Who said air couldn't hurt you?

Charles E Ruck

Royal College of Art

This paper wouldn't be possible without the help of RCA faculty and IMPERIAL lecturers alongside local businesses

Station improvements are being carried out in this station and across the TfL network for Air Quality monitoring. Station intimately closed from 28 June until Spring 2027. Check before you travel: look for publicity at stations, visit tfl.gov.uk/check or call 020 7222 1234

magnetic field
Caution Pacemaker Users

Danger
AQ Face Mask

Contents

1.1 Colours

These colours should be used across the TfL estate to produce safety and supplementary notices.

The Pantone Matching System (PMS) is to be used for print purposes.

Corporate Blue
- Non-safety related TfL messages

Corporate red
- Prohibition notices
- Alarm notices

Safety yellow
- Warning notices

Safety Blue
- Mandatory notices

Safety Green
- Emergency escape notices
- First aid notices

Corporate Blue
Pantone 072

Corporate Red
Pantone 485

Black
Black 100%

Safety Yellow
Pantone 116

Safety Green
Pantone 356

Safety Blue
Pantone 300

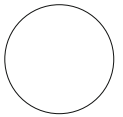
Safety Blue
PMS 300
C100 M62 Y7 K0
R0 G92 B185
NCS S 3065-R90B

Corporate Red
PMS 485
C6 M98 Y100 K1
R225 G37 B27
NCS S 1085-Y80R

Corporate Yellow
PMS 116
C0 M18 Y100 K0
R255 G205 B0
NCS S 0580-Y10R

Corporate Green
PMS 356
C96 M27 Y100 K15
R0 G121 B52
NCS S 3065-G10Y

Corporate Black
PMS Black
C0 M0 Y0 K100
R0 G0 B0
NCS S 9000-N



Corporate White
PMS N/A
CMYK N/A
R255 G255 B255
NCS S 0500-N

1.2 Pictogram

There are four types of safety related pictograms used on TfL safety signs. The type of pictogram used is determined by the message being conveyed by the sign.

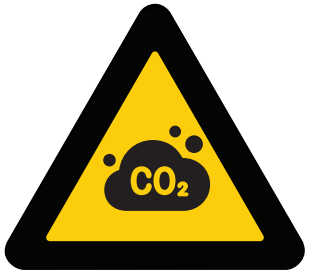
Mechanical
A notice giving information on complex machinery that could cause harm (strong magnetic field)

Warning notices
A notice giving warning of a hazard or danger (eg danger of electrocution).

Mandatory notices
A notice prescribing specific behaviour (eg face coverings must be worn).

Emergency escape/AQ shelter
A notice giving information on emergency exits, AQ shelter or rescue facilities (emergency exit /escape route/clean air)

Mechanical



Warning

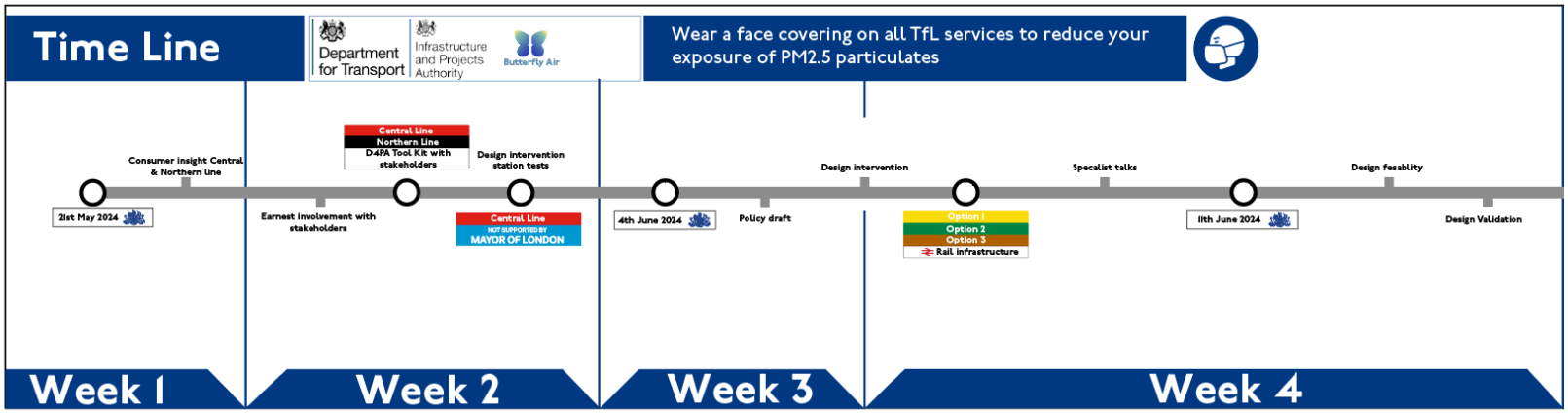
Mandatory

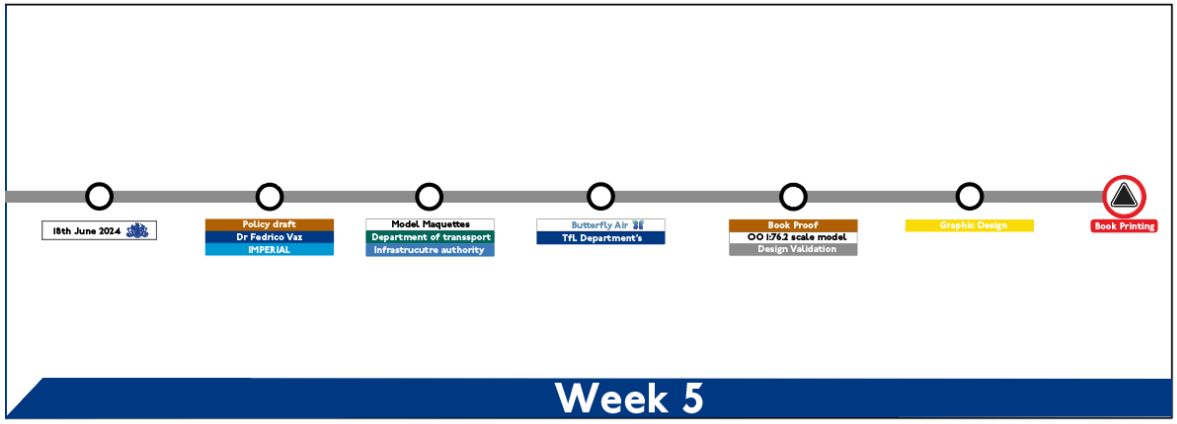
Emergency escape / AQ shelter

1.3 IRP Timeline

IRP Timeline outlook

Day to day / week to week outlook of work to be completed throughout the IRP. Where work will be completed and what work will be completed when.





Stakeholder Typology Mapping according to their Power, Legitimacy, and Urgency attributes

Latent Stakeholders

1. Dormant stakeholder; only power
2. Discretionary stakeholder; only legitimacy
3. Demanding stakeholder; only urgency

Expectant stakeholder

4. Dominant stakeholder; power and legitimacy
5. Dangerous stakeholder; power and urgency
6. Dependent stakeholder; legitimacy and urgency

Highly salient stakeholder

7. Definitive stakeholder; all attributes

Non-stakeholder

8. Non-stakeholder; none of the attributes

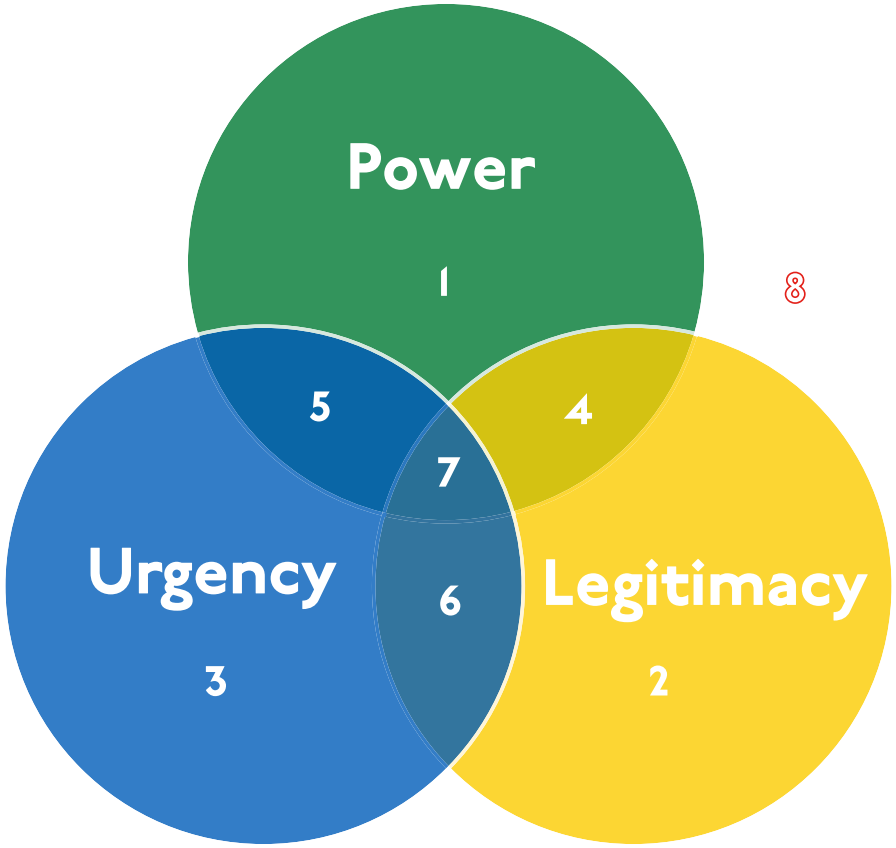


Figure 1:Qualitative Classes of Stakeholders, adapted from Mitchell, Agle & Wood (1997)

