positive	None
13	Create and promote a 'sustainability in healthcare management' module with the education department	0.16	0.37	All positive	None
14	Adopt evidenced KPIs measuring performance against sustainability and air quality criteria	0.43	0.10	Majority positive	More pressure on staff to meet more targets/cost
15	Build more and better secure cycle storage.	0.16	0.33	Majority positive	None

4. Discussion

This novel mixed-methods study has involved primary data collection and data synthesis to identify and appraise potential air quality actions for implementation at a large acute hospital trust in Birmingham, UK.

4.1. Remote Consultations

The results from interview and survey data collected in this research suggests that one of the best actions UHB can take to mitigate QEHB's impact on air quality is to maximize the amount of safe remote consultation and triage undertaken. To therefore minimize the amount of journeys patients take to the site. In 2020, there was a significant amount of new research published on the efficacy of remote patient management. A systematic review of remote triage systems [51] found a high rate of resolution with no change to the number of referrals to ED or primary care across the 8 trials analysed. It's unlikely to relieve pressure, based on current research, but they are just as safe as with in-person triaging. UHB is currently implementing remote triaging amongst other digital solutions at its A&E departments. Based on this evidence it would be recommended to continue to develop this remote system thereby reducing journeys to the hospital, in line with what our survey and interview data would support, even if the pressure of activity at A&E and on primary care are not affected.

There has also been a large amount published on the efficacy of specialist consultation. The performance of an improvised system for triaging and managing routine dermatology referrals [52] found that the system was largely workable although the telephone consultations were very time consuming for clinicians and that patients had often not submitted photographs of their skin prior to their consultations. The safety of patients appeared to not have been affected with most patients requiring routine surgery being referred without the need for additional in person appointments. This would reduce the number of patient journeys. One clinician conducted all consultations by video call and this eliminated the need for photographs being sent or uploaded by patients for inspection by clinicians, this was more efficient in this case study. Another work around is to have administrative staff triage patients and request photographs ahead of the telephone appointment. Similar work for specialist areas reached similar conclusions, these included work in musculoskeletal pain management [53], Oral Medicine [54], managing Osteoporosis patients [55], and COPD patients [56]. These studies all reached largely common conclusions on the use of remote consultation and its efficacy. That for several uses video or telephone appointments were just as effective for consultation as in-person appointments in terms of safety and the need for escalation was as evident as in-person. The uses when it was particularly effective included the management of chronic disease patients for regular reviews, triaging new patients and deciding how to commence treatment and if a patient needs to come in. It's not clear if video consultation can overcome the barrier to effective and efficient telephone consultations by overcoming the lack of live visual inspection, and this needs further research to confirm but it seems likely other than when diagnostic tests or monitoring is required.

An editorial piece on the Scottish video consultation programme [57] asserted that:

"Clinical consultations conducted through a video link tend to be associated with high satisfaction among patients and staff; no difference in disease progression; no substantial difference in service use; and lower transaction costs compared with traditional clinic based care."

The authors of this review did warn that evidence in this regard was gathered from very specific samples of outpatients where their participation was deemed low-risk given the nature of the healthcare they required. Stable chronic condition management cases are different to the current situation in many parts of UK healthcare, with significant groups of patients have been waiting beyond guideline wait times for elective care that has been cancelled and these patients are at risk of becoming acutely unwell. For these patients

telemedicine is no substitute to in person appointments. The authors [57] also emphasised that there is a need to address a large number of technical barriers to adoption of video consultation and that patients who face challenges due to mental capacity or safeguarding are at risk of being lost without in-person management. These were issues that came up whenever barriers to remote consultation were discussed in this study's interviews as well and these warning should weigh heavily on efforts to maintain pandemic levels of remote consultation and virtual review.

4.2. Transport Coordinators

In this section reference is made to examples from the literature that might help outline how the Transport coordinator role could be defined at UHB in order to give it the best chance of having a positive impact. There are three key points outlined in [33] that are relevant to this action and that are important to apply alongside appointing a transport coordinator. Firstly, although 'the most involved' mobility managers in Belgium did have a significant impact on their organisation's choice of method for commuting, there was also no significant impact for those organisations where the officer was 'less involved'. This was based on assessment of each individual at the interview for the research. So, it is essential that any individual hired for this role is assessed to be committed and highly motivated. This factor and the second are related and that is the position's official powers in the organisation and the fact that most roles such as these are advisory positions and require the commitment of other teams and individuals in the organisation to make change happen. To overcome this barrier the mobility manager would have to have a budget to spend. With the limitations of the role in mind, and assuming a transport Coordinator at UHB would be expected to achieve most of their change through influence rather than power and spending. A motivated and committed Executive Team member could be deemed as impactful as the coordinator according to the research in [33]. Finally, the lack of formal measurements to evaluate the success of the mobility manager's outputs; because the role is part of a wider system with other influences such as cultural change in the organisation and the environmental and logistical factors that the organisation is subject to. This study is set in Belgium where every large organisation is required to assess the transport modes used by their employees for getting to work. In UHB there is a voluntary staff travel survey which is already a useful tool and would probably be promoted more widely with the introduction of a transport coordinator role. The introduction of patient travel measurements as discussed above would further inform the picture of travel behaviour. These datasets would serve to measure progress but the trust would have to accept that because this role would likely be advisory, the ability to isolate and measure its impacts would be similarly blurry.

The point that: making a habit seem normal for everyone has a big impact on achieving a change, is supported by research presented in [58]. This work found that participants who received over-reporting about the amount their peers had altered their commuting habits actively reduced their own use of private-vehicles by five times more than the control group who received accurately reported data on the commuting behaviour of fellow participants.

The final core aspect of this sort of role is designing travel plans for employees and this featured a lot in the papers we found on transport coordinator roles. [59,60] emphasise different aspects of this with the first being an examination of the adoption of a personal transportation plan tool and its assistance for transport planners, whilst the second is a case study of the work done in transportation planning at a large university. Both show that working through transport plans with employees as well as designing generic transport plans can be useful for helping people explore new ways of getting to work. In the case of [59] there was also the implementation of a digital tool that members of the organisation could use to plan their own transport routes. It's not necessary now to buy or develop such a tool as there are plenty of free pieces of software available to combine active travel with public transport for individuals. The transport coordinator would likely be pointing

people in the direction of these route-planning apps or walking them through the app, if technology is acting as a barrier.

