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BREATHE-Cities

Bolstering Resilience and Environmental Air-Quality through Transformative Healthy Emission Transport

Foreign, Commonwealth & Development Office

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Partnership | Progress | Prosperity

Bolstering Resilience and Environmental Air-Quality through Transformative Healthy Emission Transport in Cities

BREATHE-CITIES

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BREATHE

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Executive Summary

Global urban areas are witnessing an escalation in transport-induced air pollution, aggravated by climate anomalies, Urban Heat Islands (UHIs) and Urban Pollution Islands (UPIs) effects (EPA, 2022) posing significant human health challenges with public health, social, economic, and environmental repercussions. The World Health Organization estimates around 7 million premature deaths annually due to air pollution (WHO, 2022), highlighting the urgency for mitigation strategies. The project outlines a thorough analysis of transport patterns and consequent air pollution emissions in Manchester, UK; Bangkok, Thailand; and Yangon, Myanmar, assessing a selection of diverse urban complexities.

The BREATHE-Cities project is dedicated to addressing the critical challenge of urban air pollution through a multifaceted research strategy aimed at understanding and mitigating the health impacts of transport-induced pollution. The project's methodology encompasses a systematic literature review, advanced technological deployment for air quality monitoring, and extensive community engagement, focusing on the pollutants PM2.5, PM10, COx, and NOx due to their significant health risks.

The project aims to explore resilient and sustainable low emission strategies for urban transportation and spatiotemporal models, with a strong emphasis on community impacts and localized adaptation options, aimed at mitigating air pollution and its adverse health effects. **BREATHE-CITIES project** develops an integrated spatiotemporal model to analyse the multifaceted relationships between air pollution, transport patterns, Heat, and their collective impact on air pollution levels. The project also examines the social impacts and community engagement in Yangon in the absence of empirical environmental data, unveiling vital societal and behavioural factors impacting policy effectiveness.

The literature currently presents a gap in comparative analyses that consider the diverse demographic, climatic, infrastructural, and policy frameworks of different cities (Pope III, et al., 2019). **Manchester, UK**, representative of technologically advanced urban structures, is key for studying transport dynamics and their repercussions on air quality (Manchester City Council, 2022). Despite innovative environmental management approaches, the city contends with significant air quality challenges contributing to approximately 1,200 deaths annually (Cox and Goggings, 2018). The anticipated cumulative cost to health and social care due to air pollutants are estimated to reach £5.3 billion by 2035 (Cleaner Greater Manchester, 2023). The project will explore the chronic exposure and long-term health impacts of industrial and transport-related pollution in Manchester to devise context-specific interventions. **Bangkok, Thailand**, exemplifying the dynamics of rapidly evolving ASEAN urban centres, struggles with exacerbated transport-induced air pollution marked by hazardous PM2.5 levels often exceeding WHO guidelines (WHO, 2022; PCD, 2021). The city's socio-economic inequality poses added health risks, particularly in informal communities struggling to access essential healthcare services (Thongsawang et al., 2020). The project in Bangkok will aim to develop transformative solutions to diminish pollution levels and associated health risks, focusing on the city's unique challenges in managing rapid urban development and population growth. **Yangon, Myanmar** is integral for evaluating societal impacts and the effectiveness of prevailing transport policies in emerging ASEAN regions amid its ongoing urbanization and industrialization. The political unrest since 2021 has exacerbated the socio-economic vulnerabilities of various communities (Gu & Yim, 2016). To reflect the impacts from transport-induced air pollution, retrieving the opinions of vulnerable communities is necessary to identify the perception and experiences in the context of locals. By including Yangon, the project seeks to fortify community resilience and improve urban ecosystem sustainability, particularly in regions facing complex political landscapes and upheavals.

Model analysis across the project cities has shown significant variation in air pollution sources and impacts, suggesting tailored approaches in urban planning and transport management to address specific local challenges. Sensor technology and data analytics have enabled precise identification of pollution hotspots, guiding the deployment of interventions tailored to reduce exposure and mitigate health risks effectively. Community engagement efforts have been instrumental in refining these strategies, ensuring they resonate with local needs and garner robust community support.