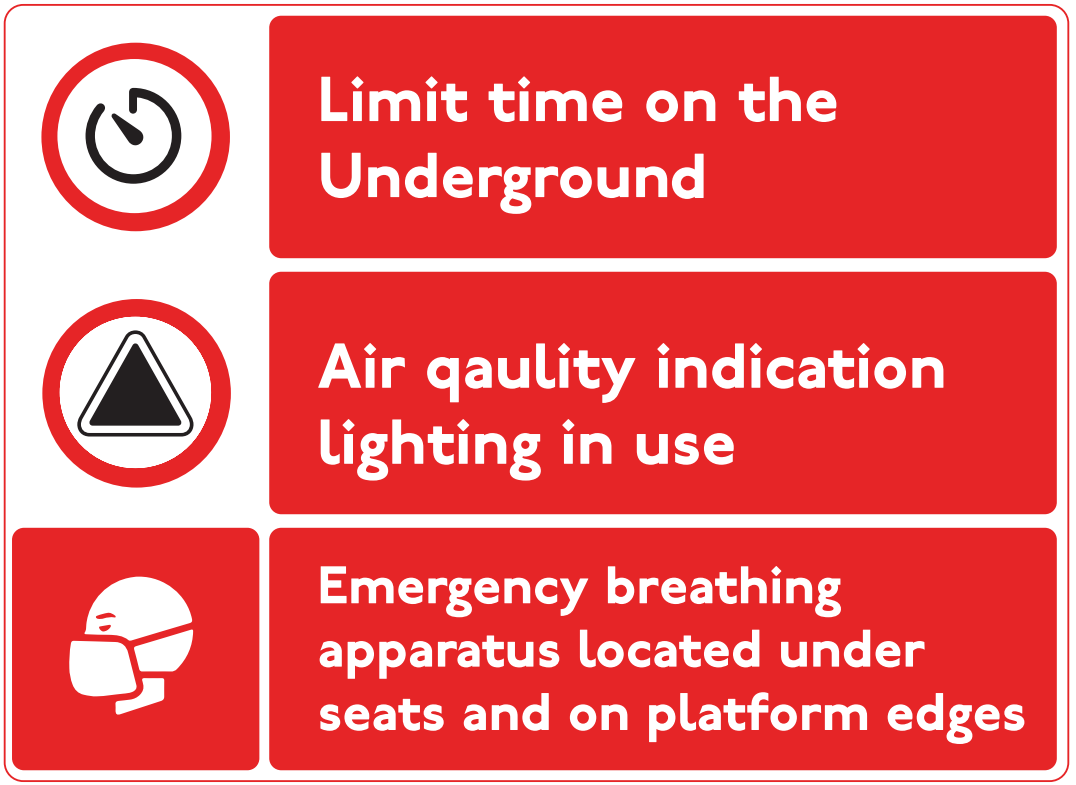
Foreword

AQi (Air Quality Index) within London since Boris Johnson and his introduction of ULEZ in 2015 and his Boris bike scheme (TfL's flagship cycle hire scheme Santander Cycles) has fallen. Howbeit the introduction of carbon policy's on the surficial world of London has neglected the subterranean levels of the capital which are pivotal for the functioning of the city.

This white paper stems to ask questions to local authorities and governances, to ascertain why design underground has been neglected. The people of London are consumers and stakeholders of this white paper. This anaglypta asked questions to local government and the office for the London Mayor.

TfL spends on average £2Million on cleaning efforts to mitigate and reduce the impact of 25µm particulates. Moreover, this is mitigated by the corporation's efforts to reduce localized pollution. This pollution is flushed from tunnels to concealed air passes, flushing contaminated 25µm particulates to local neighbourhoods.

Monetary surplus from TfL offer profusion of capital to introduce sufficient infrastructure within the TfL network to reduce 25µm particulates and airborne contamination, which will intern reduce the number of premature deaths from the streets of



Executive summary

The primary objective of this White Paper is to discern neglect from TfL corporation on failings to reduce 25µm particulates from their services within accordance to the Mayor's Office for reduction in pollutants.

City Hall have been championing their efforts at reducing London's air quality, in particular, Nitrogen dioxide (NO^2) levels. Specifically looking at roadside level sources and above ground locations, yet they have neglected Underground commuter pockets. Regions within London are below WHO (World Health organization) guidelines for concentrations of particulate matter, a sign that ULEZ has had an impact on road side environmental factors (London City Hall) [1]. Yet TfL's own internal reports reveal the real impact of daily operations on commuters and staff.

UCL findings show that 20 minutes within the LU (London Underground) has the same effects as smoking a cigarette. TfLs new stockage of S-7 and S-8 trains mitigate the implications of PM.2.5 (particulate matter) within tunnel sections of LU.

This White paper follows on from the first draft submitted for Unit3 RCA Design Products, moreover explores design principles and implications through stakeholders and governmental agencies.

1.Changing commuters and consumers mentality of using these systems may intern cause pernicious injury over extensive periods

2.Impactful design which offers simple and easy to use applications under monetary constraints, time applications and safety measures.

Transport for London and the Houses of Parliment

Royal College of Art

AQi Charge Notice

London Air Quality and Trafic Managment Act 2024
s.78 Civil Enforcement of Parking Contraventions (England) General Regulations 2007. Civil Enforcement of Parking Contraventions (England) Repersentations and Appeals Regulations 2007

Date of Service of Notice:

Penalty Charge Notice:

Vehicle registration mark:

Was seen in:
TFL TUBE STATION CAR PARK

From

On:

In Cerxumstance giving me reasonable clause to belive that the vehicel was PARKED WHERE PROHIBITTED (ON A RED ROUTE OR CLEARWAY AND UNAWARE OF POOR AIR QAULITY)

Officer:

Signature:

The AQi Charge Notice Conditions Below

A PENALTY CHARGE OF £130 IS PAYABLE AND MUST BE PAID BEFORE THE END OF THE PERIOD OF 28 DAYS BEGINNING WITH THE DATE ON WHICH THE AQi CHARGE NOTICE IS SERVED

If the penalty charge is paid before the end of the period of 14 days beginning with the date on which AQi Charge Notice is served, the amount of the charge will be reduced by 50%. to £65.

Air Quality within this area is dangerous

Transport for London and the Houses of Parliment

Royal College of Art

AQi Charge Notice

London Air Quality and Trafic Managment Act 2024
s.78 Civil Enforcement of Parking Contraventions (England) General Regulations 2007. Civil Enforcement of Parking Contraventions (England) Repersentations and Appeals Regulations 2007

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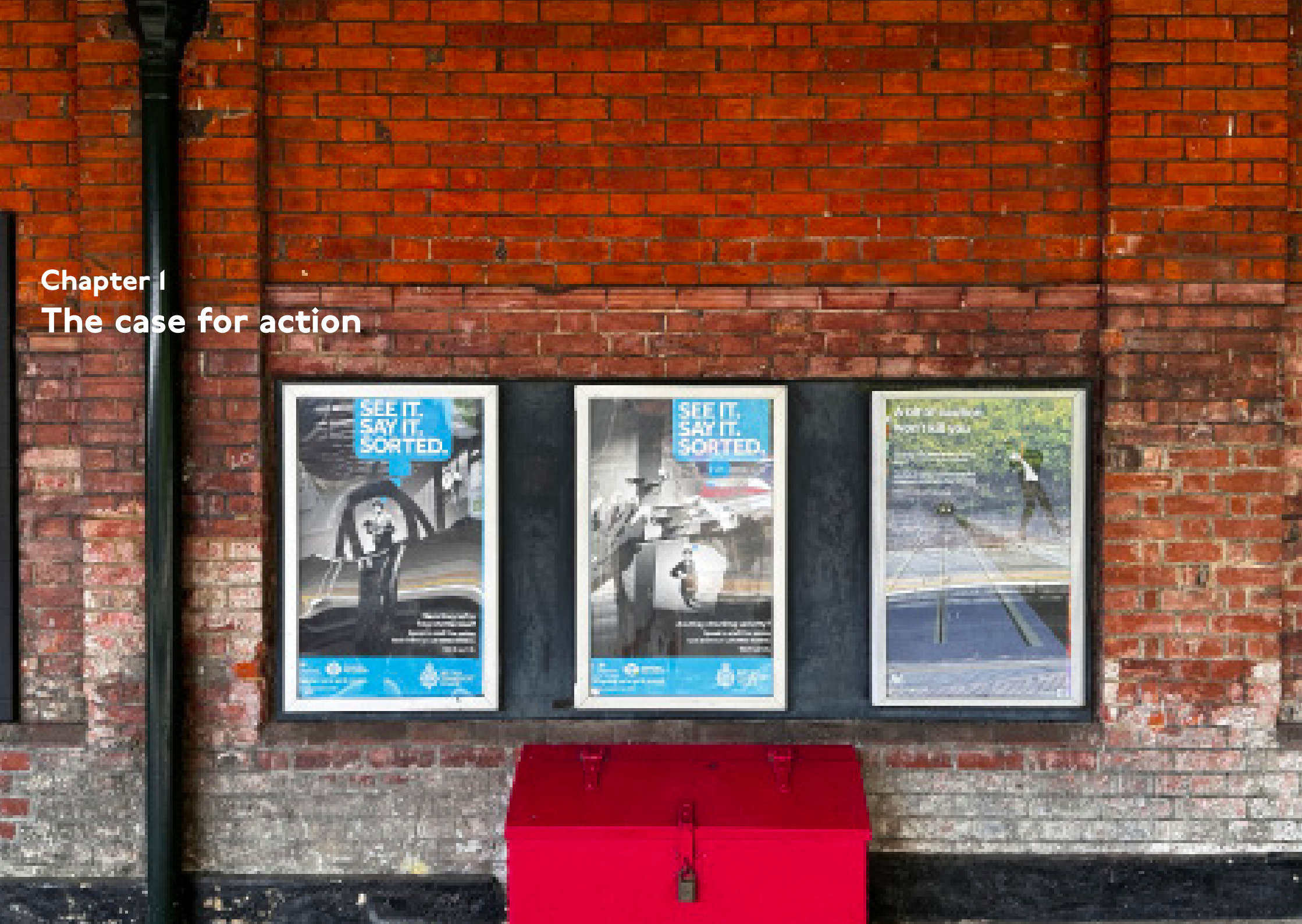


Chapter 1

The case for action

9000 people die prematurely each year from poor AQ within London. The Office for the London Mayor has been vocal at reducing AQ in particular. PM2.5 and NO^2 levels within the city have been focusing on road side ambient emissions from cars, yet neglecting the city's biggest contributor to 25µm particulates, the worlds oldest and famous UNDERGROUND. Which is seen to be a clean and sustainable piece of infrastructure. This though isn't the case.

TfL's focus on air quality stems to ULEZ and congestion charges, which in turn are designed to penalise commuters whose vehicles don't meet regulations due to the output emissions of the car. The Scheme was introduced by Boris Johnson in 2015 and extended this year (2023/2024) to the outer boroughs of London.

Key Initiatives

1.Ultra Low Emission Zone (ULEZ): The ULEZ, expanded in 2023, it is central to reducing vehicle emissions, covers all London Boroughs and imposes strict emissions standards. This significantly curbs the number of high-emission vehicles on the roads. Compliance rates for vehicles entering the zone have steadily increased, demonstrating the scheme's effectiveness (Transport for London) [2] .

2.Green Public Transport: TfL have upgraded their bus fleet to include only low or zero-emission vehicles. This includes: electric; hydrogen; and hybrid buses that meet Euro VI standards. Additionally, all new licensed taxis must be zero-emission capable, with over 6,400 already operating (Transport for London) [2] (Transport for London) [3] .

3.Electric Vehicle (EV) Infrastructure: London has become a leader in EV infrastructure, with over 11,000 charging points available, including rapid charging hubs in key locations. This supports the transition to cleaner vehicles and encourages a wider adoption of electric transport (Transport for London) [3] (Transport for London) [4] .