4.3. Implement 'Power Down' Periods of IT Equipment Trust Wide to Lower Energy Usage, e.g., Automatic Shutdown on All Non-Essential Machines

Research in one paper [61] found that relates to this action estimated energy savings of 75% could be achieved in an average UK office, without disruption to services, through simply turning off 'low-power' office equipment, that's desktop computers and monitors, during periods when they aren't in use. The data for [61] is over ten years old now and office equipment is more efficient. A full picture of energy usage due to low-power office equipment at the QEHB could be developed easily with a simple count of machines currently left on overnight, whether there was an active session with a user logged in on their account, and some generalised figures from manufacturers on energy usage per unit [62]. This would be helpful to understand if the savings on energy are going to be significant.

Another concern is that the technology to remotely switch off office machines is not as simple as our interviewees expected. However, there are also other approaches to targeting this particular source of waste [63,64] both illustrate several methods of developing change in office energy usage behaviour and this is without increasing participants buy-in to the sustainability of changes, rather focusing on other elements. [63] identifies a powerful point that this step of reducing desk electricity usage is a much lower cost intervention than others such as more efficient technology and energy management, so it is an easy win if it can be achieved either by centralised power-down or if this is not available then behaviour change.

There is not a significant amount of literature on the impact of electronic office equipment on indoor air quality. [65] found a trend between perceived effort and tiredness and ventilation but this didn't look specifically at ICT equipment. One review paper [66] found a significant range of different indoor air pollutants that are likely sourced in part by office equipment and these include computers and laptops. Both this review and [67], which characterised the pollutants present from a range of printers and copiers, found that laser printers were a notable and significant source of VOC and TVOCs in office space. When you consider that air flow and ventilation is likely to decrease overnight with fewer people entering and exiting rooms, and all windows closed for security, then it does seem likely that to keep office equipment running through the night is likely to mean significant concentrations building up. There is no work at present linking the detected levels of concentration to health outcomes. But firstly, leaving office equipment that is not in use on is a known waste of energy that costs nothing to remove and will save UHB money, it will also lessen the trust's environmental impact, and then finally it could potentially reduce the risk of health complications associated with levels of indoor pollutants such as VOCs.

4.4. Trust Builds Sustainability into Its Procurement Network with Points Given in Tender Processes for Use of Low Emission and Low Impact Supply Chains

It is clear that there is a lot of work to be done to improve the procurement processes at UHB. The research suggest that the trust should add emphasis in tender processes to the provision of LCA analysis showing a goods superiority in terms of sustainability and air pollution credentials more specifically. This will often also align with cost savings over the lifecycle of the good. It is measurement and providing a simple metric across all goods procured by the trust that is the significant barrier according to the literature and evidence from interviews. We would also suggest adding weight to the reusability of goods as it seems likely that in the majority of cases this will also provide cost and environmental benefit, providing efficient reprocessing is followed.

The research in [67] identifies this lack of standardised measurement for sustainability criteria in their research into public transport procurement and building national environmental targets into this process. Their use of life cycle assessment (LCA) research data to develop their tool successfully ranked the sustainability of different modes of transport in

testing. LCA is essentially a complete review of a goods impact across its life cycle from creation to disposal, it is given a score of its environmental impact in a common unit, often carbon and this allows comparisons between different goods. It can be applied to anything produced, from buildings to medicines. This could be used to inform UHB's procurement processes about key principles for lower impact and more sustainable procurement. A significant theme of the LCAs with a healthcare focus uncovered in our fast-scoping literature review was the reusability of devices. Applied to Laryngoscopes [68], surgical scrubs [69], and [70] who conducted LCA on the use of Single use or reprocessed medical devices. This research collectively found an advantage in terms of environmental impact and cost that could be isolated through reuse in these cases. It would be worth exploring implementing a general scoring system in UHB's procurement practices that promotes the purchasing of reusable medical devices and equipment at the trust.

The work in [70] examined reuse of medical devices versus disposable ones across seven medical device types. This study included a couple of further learning points. In the case of Deep Vein Thrombosis treatment, compression bands were found to be of extremely high impact, because of their material. This was irrespective of whether they were re-used or not. It should be considered that a full review of medical equipment and devices used in the hospital could uncover a vast quantity of goods with similar results from LCA and that substitute materials could be used to substantially improve performance in this regard. This would obviously come at a significant cost to undertake but review of evidence internationally could inform this. The main point here is that simply focussing on reusability won't provide the same impact as redesigning certain goods to lower their impact. The second finding in this study was that the cleaning and reprocessing of devices needed to be minimised in terms of inputs, this was also found in the case of Laryngoscopes, where the authors also noted overcleaning needed to be avoided. Whilst re-usability could be an easy measure to implement in procurement frameworks for medical equipment, attention should still be paid to the impacts of reprocessing these devices and the environmental and economic costs of doing this. What is clear is that there is little precedent for a whole system change in procurement to align cost-saving and environmental priorities and doing this will be extremely complex, with standardised measurement available through LCA but not necessarily cost effective to implement universally. Easier flags such as reusability can be less costly to implement in a procurement framework but won't necessarily always improve sustainability performance.