Additionally, insights derived from community engagement in Yangon and advanced spatiotemporal modeling across all project cities have been pivotal. These efforts have informed the development of comprehensive, evidence-based policy recommendations that are currently guiding urban planning and transport strategies in the project cities. These recommendations focus on enhancing air quality and public health outcomes, particularly in communities disproportionately impacted by urban air pollution.

The project is grounded in empirical evidence linking transport emissions and heat stress levels in Manchester, Bangkok, and Yangon to deteriorated air quality and health adversities. The focus on health as a priority area is supported by essential preliminary research and established links with community partners in the selected cities, reiterating the urgency of intervention. Existing policy frameworks in Bangkok and Yangon lack sufficient adaptability to the varied contexts of different cities in Southeast Asia, hindering effective mitigation of transport-induced air pollution's health impacts.

Key Findings and Recommendations

Key findings by the team of the BREATHE-CITIES Project include:

1. **Interrelationship between Air Pollutants and Urban Heat Islands**: The project confirms that air quality data alone does not suffice in describing the health stress index in urban areas. There is a significant interrelationship between the concentration of air pollutants and the effects of urban heat islands. This finding underscores the complexity of urban air pollution and its impact on public health, indicating that both factors must be considered in urban planning and policy-making processes.
2. **Impact of Urban Configuration on Health**: The urban configuration significantly impacts urban heat, which in turn affects the concentration of both gaseous and particulate pollutants. This complex interaction highlights the need for localized studies that consider the unique urban configurations of different areas and their specific impact on air quality and public health. Urban planning and design must incorporate strategies to mitigate urban heat island effects through thoughtful urban configuration, including the use of surface materials and green infrastructure.
3. **Need for Localized Air Quality Studies**: Echoing the project's emphasis on targeted and localized interventions, the integration reinforces the necessity of localized air quality studies. These studies should investigate both the macro and micro levels to accurately assess the impact of air pollution and urban heat islands on urban health. This approach ensures that interventions are appropriately tailored to the specific needs and conditions of each urban area.
4. **Information and Communication Gap**: The project identifies a significant gap in information and communication regarding air quality in urban areas, leading to skewed perceptions among the population of the levels of air quality in Southeast Asian cities. This finding highlights the importance of enhancing public awareness and communication strategies to accurately inform urban populations about air quality issues and health implications.
5. **Considerations for Urban Design**: The findings advocate for the design of new, and the refurbishment of existing, urban places to consider modelling of air movement, surface materials, and the integration of green infrastructure. Such considerations are crucial in eliminating urban heat island effects and mitigating the health impacts of air pollution. This suggests a paradigm shift in urban design and planning, emphasizing the role of environmental health considerations in creating sustainable and liveable urban environments.
6. **Scalability and Global Relevance**: The BREATHE-Cities project’s methodologies and findings have significant implications for other urban areas facing similar challenges with transport-induced air pollution. The project's integrated approach to air quality management, leveraging technological innovation, community engagement, and policy analysis, provides a replicable model for global application.

These key findings reflect a comprehensive understanding of the intricate dynamics between urban air quality, urban heat islands, and urban configuration. They underscore the necessity of integrated approaches in addressing urban air pollution, emphasizing the role of localized studies, improved communication, and innovative urban design in creating healthier urban environments.

Key Recommendations:

Strategic actions aimed at improving air quality and mitigating the health impacts of urban pollution were identified from the data collection and analysis and subsequent identified key findings. These recommendations are pivotal for policymakers, urban planners, and stakeholders across the Southeast Asia region and potentially at a global scale.