4.Healthy Streets and School Streets: TfL have implemented the Healthy Streets approach, which includes creating pedestrian-friendly zones, enhancing cycling infrastructure and promoting walking. Over 600 School Streets have been established to restrict vehicle access during school hours, improving safety and air quality around schools (Transport for London) [3] (Transport for London) [4].

5.Tackling Tube Dust: Efforts are ongoing to improve air quality within the London Underground. Measures include regular cleaning and maintenance to reduce particulate matter levels, ensuring a safer environment for passengers and staff (Transport for London) [4].

Key infomation and figures

1 Particulate matter
64-71% Iron Oxide PM2.5

2 Particulate matter
0.1-0.2% chromium, 0.5-1% manganese, 0.1-0.9% copper

3 Particulate matter
LU PM2.5 comprised 47% iron oxide, 7% elemental carbon, 11% organic carbon, and 14% metallic and mineral oxides.

Even so, these initiatives, which seem to be of TfL's gold standard along with the Mayor's office, are lackluster and do not answer the simple question of "how we keep people safe within the confines of the LU?".

Chapter 2

Data behind the Design

Conjecture of this paper putative decimate reduction of quantitive amounts of particle size 10mp & 2.5mp within the underground and surrounding areas. 40,000 deaths a year are caused by global AQ (Air Quality), TfL states that around 4000 Londoners die annually from poor AQ, insisting this is an effect of road side pollution. In 2020 Vodex Ltd reported that 'LU dust contains more than 30-40 times the respirable dust than that of a busy London road.' Withal not your typical pollutants (for example, exhaust materials) found on roadsides, the Underground network consists of non-exhaust emissions such as wear and tear of train brakes and dust from other mechanical components, producing inhalable dust in the form of fine particles. These particles, entering through your nose and mouth, deposit within your respiratory tract. Tiny sacks within the lungs absorb oxygen however studies have found that respirable dust, composed of ultra-fine particulates (MP - micron particulates (μm) have instead been filling these sacks, thus absorbing particles opposed to much needed oxygen.

We are all familiar with inhalable dust, after a trip on the deep tunnels of the LU, you commonly see black discharge from your nasal passage, this is usually soot. However we are not able to see the impact these fine particles have on us. This is not a new topic, a 2005 paper "The London Underground: dust and hazards to health" (Seaton et al., 2005) [5] concentrates on station platforms and high quantities of μm particles, inference of dust exposure to passengers and employees.

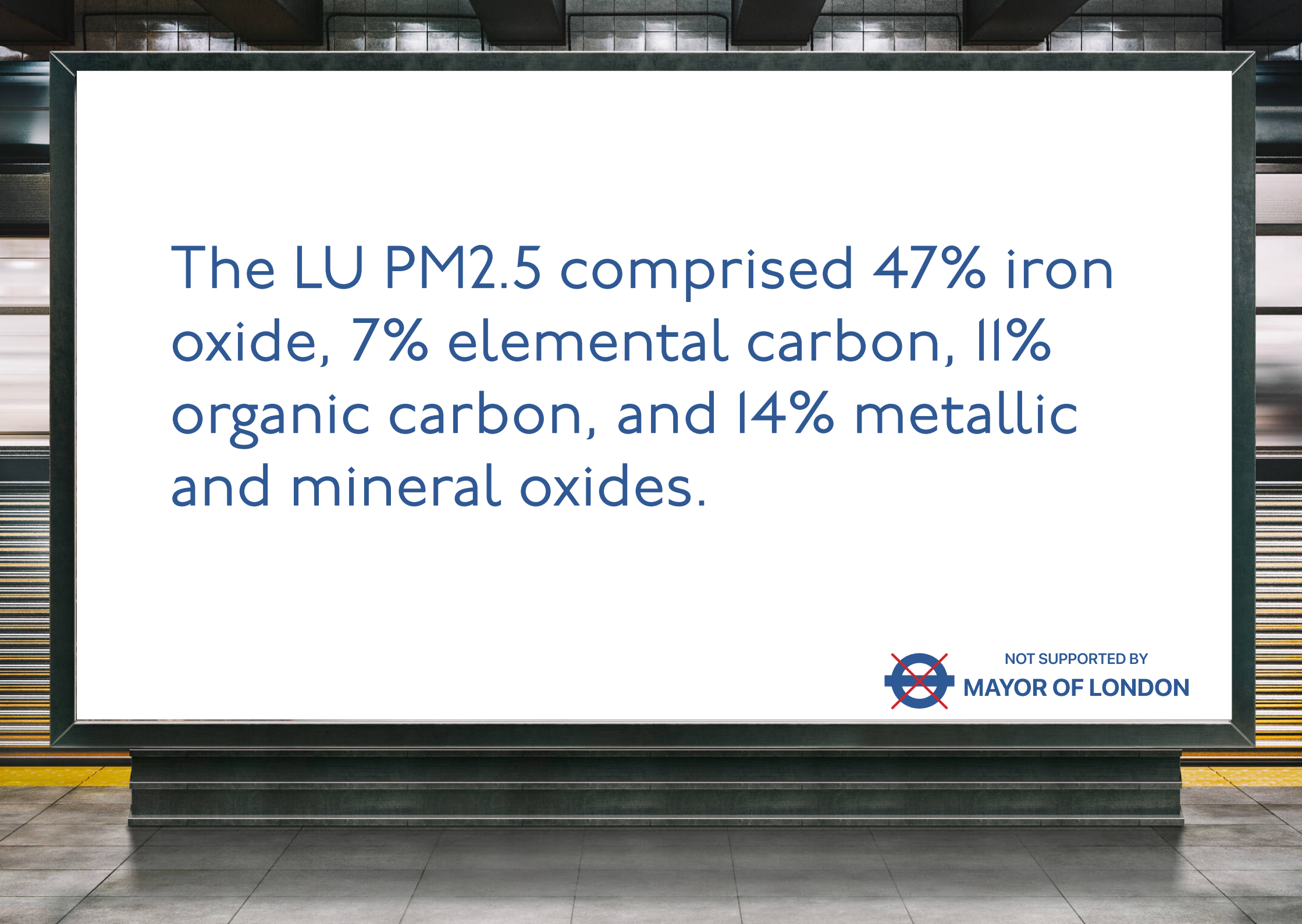
Seaton's paper identified the particle chemistry which I will delve more in depth in the Data section of this document, but to whet your appetite "LU Dust comprise 64–71% Iron Oxide PM2.5 samples. We detected 0.1–0.2% chromium, 0.5–1% manganese, ,0.1–0.9% copper, and no zinc in the same samples. Between 1% and 2% quartz was found in the respirable dust samples" (Seaton et al., 2005). [5] Newer data sets identified that the levels of PM2.5 particles present during this paper have diminished in retrospective to newer papers, which I will outline further, however they still pose a large health risk to commuters and employees of TfL.

PM2.5 stay with you far longer than you think. The toxic environment of the LU makes these particles the most dangerous, the main substances found are ferris metals. The correlation of subterranean stations, which lack of free moving fresh air, maximal levels of PM2.5 (μg m-3). Stations below eight meters, on average, tend to have particulate matter readings from 100μg m-3 to 350μg m-3. Larger concentration of theses PM are more dangerous to those who are exposed to them. "PM2.5 on the London Underground" (Smith et al., 2020) [6] states that "underground PM is able to induce oxidative damage to cells including DNA oxidation/strand breakage and lipid peroxidation in spite of an induced antioxidant response." The complex nature of high exposure to PM proportions, will in fact have negligible impact on commuters and staff health.

The findings from papers show ambient background readings of PM2.5 9 μg m−3, median 14 μg m−3 outside of the city of London, within London these numbers have risen to mean 22 μg m−3, median 14 μg m−3. Yet the numbers are 300% greater in the underground lines of the LU. The District Line, which is regulated via intercepting open ventilated tracks, saw medium levels of 4 μg m−3 despite this the levels of the subterranean network such as the Victoria line saw median of 361 μg m−3 but up to 885 μg m−3

The LU PM2.5 comprised 47% iron oxide, 7% elemental carbon, 11% organic carbon, and 14% metallic and mineral oxides

Findings by J.D.Smith (Smith et al., 2020) [6], "clear influences relating to the distance from cleaner outside air and the exchange with cabin air when the doors open. The passenger population-weighted exposure analysis demonstrated a method to identify stations that should be prioritised for remediation to improve air quality"provides an understanding, between train stock and internal AQi quality to the outside and vice versa. The notion is, that trains with HEPA filters, shown on the newer Elizabeth Line; the District Line; Hammersmith Line and City Line, show slight mitigation of reducing the abundance of poor AQi PM2.5 from the air. However, those standing on the station platform, something everyone has to do, are still exposed to poor AQi issues. Steps have been made to improve this, such as the Jubilee line, introducing barrier doors to reduce break dust, in principle this is a good concept but is shortfall by not spanning the height of the station.


The LU PM2.5 comprised 47% iron oxide, 7% elemental carbon, 11% organic carbon, and 14% metallic and mineral oxides.
NOT SUPPORTED BY
MAYOR OF LONDON

Chapter 3

Need for Intervention

1.4 Intervention

Quality of air within the LU is far behind which WHO suggests is safe. This calls for action and insight into stake holders for TfL, the active daily consumer.

With thanks to Dr Fredrico Vaz for allowing me access to D4PA_toolkit_ v1.4. (Design 4 Policy Advocacy) [7] I have designed a kit which interacts with consumers of TfL services. To achieve this I have:

1.Through the use of media

2.In-depth talks with stakeholders

3.Changing consumers opinions

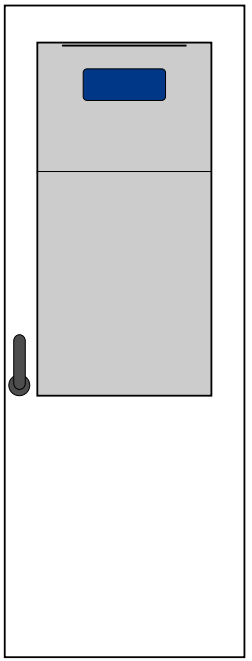
4.Portfolio of products

5.Findings

These five steps have been designed to challenge the question put forward and how to enact on it, through positive design creating change.