4.5. Add Electric Cars to the Lease Scheme for Trust Fleet, Accompanied with the Phasing Out of Cars with Harmful Levels of Emissions; '/' Trust Suppliers and Procurement Fleets Move to Electrical or Hydrogen Fuel to Replace Diesel Lorries and Vans'

There are several different vehicle sizes and drive-train types involved in these actions. EVs and Hydrogen powered fuel cells are two options proposed. Neither technology has yet been scaled up in the same way for heavy goods vehicles (HGVs) and vans as they have been for cars. The report [71] showed that most operators of HGVs had not moved to electrify their fleets and instead had opted for modernised ICEVs with greater efficiency and lower pollution complying with higher European efficiency standards, rather than make the switch to battery or hydrogen powered trains. It's not clear what will be most cost effective and efficient in the long run although it appears that both technology types will be implemented prior to total decarbonisation of transport [72,73]. There are still barriers to the use of zero tailpipe emission vehicles in van logistics as well as lorries, and even in the last mile operators [74]. This research identified key barriers for these groups, which included weight restriction on the load an electric van can carry because of the additional weight of the battery, availability and reliability of charging and then the obvious barrier of cost. It seems that many of these barriers are likely to become less significant with technological increase and as demand increases the infrastructure will also rise to meet it. With respect to what UHB should be doing currently with regard to this, we would suggest a cautious adoption, with gradual increasing capacity, taking the same approach as that suggested above for the installation of EV charging points to meet demand from

patients and staff. The capacity to meet the current needs of the hospital with an electric and hydrogen powered fleet is not there as evidenced by the research and this is implicit in the scores from our survey, but the organisation should be beginning to adopt this and learn how to manage logistics with these new vehicles so that they can grow as the capability of this technology increases as predicted [75].

4.6. Put Up More Signage around the Health Campus for Distances and Routes Connecting the Site to the City by Active Travel

There is a lack of academic literature to provide evidence on the direct impact of signage and promotion of cycle and walking routes, most implementations or promotion also comes with a change to infrastructure [39–41] so it's hard to distinguish the impact of additional signage and promotion from the impact of additional infrastructure. [40] found that those who commute by car often assume that they don't have another option. This is supported by findings in [41] that show that transportation mode choice affects spatial knowledge of an area, which is obvious when you consider that essentially those who always drive learn their personal map of that area from the perspective of planning out journeys in a car. This suggests that the group of people who travel by car, the target group to change their travel mode choice, are those who are least able to plan their commute in a new way [41]. They are likely to view the new mode of transport as more difficult and perceive more barriers to their journey because they aren't aware of the area in which they travel from the perspective of an alternative active mode of transport.

Signage could potentially help raise awareness for those using cars of the existence of safe cycle routes. But the research of [39–41] doesn't clarify if signage changes this perception of options where they do exist for those who don't already use safe cycle or walking routes. In the case of the QE the interviewee who doesn't cycle but said they weren't aware of it as an option had already missed the signs that do exist, although they could potentially be made to stand out more. Additionally, the research presented in [76] offers a theory of two approaches to promoting cycling. 'Barrier elimination' versus 'barrier negotiation', the first is where you promote cycle lane use and safe routes and eliminate the cyclists' concerns or barriers around safety, the second is the idea of developing a more resilient group of active commuters where you try to create a stronger commitment to active travel, which then leads to active traveler's developing their own solutions to routing wherever they want to go, even if a safe cycle route is removed or the weather is poor. The idea being that rather than only expecting active travelers to cycle or walk in the perfect conditions prompting them to then opt not to travel actively if the perfect conditions are disrupted, instead you have a group of traveler's who don't need perfect conditions to get to a place safely and actively. The second option is a harder project to develop, with less tangible success measures but a much more resilient long-term solution.

4.7. Create Pricing Equity for Staff and Patients between Public Transport and Driving

As the Trust's focus shifts to addressing the elective backlog and recovery back to pre-pandemic activity levels, moving staff back onto site, congestion and single occupancy vehicle use on site seems likely to become a more pressing issue, especially if advice is that public transport is safe but people don't believe this and think it's safer to drive. Based on the evidence we have from interviews, the staff travel survey and literature, the trust, should be encouraging commuting by public transport over driving to work, and making the former financially more attractive. Influencing modal shifts in commuter preference and choice is very difficult. The timing of actions is essential whereby at the point where large numbers of staff start returning onto site to work, policies need to be in place to promote sustainable travel, including public transport and this should include pricing policy.

On piece of research [77] support the use of economic incentivisation of public transport. In this paper the present a survey of 4630 commuters in the Washington DC area. The researchers found that subsidised travel to work by public transport and promotion of

cycling and walking was more effective if free parking was not offered at the same time. This would imply that the further subsidy of public transport would increase the number of people using public transport, with the economic incentive tipping further in the direction of public transport.

The systematic review [78] focuses on attributes that attract car users specifically to public transport. The paper links the issues of reliability and frequency as aspects that are influential in retaining commuters on public transport but suggests that one of the key factors in first attracting commuters to use public transport is cost. If a public transport system is considered affordable, then people are more likely to try it even if unreliability or infrequency then puts them off. If UHB were to make public transport more economically attractive rather than parking unattractive, then this would not be as likely to impact on workforce satisfaction and may even complement it in making parking easier for those who continue to still drive. Thus reducing staff dissatisfaction with parking.

This finding supports making public transport more affordable to attract commuters away from cars but also emphasises the need for an improved quality and efficiency to the service provided on public transport. This is further supported by a survey taken of commuters in Brussels. In this study participants are asked how attractive they would find 'free' public transport, whereby a system of contracts to provide public transport is set up with local government covering the cost of provision. The results of this survey echoes that of [78] whereby the economic cost, in this case, there being zero cost to the commuter of public transport would be highly attractive but that this would not make this mode of commuting universally more attractive than driving unless the service was sufficiently frequent and reliable to provide an effective substitute for the convenience of driving. Both cost and capacity [78] are key barriers to any strategy that will promote public transport and so we would strongly recommend that this action be implemented as a part of a wider programme including the actions covered in the first policy area involving pushing the local authority and transport providers to increase the capacity of public transport during commuting hours.