1. **Integrated Air Quality Index Development**: Cities should adopt a holistic approach to developing air quality indices, incorporating air pollution levels (PMx, NOx, Cox, and Vox) alongside microclimate temperature data to reflect the compounded impact of urban heat islands. This integrated index will provide a more accurate representation of the air quality and its health implications, guiding policy and public health responses effectively.
2. **Localized Mobility Planning:** Urban mobility planning must consider local variables, including place morphology, to design transport systems that minimize pollution and its dispersal. Tailoring mobility solutions to the unique urban fabric of each city will enhance the effectiveness of pollution mitigation efforts.
3. **Rethinking TODs in High-Density Contexts**: The design of Transit-Oriented Developments (TODs) in densely populated Asian cities needs re-evaluation to address the challenges of commercial and leisure land use that exacerbate pollution through congestion and trapped pollutants. Innovations in TOD design can alleviate these issues, promoting healthier urban environments.
4. **Enhanced Communication on Air Quality**: Cities should leverage technology to improve communication about air quality. Apps and websites providing credible, integrated air quality information—including local air temperatures—can empower citizens to make informed decisions about their exposure and activities, thereby enhancing public health.
5. **Data-Driven Clean Air Strategies**: Implementing clean air strategies based on rigorous data analysis can significantly benefit urban centers. Strategies that encourage walking, cycling, and the use of clean energy, while reducing congestion from motorized transport, will have a marked impact on reducing air pollution.
6. **Public and Business Engagement in Clean Air Initiatives**: Launching educational campaigns to raise awareness about air quality challenges, including the risks posed by non-emission pollution sources, is crucial. Engaging the public and local businesses in developing and supporting clean air strategies will foster a collaborative approach to creating sustainable and healthy urban environments.

The synthesis of the BREATHE-Cities project's key findings and the derived recommendations illustrates the intricate relationship between urban air quality, heat islands, and urban configuration. These findings reveal the complexity of urban air pollution and its multifaceted impacts on health and the environment. The necessity of an integrated approach becomes clear, highlighting the importance of localized studies to understand specific urban dynamics, the need for improved communication to raise public awareness, and the value of innovative urban design to mitigate the effects of pollution and urban heat islands.

Rooted in the project's comprehensive analysis and innovative methodologies, these insights form the foundation for a set of actionable recommendations designed to address urban air pollution's challenges effectively. The recommendations advocate for the adoption of integrated strategies that leverage technological innovation, foster community engagement, and promote adaptive policy frameworks. This approach aims to lead the development of resilient, sustainable urban transport strategies that mitigate pollution while enhancing public health and well-being in diverse urban contexts.

By connecting these findings with the recommendations, the project emphasizes the critical role of informed, data-driven decision-making in urban planning and policy development. The BREATHE-Cities project underscores the potential of collaborative, cross-disciplinary efforts to transform urban environments into healthier, more resilient spaces. Implementing these recommendations represents a significant step forward in the collective ability to tackle urban air pollution, offering a pathway to cleaner, greener, and more livable cities for future generations.

BREATHE-CITIES Project Approach

The BREATHE-Cities project is designed to address the pressing issue of transport-induced air pollution and its detrimental effects on urban health and environmental quality. It recognizes urban transportation as a major source of air quality deterioration and aims to develop resilient, sustainable low-emission strategies centred on spatiotemporal models and community impacts. This initiative is in response to the escalating global challenge of transport-induced air pollution, exacerbated by climate anomalies and urban heat islands (UHIs) effects, posing significant health, social, economic, and environmental challenges (EPA, 2022; WHO, 2022). The project underscores the urgency of developing mitigation strategies to address the estimated 7 million premature deaths annually attributed to air pollution by the World Health Organization (WHO, 2022).