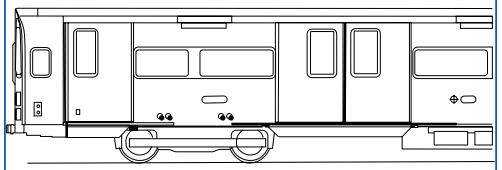
Option 1

Retrofit window filter



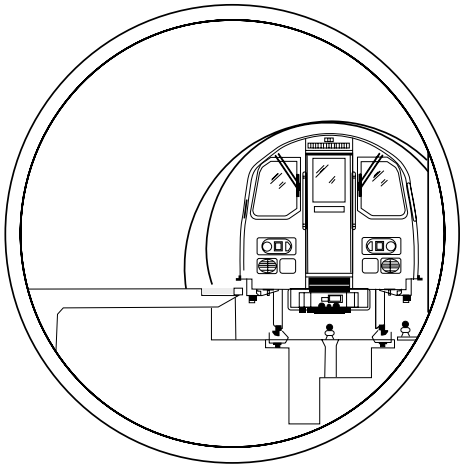
Option 2

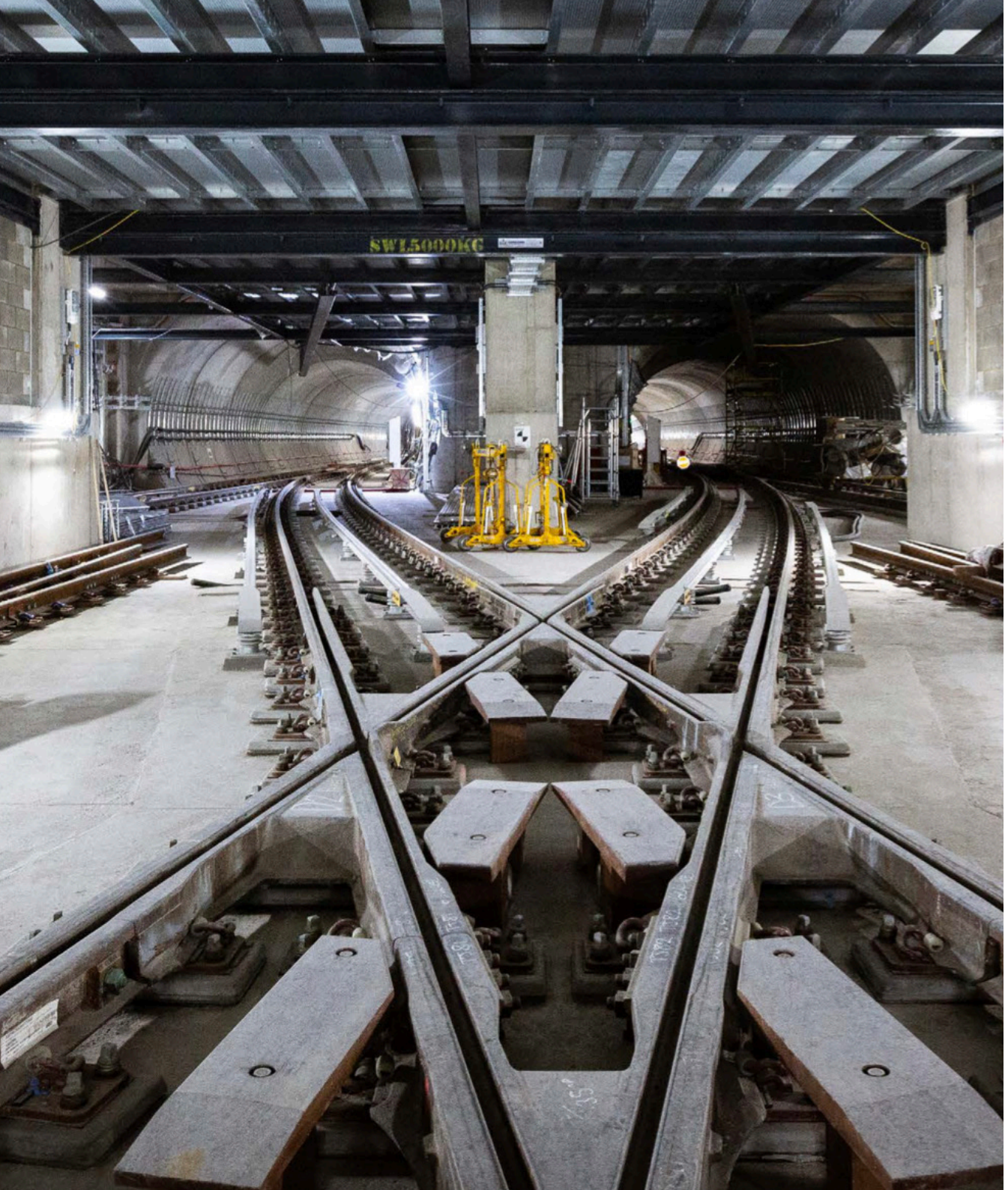
Carriage break scrubber



Option 3

Platform air scrubber





The outlook of these designs highlights issues within the transport sector. Offering outlooks for 'Infrastructure and Projects Authority' and monetary implications these may face from an infrastructure.

Outlined within this portfolio of products is appropriate fiscal approaches and a series of infrastructure programs for TfL and Network Rail, ranging from the least amount of disruption to commuters and local authorities, to considerable infrastructure investment.

This paper looks at highlighting both physical design interventions along with an earnest design approach through Public Awareness Initiatives that address' these issues without contributing to large infrastructure projects. Public awareness has been a paramount aspect to this paper, giving commuters the tools needed to make their own decisions. LU does not openly provide information regarding the severity of the implications of using their services. Contradicting this the City of Seoul in South Korea has introduced measures to reduce air borne pollution by 36% with the introduction of 'Pollution absorption mats' along with 'concrete roadbeds' and 'platform ventilation' (Seoul Metro initiates plans to reduce air pollution by over 30% - Seoul Metropolitan Government, 2024) [8]. These measures stand as an example to TfL of basic improvements made to improve AQ.

Using the examples of cities such as Seoul I have produced a policy frame work which looks at being built around these three core areas;

Technological Upgrades:

•Installation of advanced air filtration systems in both the underground stations and trains, removing particulate matter; pollutants and allergens from the air.
•Implementation of energy-efficient ventilation systems to enhance air circulation and minimise the buildup of pollutants.
•Exploration of innovative technologies, such as, air purifying plants and photocatalytic coatings to further improve air quality.

Operational Changes:

•Regular maintenance and cleaning of ventilation shafts; tunnels and station facilities, preventing the accumulation of dust and debris.
•Optimisation of train schedules and frequencies to reduce overcrowding and minimise emissions from stationary or slow-moving trains.
•Collaboration with local authorities and transportation agencies to implement traffic management measures which reduce vehicle emissions around underground entrances and exits.

Public Awareness Initiatives:

•Launching educational campaigns to raise awareness among passengers and staff about the importance of air quality and the steps being taken to improve it.
•Providing real-time air quality monitoring data in stations and trains to empower passengers to make informed decisions about their travel routes and timing.

Longevity and sustainability of employing this for long term success is key initiative for this policy.

Phase 1 (Immediate Actions):

•Conduct a comprehensive assessment of current air quality conditions across the London Underground network.
•Identify priority areas for technological upgrades and operational changes based on the assessment findings.
•Begin procurement and installation of air filtration and ventilation systems in high-traffic stations and trains.
•Launch initial public awareness campaigns to introduce the policy framework and solicit feedback from stakeholders.

Phase 2 (Medium-Term Actions):

•Expand the implementation of air quality improvement measures to additional stations and train lines.
•Conduct regular inspections and maintenance activities to ensure the effectiveness of installed systems.
•Enhance public awareness initiatives through targeted outreach efforts and educational events.
•Evaluate the policy's impact on air quality metrics and make necessary adjustments based on monitoring data and stakeholder feedback.

Phase 3 (Long-Term Sustainability):

•Institutionalize air quality management practices within the London Underground's operational framework.
•Explore opportunities for further technological advancements and research collaborations to continue enhancing air quality standards.
•Maintain ongoing communication with passengers, staff, regulatory agencies, and other stakeholders to sustain momentum and accountability.

During the course of the year, public awareness has been addressed, alongside findings of PM2.5 particulates within the LU and their implications. Public awareness has been achieved through localised consumer testimonies within the Central; District; Circle and Northern lines, through the use of station AQi stickers which have been placed to create conversations with consumers and stakeholders of TfL.

The findings at Bank Station, on the interchange of the DLR; Northern; Central lines, along with internal connections to District and Circle lines within the Monument station, found that local Londoners who were brought up within the city, know no difference relating to poor AQ within the LU and the Sooty black noses entailed with using thus transport methods. Nevertheless, commuters who travel abroad made comments regarding how using metros in other countries is far cleaner and healthier than using the LU. This creates a correlation that LU is one of the dirtiest underground networks in the world.

Despite this, talking to commuters at Bank, those commuters who were born aboard, or in the English countryside, made remarks of how poor the AQ is within London and how the city (smoke, known to many British people) hasn't changed. How outings to the capital result in sooty mucus for days after leaving the city, just one of the consequences of high particulate matter within the network and lack of clean ventilation.

This sooty mucus or soot black nose is the physical identification of the presence of PM2.5. The aim of this Paper is to identify and mitigate the presence of particulate matter of 2.5 micrometers or less within the LU, which is below the UN Level of Air borne contaminants.

Composition of PM2.5 particulates, due to their inherent fine nature, cause a superfluity of issues, Ranging from respiratory and cardiovascular diseases.

These particulates originate from a diverse areas within the LU

1.Train Operations

2.Brake & wheel wear

3.Passenger activities

4.External sources

Chapter 4

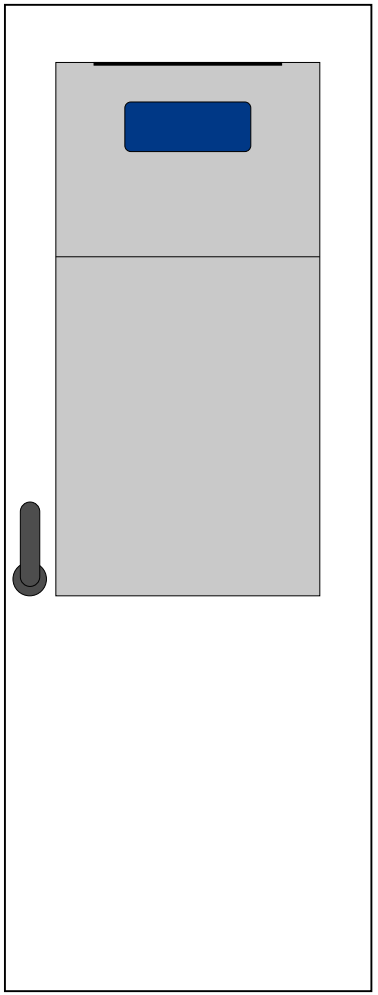
Design Portfolio

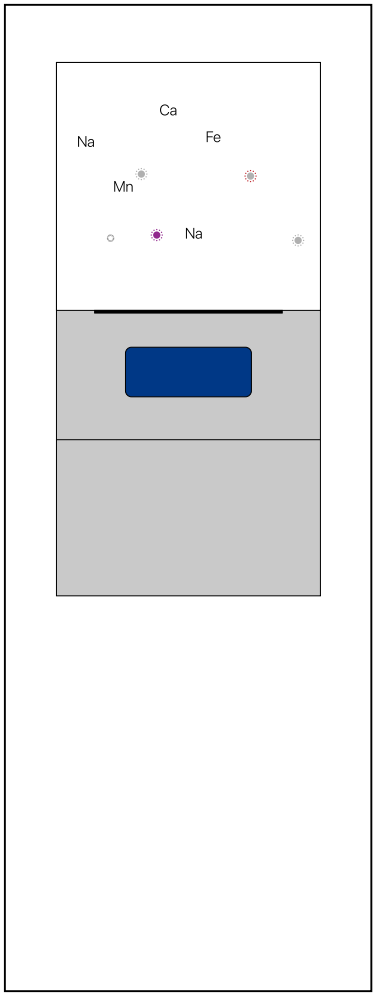
This portfolio intends to work alongside monetary allowances for TfL, also including scale of infrastructure. Data driven from 4RS AQi Monitoring for TfL Noise, vibration and Air Quality Lead (Tang and Bailey, 2023) [9] highlights the vast quantities of particles within the air in the LU.