There are precedents already set for mutually beneficial collaboration between public transport providers and NHS organizations. Where transport companies gain brand promotion opportunities. During the COVID-19 pandemic, free transport on buses and trams was offered to NHS staff in the west midlands [79]. In addition, when transport companies apply for tenders to be the provider in an area, local authorities have to pay due attention to the: 'Public Services (Social Value) Act 2012' [80] which states that commissioners of public services need to explore the opportunity to use public funds to enhance economic, social, and environmental wellbeing. These two factors could be effectively leveraged in negotiating discounts for public transport for staff and patients coming to the QE and other trust sites. This could remove some of the cost to the trust of making public transport more attractive by negotiating with the local authority and transport company that they share a proportion of the cost. In the long run, a progressive policy on integrating public transport into how staff can arrive at the trust could possibly become a factor that attracts staff to the trust, as staff see it as a progressive outward looking organisation that considers wider social issues. Organisations that are socially responsible are well placed to recruit staff as these considerations are a growing prioritisation for younger cohorts of staff, this is evidenced in [81] for millennials and the attractiveness of different organisations, and in [82] whose systematic literature review shows that corporate responsibility is a powerful tool for recruitment.

4.8. Cargo Bikes for Hospital Logistics in the Long and Short Run

The lack of understanding of the capability of E-cargo bikes and their range, amongst the people we surveyed, is perhaps a reason that can explain the low score given to this action [83,84]. Despite the precedent set at the John Radcliffe Hospital in the survey question, brought to our attention by the other participant with whom we discussed the subject as the scoping interview. This is a major specialist and acute care provider in

Oxford, and a site with comparable layout to the QE. Some further scoping work could be of great use in informing what proportion of logistics could be transferred onto this method of transport as we weren't able to access information on the distribution of parcel sizes and weights for the trust to see what share could be transported on a cargo bike. Particularly battery powered cargo bicycles (E-cargo bikes) are being more commonly seen as an effective tool for carrying small and medium sized cargo for the first and last miles [85] in delivery of goods [84]. Although this could feasibly be over a significantly longer distance shown in current innovative distribution models [85].

4.9. Embed Sustainable Transport within Patient Correspondence

To personalise patient communication would simply have to include the start point set to 'my location', on the navigation app on google maps, this would then prompt the app to request permission to access location for any smart device or computer and would have a ready-made personalised route via Bike, Walking, or Public Transport depending upon the link used, for anyone who opened the link. This solution is ready made with the advantage that it is basically a 'free' service offered by google. Other options could be pursued if the trust wanted to use different tools such as 'Waze' or alternative paid services but this may impact on both the reliability of the app used, the universal compatibility of google apps, and the fact that this action is only so highly regarded because it is so easy to implement [86]. This action will be most impactful by being personalised as much as possible to make it most effective [37] but equally it must remain as simple to develop as possible otherwise it's unlikely to offer the proportional return that makes it attractive.

Changing what's on the back of appointment letters and moving to embedded travel plans in digital patient correspondence in the first instance are changes that are fast and easy to implement. There is potential to expand on this with systems with further personalisation of this advice. The suitability for instance of a sustainable travel route will depend on the mobility of the patient wanting to come to the hospital. There are already systems developed that are devised to help people in these contexts and ongoing research investigating how to improve them [87–89]. Google Maps already have an accessibility mode on their free application with richer data powering it. Signposting this to patients or building it into the embedded digital communications made to patients could improve the personalisation further and help to enable some of the vulnerable populations mentioned in our initial literature review.

4.10. Develop and/or Adopt Key Performance Indicators on Sustainability and Air Pollution

A surprising setting to find some insight into the use of Sustainability KPIs in UHB's operations is in a study of KPIs impact on sustainability in the work of Port Authorities in Italy. This study [90] assessed through case study the use of KPIs in Italian ports. They developed a set of KPIs assessing energy efficiency and pollution which also fits with both aspects of the performance measures needed at the QE.

UHB should also target sustainability performance with regards to transport, with metrics that could be monitored as KPIs, these are not covered in [90]. Developing these metrics for travel might a focus of a transport coordinator or team. Due to the numerous different aspects requiring measurement, evidenced by the breadth of this study, one real quantity cannot be the proxy for performance across all areas. Potentially an index could be constructed instead. Somewhat like a mortality index, that can be used as an initial indicator of overall performance and could even be used in benchmarking. This is a method used in a research project to develop an index called the Dow Jones Sustainability Index [91]. This index is costly to produce however and won't isolate areas for improvement, so it would require an understanding of all the elements used to calculate the hospital's own sustainability index to then unpick these if you detected an issue. However, some form of index could be a useful tool for overview.

Finally, [92] undertook an excellent review of all research on KPIs looking to identify effective KPIs. Many of these could be implemented at UHB and potentially prove

impactful. It is an excellent illustration of the wider measures needed to target wider sustainability such as social and economic sustainability. We would recommend the trust start by reviewing these measures if trying to isolate effective sustainability KPIs.

4.11. Research Limitations and Considerations

COVID-19 had a major impact upon primary data collection activities, including a delay of nearly 7 months between undertaking interviews and administering the survey, during which time some actions had changed in their context and relevance. All but one of the interviews were held before the first national lockdown in March 2020. As a result, there were actions discussed in interviews that had not seen significant uptake before the first COVID-19 lockdown, including the cancellation of elective treatment for an extended period and all outpatient management being made remote, either by phone or video call. Also, due to the COVID-19 pandemic, all but service essential staff were moved to working from home where possible. Thus, in a very short window, there was unlikely to be any further quantity of working from home or remote care that could be increased to reduce travel further. In cases such as this, the actions for the survey were revised to target the ongoing sustainability, and improved quality, of these measures rather than the original scoped action to increase the uptake of remote working and consultations. Having adapted the actions proposed to the post-COVID-19 context, and by having data collection that spanned from 3 months before the first lockdown in the UK to 9 months into the pandemic, we have a rich set of perspectives on what is possible and how fast change can be implemented. Further research on how these actions might be adapted to the context as the recovery from the pandemic unfolds would further enrich the insight offered in this project.

We recognise that participants were those identified by discussion with key figures at the Trust and by snowball sampling, therefore not all areas of relevant expertise are included (such as specialists in hospital ventilation). However, we do include a broad range of Trust employees including those with practical 'on-the-ground' and operational insights relevant to the CAHF. We also acknowledge that including participants from only within the Trust or University, as opposed to a broader range of employers (e.g., contractors, local authority) may limit the range of perspectives; however, this approach was justifiable due to the need to focus on specific contextually relevant actions. We also did not have sufficient resources to undertake similar studies at other UHB sites which could provide insights into the importance of context when identifying and appraising CAHF actions. Extending this research methodology to a range of settings including District General Hospitals and Community Trusts would be valuable future research, particularly in context of the more recently developed framework for air quality actions within Integrated Care Services, launched by Global Action Plan in June 2022. (https://www.actionforcleanair.org.uk/health/ics--framework, accessed on 20 June 2022).