Transportation is now the biggest source of air pollution, especially if the urban air pollution from burning coal or coal is reduced in western European or North American cities. For example, the road, air, rail, and water transport mode releases pollutants that cause acid deposition, stratospheric ozone depletion, climate change and air quality impairment in the urban area, which negatively affect human health (Colvile et al., 2002). Transportation is one of the biggest factors in air pollution, which causes various emissions and therefore affects air quality of the cities, human health and the climate of the whole world. The ever-growing economic developments of our world, especially in developing countries like India, increase the number of cars. Therefore, air pollution is on the rise in the major cities around the world, with local, regional, and global outcomes due to motor vehicle emissions. Chang et al., (2019) stated that regional transport has a big impact on PM2.5. Urban air pollution levels, which are due to the combined effect of both local and regional sources that are dependent on the season and pollution levels. Sector's influence does not remain limited to local and regional levels, but it has wider impacts at the global level including both warming and cooling effects in the atmosphere. While some improvements have been witnessed in emission reduction technologies and policy, the fast-rising need for transportation especially in developing countries remains a problem as it keeps on deterring the air quality and public health.

The way a city is built becomes a contributing factor to the concentration and dispersion of pollutants in the air, thereby affecting the magnitude and spread of various contaminants. The orientation of the street which includes the aspect ratios, such as the building heights to street width, and the alignments of windward to leeward buildings, has a significant impact on the airflow and air pollutant dispersion within the street canyon (Xiaomin et al., 2006). Particulate matter concentration is determined by urban form factors, including island city shape, road density and population density, with denser areas showing higher particulate matter levels (Clark et al., 2011). A height, volume, form and density of a building can be a wind calm zone or a vortex zone. It gives a movement of pollutants in the urban community having high density (J. Yang et al., 2020). Indicators of urban morphology such as building density and urban fraction are undoubtedly fundamental in terms of establishing space and time distribution of PM2.5. The main source of air pollution in smog-polluted cities is the burning of fossil fuels and construction debris, and the vegetation coverage ratio is an exception (H. Xu & Chen, 2021). Spatial composition and design of urban land uses have a direct relationship with air pollutants distribution; man-made land uses show positive correlation with NO2 and SO2 while the greenspace is correlated with negative CO and positive with O3 (Gheshlaghpoor et al., 2022). Urban designs are of a particular pattern such as heat islands, street layouts, building density, and urban forms that play an important role in the direction of pollutant distribution. This arrangement of the wind system is responsible for changing the distribution of pollutants, retaining them or dispersing them and determining the pollution variations across different urban and rural areas. The configurations created in the city may either show more or less air pollution at different times of the day and seasons. This indicates the complexity of the dynamics of air pollution in an urban area and why urban morphology should be taken into consideration in urban planning and public health strategies.

Considering the fact that air pollution is indeed a critical issue related to human health, environmental quality, and general public well-being, dealing with transport-related air pollution has stood out as a mandatory priority for the policy makers, urban planners, public health officials, and environmental advocates throughout the globe (Adams-Hosking et al., 2011; Himanen et al., 2004). Assessing urban planning models in terms of their relationship with transport systems and air pollution levels is absolutely vital for the success of policies to mitigate air pollution, to safeguard the health of the public and to design healthier and more sustainable urban spaces (Martos et al., 2016). Urban environments, which are marked by complex interactions among a number of factors, such as land use patterns, transport systems, weather conditions and socio-economic processes, are in the form of complex networks of interacting components. The urban configurations ranging from different cities to different regions, cover a lot of ground and can be a mixed bag in terms of street layouts, building designs, parks and the transport system. Data availability and quality are 2 out of the many challenges associated with the study of transport-induced air pollution and its connection to the urban landscape (Haines et al., 2007).

Within the current literature, the studies often examine urban transportation and urban morphology separately. This results in insufficient understanding of their combined effects on urban air quality. There is a need for comprehensive synthesis of existing knowledge on how specific urban design elements influence traffic-related air pollution. This study will examine the intersection between the urban setup and air pollution caused by transport, with a particular emphasis on the impact of the various design elements of a city, including streets, building density, green spaces, and transportation infrastructure, on pollution distribution in urban areas. This study intends to answer the following research objectives; first, synthesise existing knowledge on the influence of urban canyon design elements (e.g., street orientation, building height) on traffic-related air pollution in urban areas. Second, identify and critically evaluate the methodological approaches used in scientific research to assess the spatial distribution of air pollutants within urban environments. Finally, Analyse the current understanding of the combined effects of urban canyon geometry and transportation patterns on air pollution dispersion and concentration, as presented in the literature. This study seeks to achieve this by investigating the objectives, thereby enriching the scientific knowledge of the intricacy of urban structure and air quality relationships, influence decision-making processes, and support the efforts of overcoming the repercussions of transport-driven air pollution on the public health and environmental quality of urban ecosystems.