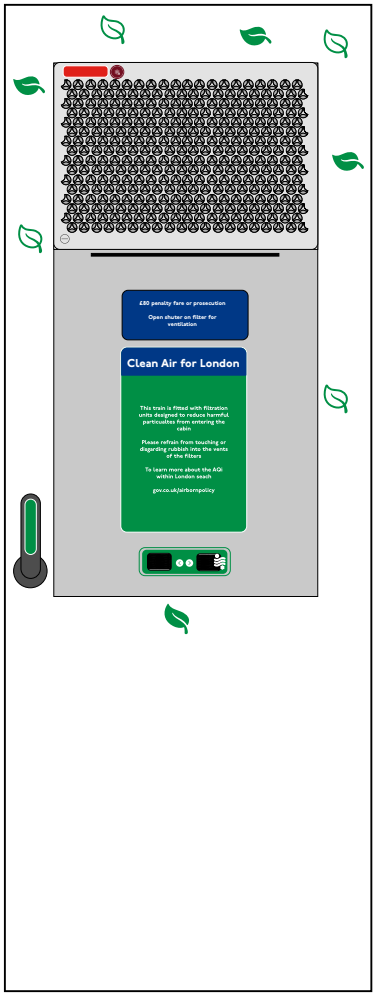
Retrofit window filter

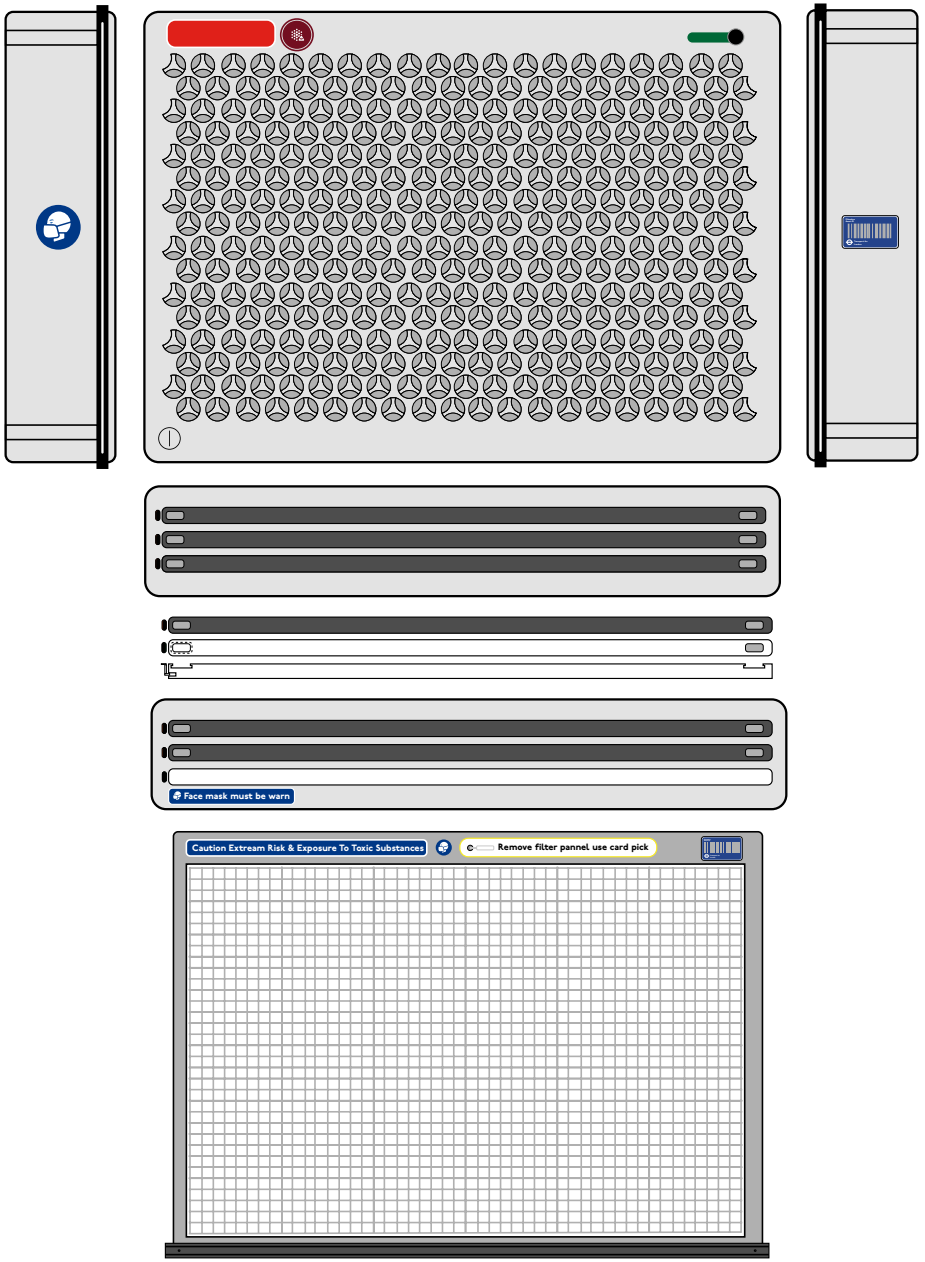
Window filters intend to minimize airborne contaminates within TfL stock carriages, in turn reducing internal contamination (Smith et al., 2020). [7] This suggests that the internal AQ supersedes external factors for airborne contamination, due to likely increased human and animal* presence.

Window filters would defenestrate a leading factor for internal cabin contamination, placing a physical barrier between external tunnel air and the air within the carriage allowing filtered ‘fresh air*’ into carriages. “Retrofit Filter” would be designed to work in a series of infrastructure products ranging from localised solutions to non localised systems, creating a triptych of designs .







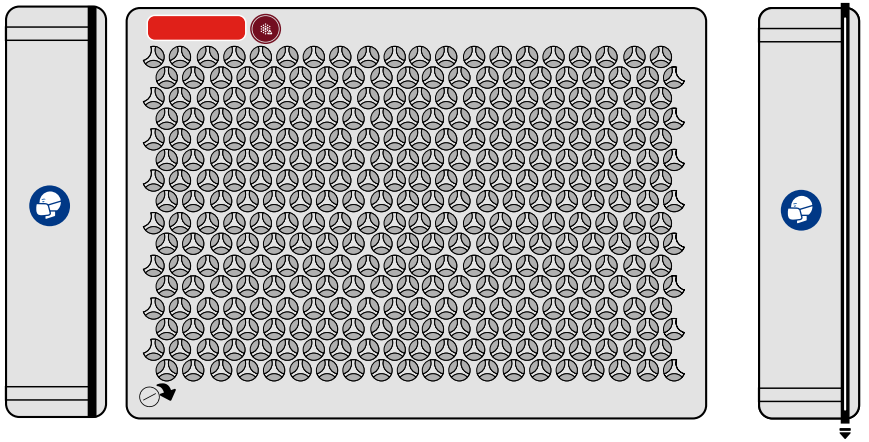


Filters would be placed on TfL stock within external door windows at the forward / aft of the carriage, Windows would be locked open and filtration unit placed inside of the open gap. An “O” ring gasket would lock the filter between the window opening and train, creating an airtight gap*.

Comprised of three ULPA (Ultra Low Particulate Air) which are designed to withstand, as well as trap smaller particulate matter compared to HEPA. ULPA can capture foreign particulate matter with a sub-micron size of 0.125 diameter or larger with 99.999% effectivity rating. HEPA are regulated to withstand PM of 0.3, which would not be able to remove ultra-fine particles from the air within the LU.

Three ULPA are encased within a series, creating a barrier between contaminated air and the stakeholder. Three filters try to remove as much external debris and fine PM as possible, within a small space.

For cleaning: panels can be removed from the main filter housing and cleaned. When the filter has subsequently been cleaned and can no longer filter, the panel can be removed via a pic tool, which would release the filter, a new filter can then be attached within seconds and placed back into the filtration unit. This allows for quick and easy repairs for TfL staff when trains are in maintenance or at the end of the shift at the depo. However, this stands a short-term remedy for AQ issues within the LU, other designs would need to be implemented to enact real change by reducing PM at their source.



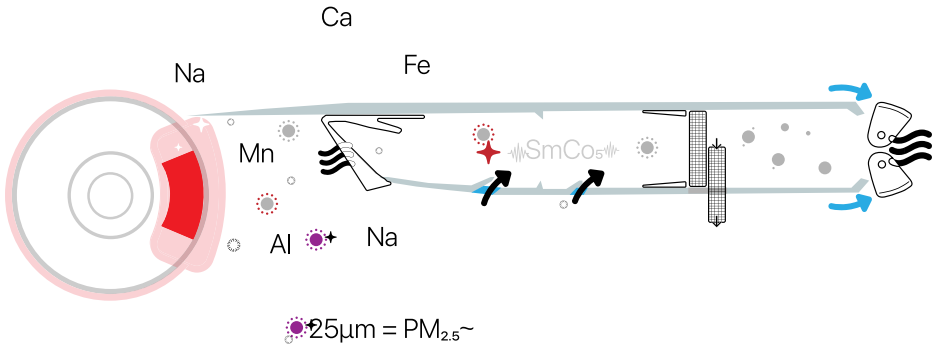
Carriage break Sled

The carriage sled looks at collecting metallic airborne continents from the surrounding areas of tracks and train wheels. The supposition of this idea stems from (Tang and Bailey, 2023) [9] report which highlights ferris properties of PM. P.M2.5 paper (Smith et al., 2020) [6] suggesting the high essence and quantities of metallic matter presence within the LU and the impact it has to health. This led to the abstraction of using air friction / metallic attraction to collect metal particles. Magnetism in micron-scale ferromagnetic metals (Ye et al., 2020) [10] exhibits how metallic micron particles can be attracted to magnetised surfaces, offering a passive filtration system to be employed to collect PM from the leading issue of high level PM2.5 within the LU from train brakes along with the tracks and sleepers.