The identification of actions that were not independent placed an unanticipated limitation on the findings. The best example of such a set of actions is a group that target the diffusion of responsibility for sustainability and pollution reduction throughout the operational management structure in the trust. The culmination of this chain of actions was to assign specialties financial responsibility for their energy usage, but this requires a number of additional actions starting with a basis in training operational managers about sustainability and energy management, then designing and monitoring KPIs to gain assurance on the performance of specialties against sustainability criteria, finally building up to this establishment of devolved responsibility with staff enabled to take informed well informed decisions about how to improve performance. There were five distinct actions in total that layered up to reach the final action but it was an oversight in the survey design not to build this into the logical flow of the survey. The result was that participants scored the actions as more and more un-achievable as the actions progressed along each chain so the final action was always scored very high for impact but so poorly for achievability that it was unlikely to be recommended because of this. The solution, having

gathered the survey data and then found this pattern, was to weigh this up in considering the evidence from interviews in support of the actions caught up in these strings. In future work we will build these dependencies into the logical flow of the survey by asking conditional questions.

Several actions had positive externalities for the broader sustainability agenda. This was a common occurrence from the outset of this research. It was clear that in many interviews participants considered air quality under the umbrella of sustainability rather than a separate issue. Actions in the CAHF also blur the lines between reducing emissions of carbon dioxide, a key indicator used in mitigating the effects of climate change, and more specific pollutants associated with air quality and directly affecting human health. This was most prominent in the sections less specific to operations that were focusing on leadership, training and outreach. The subjects are undeniably and inextricably linked in that so many of the contributing factors and solutions are the same, for instance prioritisation of travel modes directing people to reduce travel by single occupancy vehicles in favour of active travel or public transport, as these have a smaller carbon footprints. Hence why published tools for targeting air quality can't help but also touch on issues of environmental sustainability as well. With this relationship common to the other elements of our research, and the broader collective understanding of the issues, we chose to also include papers form our fast-scoping reviews that focused on the broader topic of environmental sustainability, especially where literature wasn't available to evidence specific impacts on air quality. It seems worth exploring whether this damages the project of improving air quality, with the wider societal perception of green activism and environmentalism.

In the interviews one of the key barriers to change that made many potentially impactful actions to do with estates at the QEHB site appear unachievable was the fact that changes to estates and energy generation at the QEHB was something over which UHB as an organisation did not have direct control. As a result of the Private Finance Initiative (PFI) contract that helped to finance construction of new QEHB building, any management of the trust estate on the new QEHB site, such as new programmes to target more efficient energy usage would face a layer of complexity by requiring renegotiation of the PFI contract. Several interviewees, members of senior leadership at the trust, suggested that changes to the PFI contract can also prove extremely costly as well as taking a lot of time to resolve. Findings from interviews with members of staff responsible for estates management clearly indicate that actions that do not require renegotiating the PFI contract are far more likely to be implemented and achieve their full potential. Any actions that would require changes to the PFI contract have therefore been left out of the recommendations from this work. These actions include those around installation of a ground/air source heat pump, installation of solar energy generation on site, and replacement of boilers to low NOx options. As the Trust continues to review its building stock it would be advisable to consider energy efficiency and air pollution when making decisions on future capital investments. Without the significant barriers of PFI and cost, then these actions would have offered excellent impacts and improved the trusts performance both in terms of air quality impact as well as broader sustainability measures. Based on interviewee's insight this is being done on the new private hospital at the QEHB site, and the new ACAD building at Heartlands. The full list of actions for all policy areas, including those concerned with estates and energy, are presented in Appendix B.

The decision was made not to use a triangulation method for combining the survey and interview data together in the final analysis and to keep the initial analyses separate to serve different purposes and evidence different topics for each of the actions. Triangulation was not deemed useful as taking the qualitative data from the survey and giving counts of different words as outlined in [92] to combine the two sources of information would really defeat the purpose of the interviews. Which was to access the rich insights of these conversations. A numerical output of this would lose the richness of these solutions and problems that had been identified and would not have provided any additional insight. As the same questions were not asked in each interview then comparison of counts of

instances of support for each action would not be a fair comparison. If this project was undertaken again, it would likely throw up different results as it is vulnerable in particular to the opinions and limitless variation that comes with consulting a panel of subject area experts especially when the panel are experts on multiple different fields that they don't share in common. This however is the source of the richness of the project and the value it adds. Whilst another panel would undoubtedly offer different prioritisations, it seems likely that these prioritistations would be similar and one of the purposes of including the fast-scoping reviews is to try to provide evidence to firm up these conclusions and control for the potential biases in interview and survey responses of our participants.

Finally, a short note on how the perception of actions in the shortlist evolved over the time of data collection and how this evolution should be seen as a window of opportunity that is unlikely to remain open indefinitely. The first year of COVID-19 forced many unforeseeable transformations in behaviour across society in an incredibly short timeframe. Many actions, previously expected to take 5 to 10 years to be embedded, like the expected time for adoption of remote working and patient management, were operationalised overnight. Failing to ensure these behavioural changes are made sustainable at optimal levels could be one of the most significant missed opportunities in modernising healthcare in living memory. Air pollution is not the only reason for doing this, but it and the wider issue of providing environmentally sustainable healthcare are both areas where it could have an enormous impact. How the post-COVID-19 recovery in healthcare is undertaken could come to determine whether the NHS across its devolved forms is able to achieve its sustainability goals for the first half of this century.

Inclusion of air quality data in the appraisal phase was beyond the scope of this current study. However, integrating quantitative estimates for emissions changes associated with the shortlisted actions over respective timeframes would be valuable future research.