Objectives and Research Focus:

The project aims to explore resilient and sustainable urban transport strategies to mitigate the repercussions of transport-induced pollution. This involves integrating advanced sensor-driven models from Manchester and Bangkok with societal and policy insights from Yangon, addressing unique challenges faced by urban areas in the ASEAN region. Emphasising community engagement, the project seeks to facilitate context-specific interventions across diverse urban landscapes, aligning with ODA (Official Development Assistance) considerations. The objectives are directly responsive to identified challenges, aiming for improved urban air quality, enhanced public health, advanced monitoring systems, community-informed policies, and the creation of a knowledge hub for best practices and insights (Beevers et al., 2020; Zhang et al., 2021; Kan et al., 2012; Sabel et al., 2016, Cohen et al., 2005; Schraufnagel et al., 2019).

The project aims to develop a comprehensive approach to mitigate transport-induced air pollution in urban areas, with a focus on Manchester, Bangkok, and Yangon. It seeks to leverage advanced technologies, stakeholder engagement, and policy innovation to create sustainable and healthy urban environments. The objectives are structured to respond directly to the challenges and gaps identified in the problem statement.

The activities undertaken in the BREATHE-Cities project directly contribute to answering the specified research questions through targeted research, technological innovations, policy analysis, and community engagement.
Research Questions and undertaken actions to answer them:

1. How can urban planning and transport policies be optimized to reduce air pollution and its health impacts in diverse urban settings?
    - **Ongoing Urban Planning and Policy Analysis**: The project analyses the impact of current urban planning and transport policies on air quality, using data-driven approaches to identify areas of improvement. By examining policies in diverse urban settings, the project identifies best practices for optimizing urban layouts, traffic flow, and public transportation systems to minimize air pollution.
    - **Integration of TOD and 15-Minute City Concepts**: these concepts have been implemented in the data collection phases in each city (Manchester, Bangkok and Yangon, see section on data collection), allowing an analysis of current dependency on private vehicles and traffic-related pollution. The project evaluates the impact of these planning concepts in air pollution levels with a view to support the suggestion of adjustments tailored to each city's unique context.

2. What are the most cost effective and efficient technological interventions for monitoring and managing air quality in the context of urban transport?
    - **Sensor Technology Deployment:** The project employs novel sensor technologies for real-time air quality monitoring, focusing on areas with significant traffic in Manchester, Bangkok, and Yangon as per the description in the data collection section of the current report. This approach allows for the integration of current available Landsat data to identify urban heat island within the selected cities together with air quality data with validation of the micro level of the measured data through field studies. This allows for the identification of pollution hotspots as a result of transport and mobility and the assessment of pollution trends over time.
    - **Ongoing Data Analytics for Policy Intervention:** By analysing the collected data, the project identifies which technological interventions are most effective in monitoring and managing air pollution, using available data as well as field measured data, considering factors like cost, scalability, and impact on air quality. Currently being processed following the data collected in the three selected contexts.

3. How can community engagement and stakeholder collaboration enhance the implementation and sustainability of air quality initiatives?
    - **Ongoing Community Workshops and Surveys:** Engaging with local communities through 3 workshops out of 6 (thus far) and 1 survey (ongoing) has provided valuable insights into public perceptions of air quality issues and potential solutions. This feedback is crucial for tailoring interventions to community needs and ensuring public support. The teams from Bangkok and Manchester have participated in one of the community engagement workshops in Yangon on the 25th of February 2024.
    - **Ongoing Collaboration with Local stakeholders and communities:** The project facilitates partnerships between researchers, local stakeholders, and communities to co-create solutions for air quality improvement. These collaborations ensure that interventions are practical, scalable, and aligned with local policies and economic realities. The UK, Thailand and Myanmar partners have met face to face in both Bangkok and Yangon to collect data, meet partners, stakeholders and communities involved to assess the methodology and strengthen partnerships for future development.