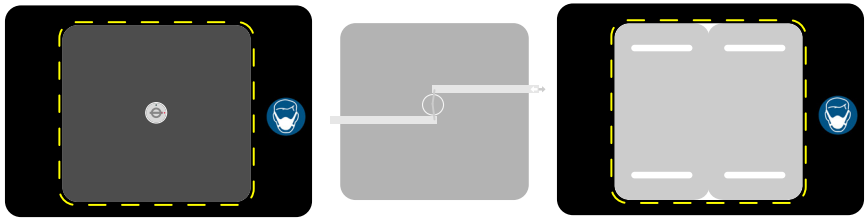
Samarium-cobalt (SmCo5) magnets offer high retention yields through higher strength and temperature stability, alongside being corrosive resistant, lending to the ideal magnetic material for the hostile conditions of the LU.

SmCo5 would line a brake sled where Bernoulli's principles of fluid aerodynamics can create a passive filter. When low pressure of air pockets are created within the tunnel sections of the Tube the train pushes high quantities of contaminated air from the tracks below as well as new particulate matter from the brakes. The sled uses this principle to push moving air through the sled boxes capturing particles as the brakes are enabled along with PM from the floor and surrounding air.

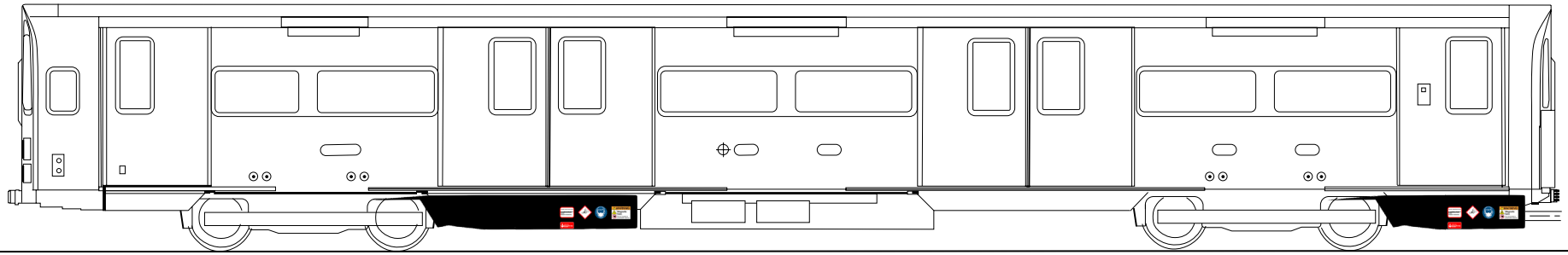
PM is captured through a samarium-cobalt lined sled, attracting metallic matter from the wear and tear of carriages and tracks. Alongside the cobalt linings, two ULPA filters line the hindmost section of the sled, sanguine that the air coming out of the back of the sled is 99.999% clean and free of contamination. Also working when the train reaches a station platform, enabling the design to collect PM whenever the train is moving and collecting the harshest matter constantly.



Air flows into the sled via an opening at the front where magnetic particles are attracted to the side of the walls. Openings in the bottom draws further air into the sled. Air pushed through the sled is then pulled through two ULPA filters.



Filter access hatch is located at the bottom of the Sled. Allowing access to train technician's for repair and cleaning.



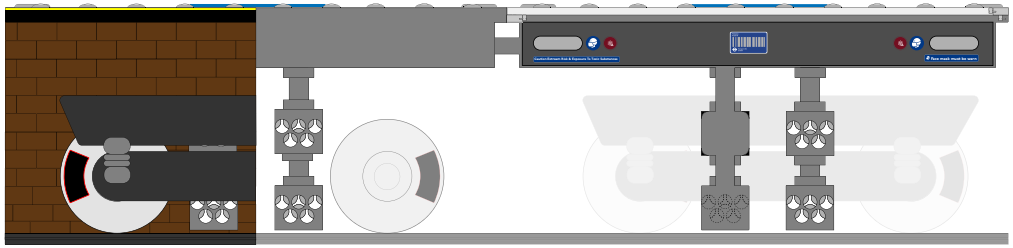
Platform Air scrubber

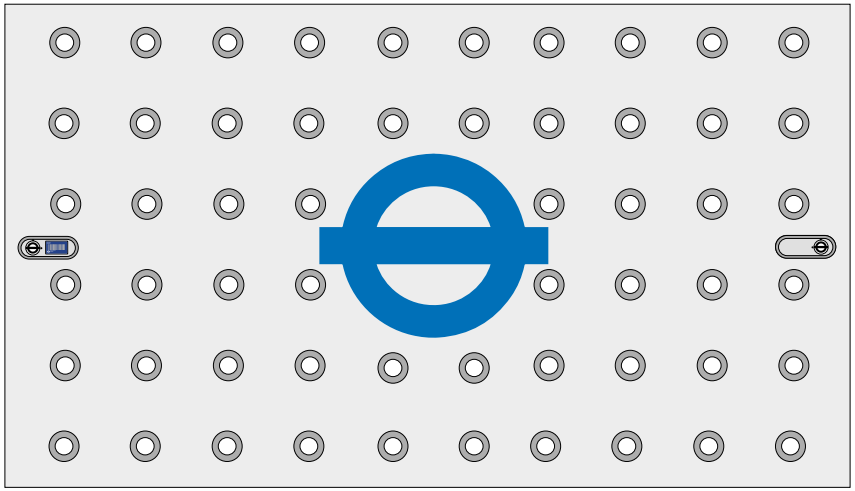
Platform filtration within the Underground is difficult due to the historic nature of the LU and it's infrastructure from being built over 150 years ago. Consequently bringing fresh air into stations is difficult, as well as cleaning the contaminated underground air too.

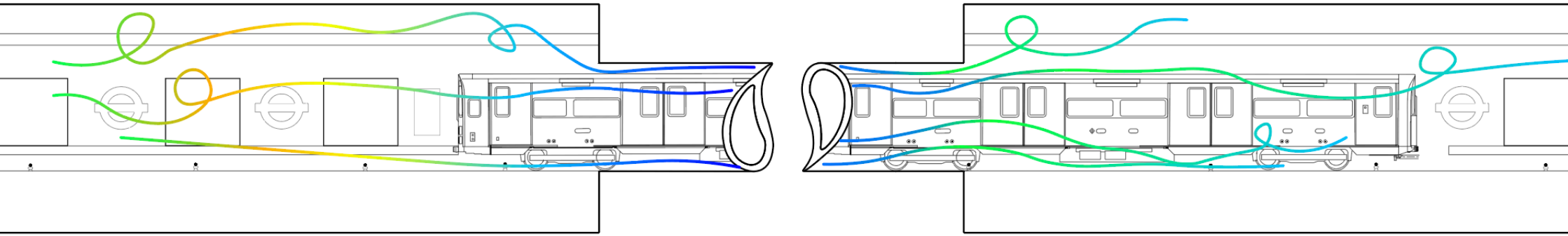
Air scrubber would be designed to replace existing blister flooring, designed to allow visually impaired consumers to find the platform edge along with street side crossings. Retrofitting this government regulated design with a new layout and TfL roundel centre piece, would allow consumers the ability to visualise the Tube Line which they are travelling on, reflecting line colours used throughout station walls.

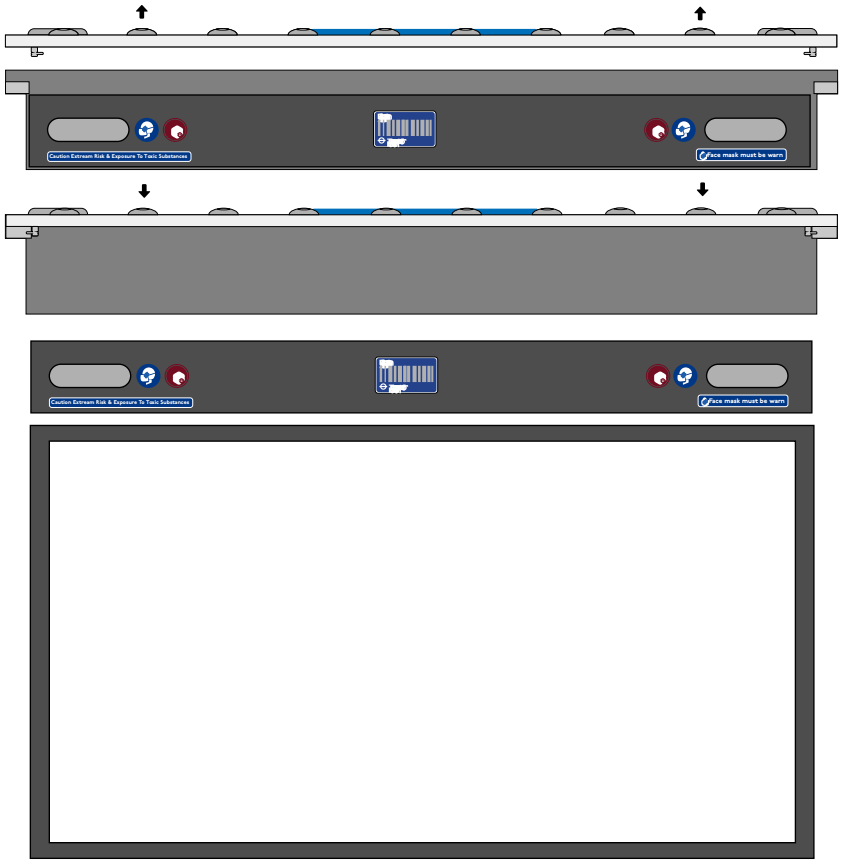
My design has 700-400mm holes within the rumble sections of the blister plates, sized at one and half traditional plates, allowing them to fit where existing plates are. These platform plates act as passive air filtration scrubbers, containing ULPA filters, placed to collect moving PM. These packs are connected via smaller air boxes allowing air to flow between each unit.

> Concept proposal intends to harness the power of the trains, Bernoulli's theorem for 'Compressible Flow Equation' states that air seen as a 'FLUID' is compressed and fluid is sped up due to its compression through constricted environments. <









Station platforms provide the perfect environment to implement a compression flow method. As the train pushes through the tunnel, sections air is compressed until it reaches the next station. This signifies to consumers that the next train is approaching, moreover, pushing a toxic mix of contaminated air into those standing on the platform edge.

As air is moved into stations, platform filters lie collect airborne PM from oncoming trains, these filters are positioned on the platform edge alongside ventilation tubes which are placed next to track and breaks collecting* more PM from trains as they stop, reducing inhalation risk to harmful brake dust.

ℹ However these designs are perceived to be localised solutions to a network wide PM issues. Triune concepts enact design change and collection possibilities within the LU network reducing train operation wear impact.

Chapter 5

Pilot Trials and Roll Out

A phase roll out of concept designs would be implemented at stations with frequent high footfall alongside its geographical location and depth within LU network.