5. Conclusions

This in-depth case study provides an example for a methodological process followed to answer the question of what actions a specific organisation, University Hospitals Birmingham, should prioritise to address its impact on local air quality and to protect its patients, staff, and local community from the dangers of air pollution. The focus for site specific actions is on the trust's largest hospital site the Queen Elizabeth Hospital Birmingham (QEHB). This prioritisation exercise is undertaken within the specific context in which the hospital and trust operates, adopting a mixed-methods approach. In an extremely complex operational setting, a list of distinct potential actions was composed and then appraised using evidence from a range of different sources to offer a shortlist of the actions deemed to be most likely to have the most impact and be most achievable. There is potential that other NHS healthcare providers could (i) adopt an adapted version of this prioritisation framework to operationalise the CAHF, or (ii) adopt the prioritised, shortlisted actions evaluated, if operating in similar contexts to the QEHB. This research also has wider relevance to other large organisations which are seeking a practical approach to making evidence-based decisions to improve environmental sustainability in their own contexts.

Appendix A. Participant Information Sheet, Consent Form and Interview Sample Questions

Participant Information Sheet:

Please read or listen to the following information explaining the study and your involvement.

Study Title: How effective is the Clean Air Hospitals Framework for the Evaluation of Hospital Operational Impacts upon Air Quality?—A case study of Application and Implementation at the Queen Elizabeth Hospital, Birmingham

Principal Investigator: Dr Suzanne Bartington

Researcher: Mr Owain Simpson

Invitation:

You are being invited to take part in this research study investigating the impacts of Queen Elizabeth Hospital upon local air quality and informing recommendations to University Hospitals Birmingham (UHB) NHS Foundation Trust on reducing pollutant emissions. This research project is a subsidiary study within the West Midlands Air Quality Improvement Programme (WM-Air)—A five-year project funded by the Natural Environment Research Council (NERC), applying environmental science research expertise to improve air quality in the West Midlands and deliver health, economic and environmental benefits [ethical approval ERN_18-1998].

Before you decide to take part, it is important that you understand why the research is being done and what it will involve. Please read or listen to the following information and ask us any questions if you need more information. If you decide to take part in this study, you will be given a copy of this information sheet and will be asked to sign a consent form. Thank you for reading or listening to this information.

What is the purpose of the study?

The project will use a framework developed for hospitals to assess their operational impacts upon air quality called the Clean Air Hospitals Framework (CAHF), applied to the Queen Elizabeth Hospital (QEH), Birmingham. We will use the outputs from the framework to supply an executive level report on key strategic changes which could be implemented to reduce existing operational impacts upon air quality. The second aim of the project is to evaluate the process of tool implementation to understand strengths and limitations in this context.

Why have I been chosen?

You have been chosen because you are a key member of staff at UHB NHS Foundation Trust with expertise in a specific area relating to the air quality impacts of the QEH site.

Do I have to take part?

Your participation in this study is completely voluntary and it is up to you to decide whether or not you take part. You are free to withdraw from the study for up to 1 month from the interview taking place. If you decide to withdraw within this time period please notify the research team. Contact details for the research team can be found at the bottom of this information sheet. Your withdrawal from the study will mean that all records of your data will be destroyed.

What will participation in this study involve?

If you agree to participate in this study, you will be asked to take part in an interview lasting approximately 1 h. The interview will be a discussion covering the following topic points; (i) existing activities at the QEH site which impact upon air quality; (ii) potential changes that could be made to mitigate pollutant emissions; (iii) feasibility and achievability of these actions; (iv) exploration of predicted changes (impacts) including co- and dis-benefits.

After the interview we will send you a survey including a brief summary of the actions discussed in the interview that could be taken forward to improve the QEH site operational impact on local air quality. We will ask you to rank these actions in terms of both achievability and effectiveness. Along with the survey we will attach a copy of the transcript from your interview so that you can cross-reference this when checking you agree with the actions included in the survey.

If you do not agree with our summary actions or you wish to alter a comment or anything else you said in the interview we can review after you have received the transcript and our summary survey, this way we can reach a consensus on the possible actions and you can then rank them as described before.

There are no other commitments involved in study participation and you can decline to take part at any point of the process.

What will happen to the interview data?

The air quality data will be initially an audio recording. We will then create transcripts of the discussion and store these transcripts along with the original audio files in a secure location on the study computers at the University of Birmingham and UHB NHS Foundation Trust. We will undertake thematic analysis of information obtained from the transcripts, creating summary actions, for you to rank and to take forward as advice for future hospital strategy. When our study is complete, our findings will be shared with the UHB NHS Foundation Trust Board, project partners in the WM-Air Project, stakeholders across the Birmingham and Solihull Sustainability and Transformation Partnership (STP) and the wider public in summary form. We can also provide you with a summary report.

What will happen to my answers?

The researcher will transcribe the audio recorded discussion. Later, the data collected will be entered to our study computers at the University of Birmingham, and UHB NHS Foundation Trust. The responses will be compared and synthesised with other participant answers to identify common themes. When our study is complete, our findings will be shared with the UHB NHS Foundation Trust Board, project partners in the WM-Air Project, stakeholders across the Birmingham and Solihull Sustainability and Transformation Partnership (STP) and the wider public in summary form. We can also provide you with a summary report.

Will everything be confidential?

Any information collected in this study will be strictly confidential. All hard copies of consent forms and questionnaires will be stored in a locked cabinet in our study offices. All electronic records will be stored securely using a password protected file on a password protected computer in accordance with Data Protection policies and guidance. Your identity will be kept anonymous in any publication of this research and only researchers on this project will have access to your details for the purposes of organizing interviews, follow up communications, and sharing our results and publications with you if you express an interest in reading these. The data concerning your identity will be stored with the same level of security as for the transcribed responses you give in accordance with Data Protection policies and guidance outlined above. In documents made public your identity will be protected with the alias Participant X where X is a number that has no meaning or relevance to your participation.

What are the possible risks and benefits of taking part?