Pilot Projects and Technology Trials:

•Initiate pilot projects to test the effectiveness of different mitigation technologies and strategies in real-world underground environments.
•Collaborate with industry partners and research institutions to conduct technology trials and evaluate innovative solutions for PM2.5 reduction.

Rollout and Monitoring:

•Deploy mitigation measures in phased stages, starting with high-priority locations and expanding gradually across the underground network.
•Establish a comprehensive monitoring program to track changes in PM2.5 levels, air quality parameters, and health outcomes following the implementation of mitigation measures.

Continuous Improvement and Stakeholder Engagement:

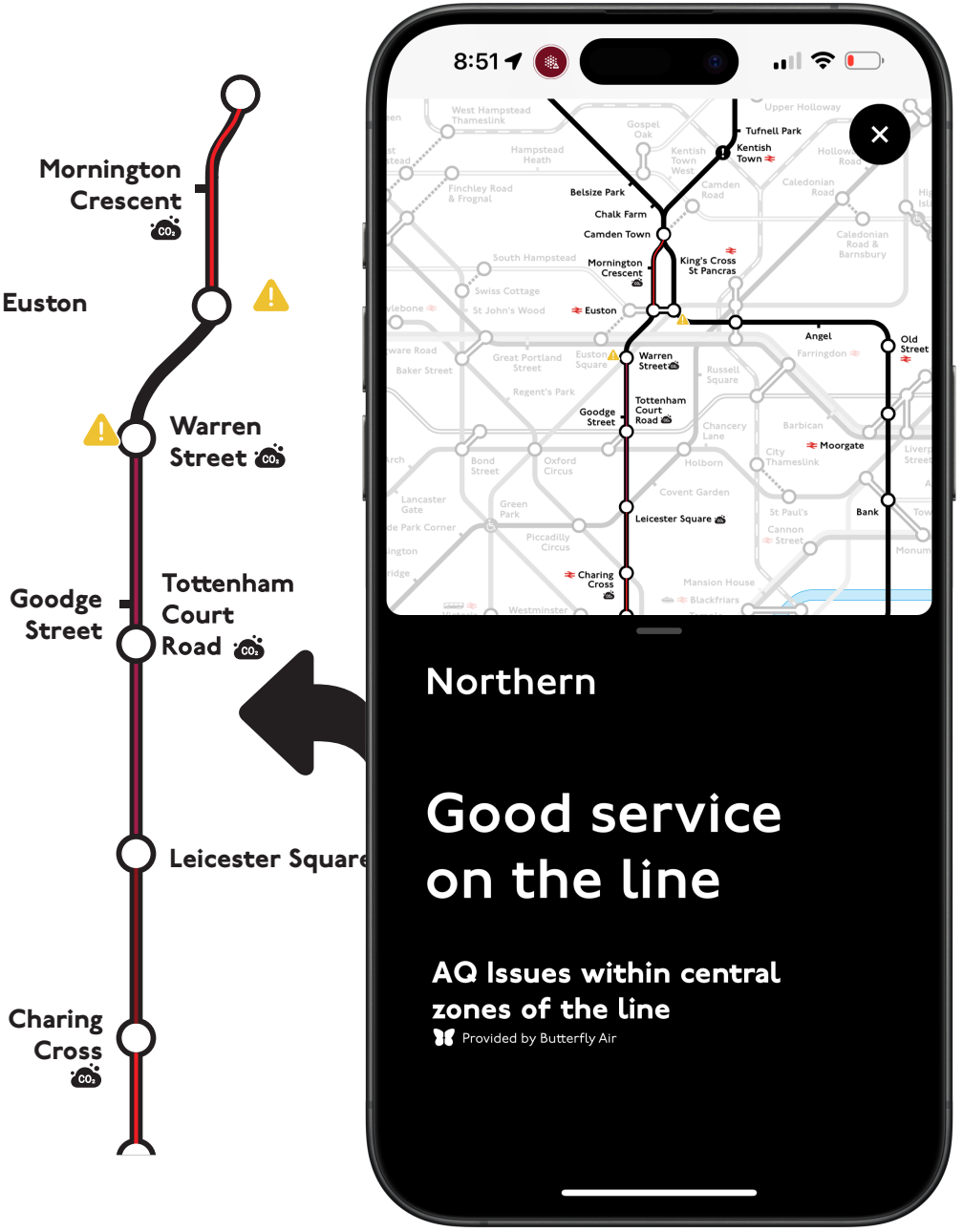
•Regularly review and refine mitigation strategies based on monitoring data, technological advancements, and stakeholder feedback.
•Engage with commuters, staff, local communities, and regulatory authorities to ensure transparency, accountability, and ongoing support for air quality improvement initiatives.

Alongside these, passenger engagement and behaviour change is pivotal in implementing design change within the LU and finding pivotal design changes. Without input from passenger stakeholders there would be no tangible design outcomes.

Areas where AQ monitoring could help is in areas of real time data collection. Butterfly, an Imperial London company, in conjunction with TfL would offer discrete and affordable monitoring for customers and staff. Butterfly make domestic readers in Britain, highlighting internal environmental air quality within the home. The distinct difference with Butterfly is the gloWING interface that glows to different hues depending on the atmospheric readings. Creating an intuitive system. The companies IAQ (Indoor Air Quality) readers can be retrofitted for life in the Underground. Butterfly's API can be designed into TfL's systems as well as Google LLC (Alphabet Inc) and Apple Ltd.

This tool will empower consumers to create choices based on data provided to them, through intuitive tools and information at their fingertips. This data can be displayed on TfL train stocks as well as stations and platforms.

However, the implementation of these tools will have to be tested and connected to high speed networks within the underground to be effective.



Data provided to customers via Butterfly-Air API

Chapter 6
Behaviour Changes of Commuters

Throughout this paper the need for intervention is highlighted through the use of localised design solutions which mitigate the presence of airborne contaminants throughout the LU. Moreover behaviour change of commuters is the main premiss to enact change throughout the LU and Governance. Without support and enthusiasm from consumers / stakeholders this paper will not be enacted on nor used to address issues surrounding PM within the Underground.

Commuter feedback for localised solutions bring's some form of relief, that there maybe solutions to remove contaminants from the air during their daily commute. Moreover the concurrence from these conversations is that commuters spend far too much money on TfL services and receive nothing in return and feel these systems will be used to mitigated AQ within the whole network. The assumption from most is that the corporation needs to reduce and mitigate the impact of AQ & PM within the worst of the worst.

As addressed within 'Chapter 5 Trials and Rollouts', the preponderance feel that key critical stations to be used as pilots and then full roll out to these stations.

Out of the design concepts, many feel that addressing the issue with AQ within train stock is a key concern rather then passive filters within the station platforms and that the corporation could in fact redesign TfL stations and retrofit with fresh air ventilation, 1. bringing in fresh uncontaminated air* 2. reducing the heat within deep stations on the network

Chapter 7
Air Quality Monitoring & Studies

Air flow within stations needs to be conducted during peak and non peak hours that coincides with TfLs efforts to attain data during closed periods. This would allow researchers to conduct studies and build flow models to contempute the air flow within the duration of service and how long air flow stays stagnant or how air ungulates within volatile air currents, which in turns throws PM into constant movement reducing the ability for PM to surface. Or in turn PM is immobilised, due to air volatiles PM is thrown back into air streams when compressible air flow coefficients.

An Imperial College London start up Butterfly-Air has agreed to facilitate the necessary tools and equipment necessary to develop viable and accurate data to customers and TfL. Butterfly deliver data to 'WELL Standard' specification for building regulations.

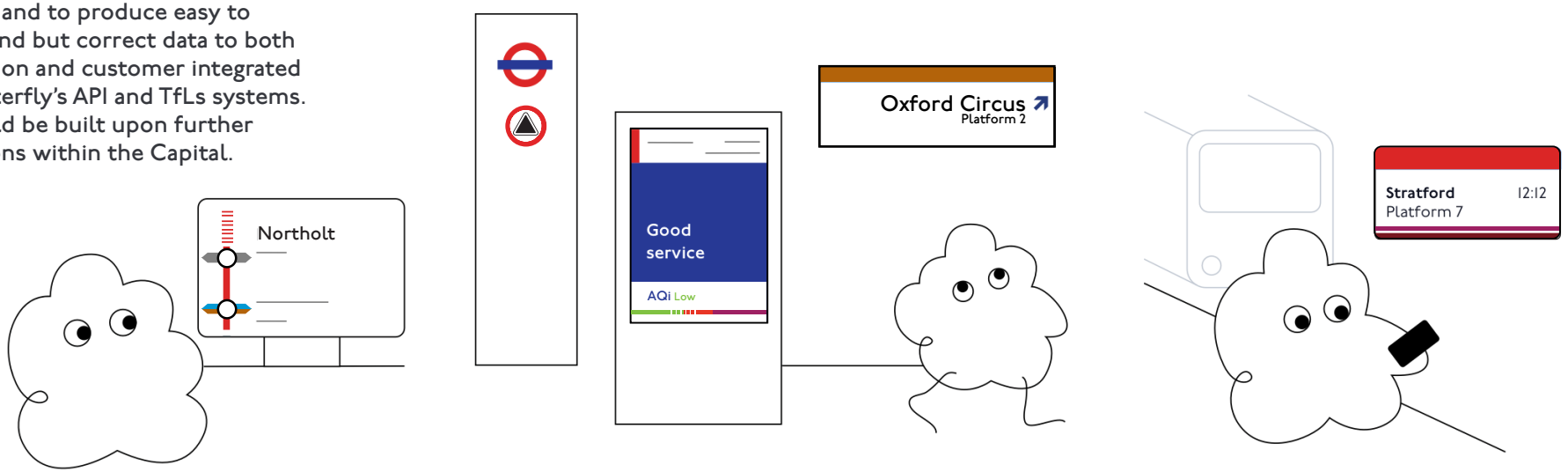
Our stance and to TfL is we are committed and invested to explore how Butterfly and TfL can work hand in hand to produce easy to understand but correct data to both corporation and customer integrated with Butterfly's API and TfLs systems. This could be built upon further institutions within the Capital.

Chapter 7.1
Legislative change within the coming years will make it a legal requirement for companies to show customers AQ within their buildings. If this is not from a legal point this could be drawn from an insurance point which requires AQ monitoring.

Consumers using public transport across the globe are becoming more aware of NO2 levels as well as AQ. For the last decade both Apple Maps and Google Maps showcase area AQ levels through AQi (Air Quality Index). Working in tangent with Butterfly, TfL can create a program which can supply reasonable answers to its own impact on producing high levels of PM and its approach to attenuate these from there premises keeping both staff and consumer safe throughout their journey.

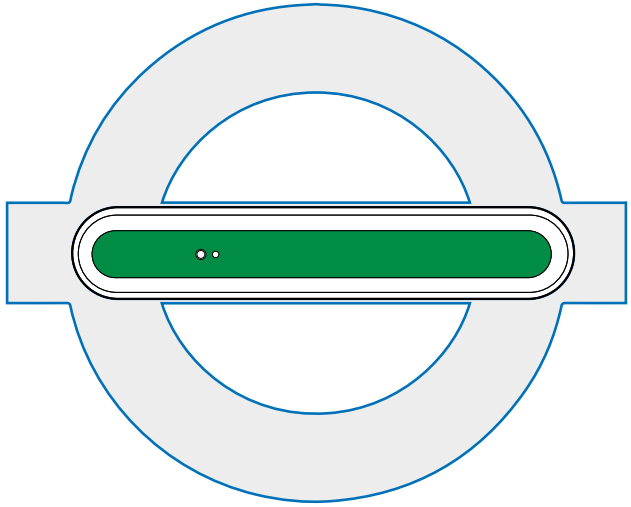
This partnership could bring the UK as a lead and champion for AQ and how to reduce these from day to day life. TfL could be a case study showing the globe, UK innovation and Design is at the forefront to becoming a green clean society.

The Butterfly readers would be changed and retrofitted with TfLs Iconography placed within strategic locations in stations and TfL buildings alongside inside of carriages. The data may become complex to find due to multiple external factors obscuring data from foreign matters and external sources. However this could paint a picture of dynamic situation and flow of air within trains and platforms to design targeted solutions.

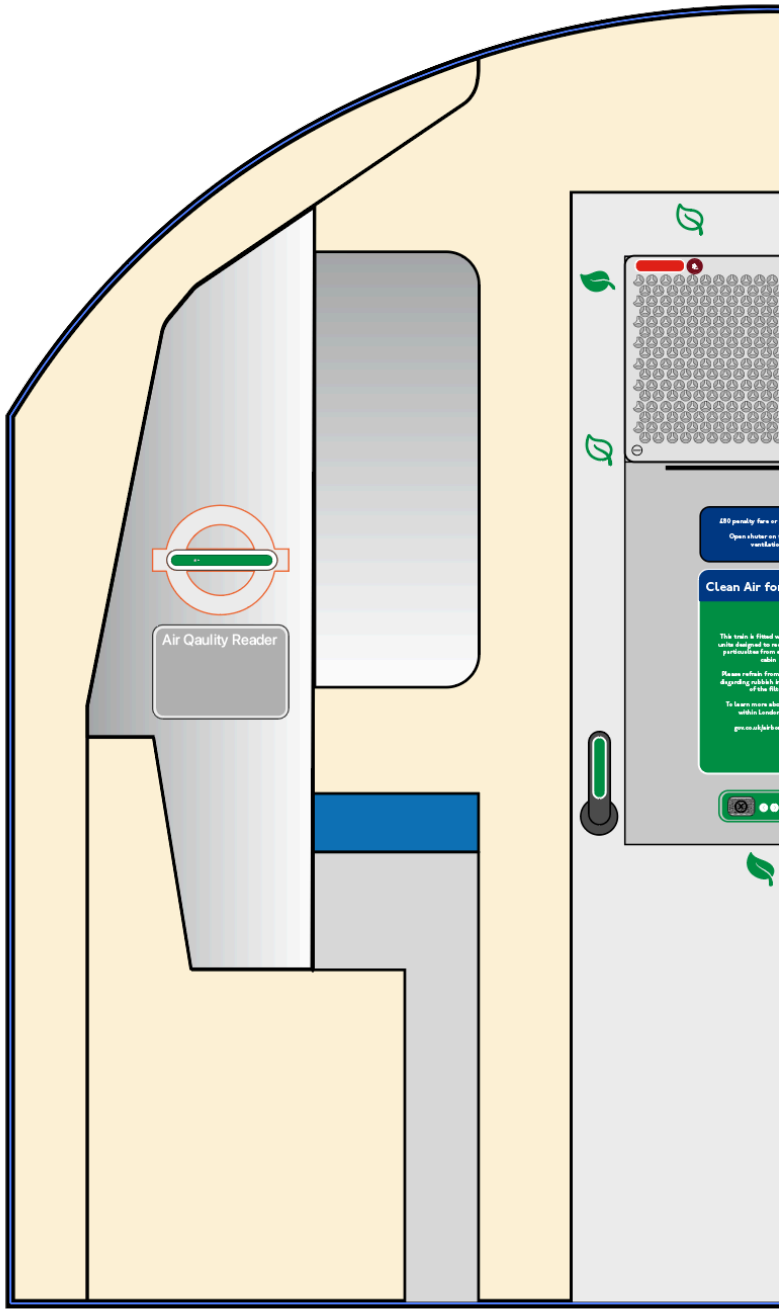


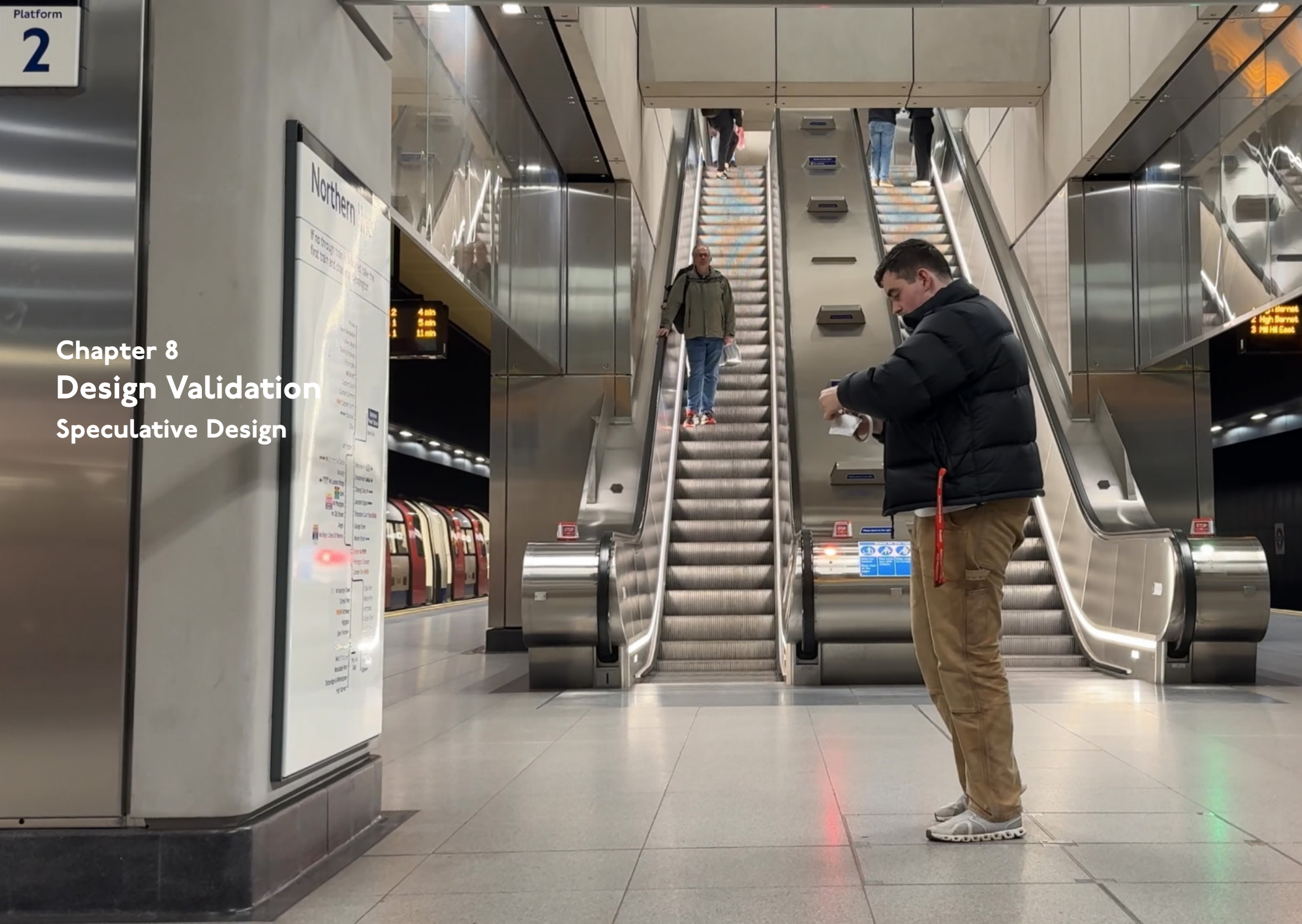
1.5 Butterfly Air

Butterfly Air, an IMPERIAL London start up, has agreed to partner with myself and TfL with the intergration of AQ monitors within the LU. These moniters would be in the style of TfL with branding iconography such as the roundel and how this could be invisaged and used within TfL stock.



AQ moniter would illuminate hues of blue, green and orange indicating the AQ levels within that section of the tube. This would monitor air within real time, creating real time meaningful data to consumers and TfL.





Chapter 8

Design Validation

Speculative Design

A model to map AQ and air pollution by Imperial College London could be used here. The devised method known as Dynamic Neural Assimilation (DyNA) combines the power of Ai networking with real time data, in turn being used in conjunction with Butterfly Air. To effectively design prediction models to control internal real-estate AQ in real time introducing targeted ventilation alongside introduction of topside air ingress into platforms.

The validation of these designs are based on the presumed nature of air flow measured by Δp. Which according to Validation methods form 3M and other manufacturers attains the effectiveness of ULPA filtration. IQAir, stipulates that HyperHEPA filter in fact prevent PM2.5 particles from being captured. However the heath of Staff and consumers requires more robust filtration systems which sees ULPA filters being deployed throughout TfL's portfolio of buildings and underground systems.

Validations for this Speculative Design Intent to capture PM ingress into TfL stock carriages and the collection of PM from respective mechanical components. Not limited to the use of wind tunnel simulation and pressure models.

Standalone ULPA filters are regulated to capture particulate matter at 0.12µm diameter or larger, which has the effectiveness of prevention PM egress of 99.999%(recurring dot). Moreover the consensus of data produced from filtration companies highlights that design validation is not obligatory in the design premise of carriage filtration. Howbeit for more localised and sophisticated outputs such as platform scrubbers.

In spite of this speculative design avenue, Siemens (TfL train manufacturing contractor) are creating 94 New Piccadilly trains, intending to increase the capacity and comfort of consumers through the introduction of open carriages and air-conditioning as seen on the S7-S8 trains on the District, Circle, Hammersmith & City Lines. Yet the design to create more comfort inside of the trains with creating single carriage* trains reduces the risk of PM ingress from open end carriage windows however still negates the PM creation form mechanical systems such as wheels. Steel wheels equate to a 90% reduction in PM creation to those made from rubber, which in turn is effective yet this still doesn't account for the metallic PM inception due to train breaking.

Validation for these design's would have to go through a series of external tests and validation methods to be certified for use within the public transport remit.

Chapter 9

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