There are minimal foreseeable or expected risks of being involved in this non-invasive study. Risk of physical or psychological harm is no greater than normal day-to-day living. It is expected that the information gained from this study will benefit the scientific research community, the healthcare industry and the wider public by helping to fill the evidence gap regarding how hospitals are able to assess their impact on local air quality and make informed decisions on where to concentrate their efforts. It will offer valuable feedback on the use of framework evaluation tools for this purpose.

Further questions?

If you have any questions or require any further information please ask. If you would like to speak to a member of the research team please contact the study Principal Investigator:

Dr Suzanne Bartington

Address: Institute of Applied Health Research, University of Birmingham, Edgbaston, Birmingham, B15 2TT

Email: s.bartington@bham.ac.uk; **Telephone:** 0121-414-7742

If you would like to participate in this study, please fill out the consent form provided. We appreciate your participation in our study.

Consent Form:

Study Title: How effective is the Clean Air Hospitals Framework for the Evaluation of Hospital Operational Impacts upon Air Quality?—A case study of Application and Implementation at the Queen Elizabeth Hospital, Birmingham.

Principal Investigator: Dr Suzanne Bartington

Name of Researcher: **Owain Simpson**

Participant Identification Number: _____

Participant Date of Birth: _____

Please initial each box

1. I confirm that I have read the **Participant information sheet** version____dated_____for the above research. I have had the chance to consider the research information, when necessary, ask questions and have had these questions **answered satisfactorily** by a member of the research team.

2. I understand that my participation is purely **voluntary** and that I am free to **withdraw within 1 month of the interview date** without giving any reason, without my **legal rights** being affected.

3. I understand that the information collected during interview will be used to support other research in the future, and may be shared **anonymously** with other researchers.

4. I agree to take part in the above research study.

5. I agree to researchers on this study contacting me and asking me to take part in a follow-up survey assessing recommendations based on my original interview.

Your signature below indicates that you have agreed to volunteer as a participant in this research study, and that you have read and understood the information provided above and in the Participant Information Sheet. You will be given a signed and dated copy of this form to keep, along with any other printed materials deemed necessary by the study investigators. _____

Name of Participant (print) Date Signature

Name of Researcher Date Signature

Sample Questions:

Travel:

Question: "What do you think the hospital could be doing more of to increase sustainable travel that it isn't doing already?"

Prompts: "How much uptake do the schemes the hospital runs have, how could we improve this?"

"Could we access patient and visitor transport information in the future/how?"

"Do Q park have data that the trust could access on the movement of patients visitors and staff?"

"What information is there available from the project to expand the University train station on the number of people arriving there to visit the hospital?"

Question: "What openings are there for technological innovation to improve the hospitals impact on air quality?"

Prompts: "Could the hospital undertake collaboration with the Ambulance trusts and Community Health trusts on optimisation of routing and transport. "

"What is a feasible long term target for reduction of outpatient appointments and how is this going to be achieved?"

Estates:

Question: "What are some feasible steps considering where we are at right now that we could take to reduce the operational impact of our estates and capital's impact on air quality?"

Prompts: "Could we install more efficient and lower impact CHPs and Boilers?"

"Is there potential for increasing energy generation on site from renewables e.g heat pumps, solar energy, wind . . . ?"

"Would it be possible to control air flow and air mix within the hospital, controlling levels of internal ventilation and external depending on pollution levels?"

Design and Construction:

Question: "In the future what more could be done with projects to lower their impact on air quality?"

Prompts: "Could we coordinate delivery vehicles to also remove waste reducing journeys to and from the site?"

"Could we substitute more efficient machinery and equipment into the construction projects, is there scope for using hybrid excavators for instance?"

"Could the trust start to monitor indoor and outdoor air quality?"

"Would it be possible to control air flow and air mix within the hospital, controlling levels of internal ventilation and external depending on pollution levels?"

Procurement:

Question: What steps do you think procurement could make to lower the AQ impact of the QE's supply chain?

Prompts: "Could we put more emphasis on air quality during tender processes?"

"Would it be realistic to work on educating our suppliers on impact and working with them to lower theirs?"

"What further efforts could we make to reduce wastage and make our supply chain and ordering system more efficient?"

Local Air Quality:

Question: "What more could the trust do to try and improve patients' awareness of Air Quality and help to minimise the impact it has on our patients?"

Prompts: "Could we do more to improve our sharing of information?"

"Could we roll out social prescribing by doctors at the trust?"

"Do we work closely enough with primary care on the subject of Air Quality?"

Strategy:
Question: "What more could we do with the council to coordinate on more integrated sustainable travel?"

"What work can be done with the board to increase their commitment, could we introduce monitoring reports against targets as part of a clean air action plan?"

"How can we balance the arguments for allowing smoking that strikes a balance between safety, minimising patient's and vulnerable people's distress whilst also trying to minimise its occurrence on site?"

"Could the board and HR agree to fund positions responsible for air quality and environmental responsibility at the trust?"

"How could the trust do more for next year's clean air day?"

Prompts: "Could the Trust join other organisations including significant NHSFTs in other large cities in declaring a climate emergency and acting on this?"

Appendix B. Complete List of Actions Feature in Survey and Sorted into Policy Areas of Analysis

The actions in bold and underlined are the actions that we recommend the trust undertakes and a summary matrix to support these recommendations can be seen in the summary Section 3.

Strategy and Policy on Travel
Introduce and enforce a strict no idling policy on site.
Step up engagement with the combined authority, UoB, BW&Cs to establish more safe cycle routes, particularly from Harborne and Quinton to the QE Hospital site, and also peripheral routes linking to the established major cycle routes.
Embedding sustainable transport within Patient Correspondence
Step up working with UoB, W&Cs, and combined authority on Bus and transport links to Hospital
Develop an emergency transport strategy for returning to work, using evidence based optimum levels of working from home and targeting increased proportion of staff using sustainable transport (incl. buses and trains)
Increase the rate of penalties for illegal parking on-site, specifically targeting delivery vehicles not using correct drop off locations and causing congestion.
Patient travel data collection through outpatient check-in system.
Resource and Recruit a Transport Coordinator for the trust.
Understand how much of our appointments and clinics are now run remotely and concentrate on improving that experience, ready with a plan for post-lockdown when patients wish to start returning to hospital.
With University of Birmingham, and other stakeholders in the University Station upgrade, construct business case for electrification of the cross city line.

Incentivising Lower Impact Travel
Offer staff who cycle to work a free breakfast.
Put up more signage around the health campus for distances and routes connecting the site to the city by active travel.
Taxis booked by the hospital are zero tailpipe emission vehicles.
Work with Engie to increase security on bike storage areas.
Negotiate for adaptive bikes to be made available on the cycle to work scheme.
Invest in secure cycle storage and more changing facilities across the QEUHB site.
Create pricing equity for staff and patients between public transport and driving.
Encourage the use of e-bikes to the site and publicise that staff are welcome to recharge batteries here.
Engage Canal and Rivers Trust on improving disabled access to the canal as part of University station project.
Implement a park and ride service from Longbridge.
Install EV charging in convenient places in car parking across trust site.

Procurement
Use more social prescribing for preventative healthcare at the staff well clinic.
Use cargo bikes for blood collection, transporting chemotherapy drugs and other logistics, this is already done at the John Radcliffe Hospital in Oxford.
Trust builds sustainability into into its procurement network with points given in tender processes for use of low emission and low impact supply chains.
Trust suppliers and procurement fleet do not leave vehicles idling on site.
Trust suppliers and procurement fleet move to electrical or hydrogen fuel to replace diesel lorries and vans.
Trust suppliers and procurement fleet invest in cycle courier logistics to replace transport of supplies.
Prescribe dry rather than wet inhalers for patients for whom it can be just as effective.
Build business case with STP and its members specifically west midlands ambulance service to invest in digital transformation of system wide fleet coordination to join up logistics and commissioned patient carriage. For example patient pick-up vehicles leaving hospital site carry medications to pharmacies.
Add electric cars to the lease scheme for trust fleet, accompanied with the phasing out of cars with harmful levels of emissions.

Construction & Design
Work with construction firm on new hospital site to monitor air quality impact.
Assess air quality in wards in the new QE for patients that are already vulnerable, e.g., respiratory and cardiology.
Work with construction firm on new hospital to choose more sustainable building materials with less air quality impact, low VOCs etc.
Target the use of new technologies in the new hospital building for improved air quality control. e.g., AQ monitoring and live AQ control on air conditioning.
No idling policy for construction vehicles is established and enforced on site for the new hospital project, for both move-able and non-movable machinery.

Energy
Implement 'power down' periods of IT equipment trust wide to lower energy usage, automatic shutdown on all non-essential machines etc.
Increase the amount of energy generated through solar panels on site.
Work with Engie and PFI provider to build business case for ground/air source heat pump installation on site.
Invest in low NOx boilers in the heritage building and other trust owned buildings on site.
Leverage investment incentives for installation of photovoltaic cells on the roof of the New Queen Elizabeth Hospital
Strongly promote behaviour change in staff to start think about energy efficiency, e.g., wear jumper don't just turn on the radiator, turn down radiators don't open a window, turn off lights, turn off computers.

Direct Targeting of Local Air Quality
Develop our own dashboard of air quality measurement taken at the hospital for patients and staff to access live.
Install further and fixed AQ monitors around the site to build a better picture of AQ around the health campus.
Publicise local air quality information Tools to patients and staff.
Engage UoB and BW&Cs to take a combined approach to smoking across the health campus.
Facilitate Walking Meetings and meetings in outdoor spaces.
Implement a smoke-free hospital site.
Implement stronger and stricter rules on staff smoking on site to at least stop staff being seen smoking in uniform out with smoking shelters.
Improve rates of prescription of smoking patches for inpatients.
Invest in staff smoking cessation programme through staff well clinic.
Install hypoallergenic plants where it is safe and sensible to do so in the hospital. To improve air quality and environment in wards and other spaces.
Install protective screens and living walls in places where people are exposed to transport related air pollution on site (Atrium area, ED area, University station)
Trial stricter smoking enforcement in order to form an evidence base on direct and indirect consequences, gather more evidence for trust policy so that we know our policy is sound and valid.

Communication and Training
Organise a hard hitting seminar and awareness raising presentation for the trust's board of directors on the seriousness of local air quality impacts on public health, and how localised change really makes a difference.
Add messaging around behaviour change to pay slips promoting active travel and sustainability
Collate Patient experiences of suffering as a result of air pollution. Publicise these accounts to raise awareness and promote behaviour change.
Create a sustainability in healthcare management module with the education department to disseminate knowledge and raise awareness.
Create medical training materials to feature on the grand rounds or generic teaching groups advising on current best practice around air quality
Develop staff guidelines for engaging with patients on issues of air quality and active travel.
Use posters and e-posters on electronic check-in to convey information on Health Impact of Air Pollution and how to protect yourself.
Adjust Trust policy on employees using social media in a professional context. Work to enable any staff wishing to use social media to raise awareness of health issues to do so, rather than attempting to present a single communication point.
Resource and Recruit an engagement lead who can engage in conversation with the public on a number of subjects, one area of which would be sustainability and air quality.

Outreach and Leadership
Add Sustainability criteria into operational management responsibilities across the divisional structure
Build Energy costs into department budgeting alongside training in energy resource management.
Create voluntary health and wellbeing ambassadors for promoting behaviour change in staff and patients.
Develop and/or adopt key performance indicators on Sustainability and air pollution.
Work with Engie on their corporate sustainability strategy and try to drive change in their operations on our site.
Engage with external organisations for Clean Air Day, use our platform to raise awareness, but keep funding for other projects instead.
Proactively Engage with local schools to raise awareness and develop change leaders who care about air quality impacts on health and actions we can take to improve.
Commit to resourcing activities for a Clean Air Day event and really make a big deal out of it.
Resource and Recruit staff with 'enabling change on sustainability' as an explicit part of their job description.
Seek out and commit to research collaboration with external and national organisations on air quality and sustainability in healthcare.
Work with Respiratory to develop a clear message to patients on the impact air pollution has on their health and then implement this across trust activities.

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