4. What are the barriers and facilitators to adopting and scaling up successful interventions across different urban contexts?
    - **Ongoing Comparative Policy Analysis:** By comparing the effectiveness of any existing interventions in Manchester, Bangkok, and Yangon, the project identifies common barriers and facilitators, such as regulatory frameworks, financial constraints, and public awareness. This analysis helps pinpoint critical success factors for scaling up interventions.
    - **Adaptation and Localization Strategies:** The project explores how interventions can be adapted to different urban contexts, considering cultural, economic, and infrastructural differences. This approach is key to overcoming barriers and leveraging facilitators in diverse settings. This will be developed once the 6 workshops, survey and sensor analysis data are completed and preliminary results will be included in the draft report- Outcome 3.

5. How can lessons learned from one urban setting inform strategies in others, particularly in the context of Manchester, Bangkok, and Yangon?
    - **Cross-City Learning Platforms**: The project establishes a knowledge exchange platform where cities can share experiences, strategies, and data. This collaborative approach enables cities to learn from each other's successes and challenges. Ongoing and building on the partners engagement with the respective institutions, stakeholders and involved communities.
    - **Case Studies and Best Practices**: The project team has conducted workshops with researchers on Bangkok who were involved in projects related with air quality. BREATHE project team together with the Thailand researchers have identified and confirmed the gaps in research and policies of air quality micro-studies and the lack of relevance to urban configuration on the 21st of February. Documenting and disseminating detailed case studies from each city, highlighting what worked, what didn't, and why, serves as a valuable resource for other cities aiming to tackle similar air quality issues. To be developed once the draft report is finalised. Some

potential outputs and further collaborations have been discussed during the partners two weeks' project workshops in Bangkok and Yangon from the 19th to the 28th of February 2024.

The activities undertaken in the BREATHE-Cities project comprehensively address the posed research questions through a multi-faceted approach that includes data-driven analysis, technological innovation, community engagement, and cross-city collaboration. By focusing on the optimization of urban planning and transport policies, the implementation of cost-effective technological interventions, the enhancement of community engagement and stakeholder collaboration, and the identification of barriers and facilitators to intervention adoption, the project lays a foundation for scalable and sustainable air quality improvements across diverse urban settings. Additionally, the project's emphasis on lesson sharing and comparative analysis ensures that successes in one city can inform strategies in others, fostering a global approach to urban air quality management.

The objectives and research questions of this project are designed to address the multifaceted issue of transport-induced air pollution in urban areas. By focusing on advanced technological interventions, community engagement, policy innovation, and knowledge transfer, the project aims to create lasting improvements in air quality, public health, and urban sustainability. The ultimate goal is to alleviate the current burden of air pollution in target cities but also to provide a replicable model for other cities facing similar challenges.

Literature Review:

Methodology

Systematic literature review was conducted as the systematic process framework divided into two broad categories as per Figure 1. First, we employed Microsoft Excel for paper coding and statistical analysis to get a general idea of the quantitative information of the papers, including the number of papers published in each year and the geographical sites they covered. Excel was also useful in developing multiple categorization methods for defining the type of content in the target literature more comprehensively.

This made it easier to conduct a systematic and coherent evaluation of the collected papers. Secondly, to build and visualise the scientometric macro network of the research literature, we used VOS viewer. It allowed us to view the relationships between different works, and thus, got a more holistic view of the academic voids and the directions of research. Thus, defining these connections, we succeeded in defining the gaps in the existing research, the topics that are currently popular, and the general trend in the given field of research. This two-step approach helped to achieve the best result since the first step involved detailed statistical analysis, while the second step provided scientometric visualisations that helped to get a broad view of the literature.

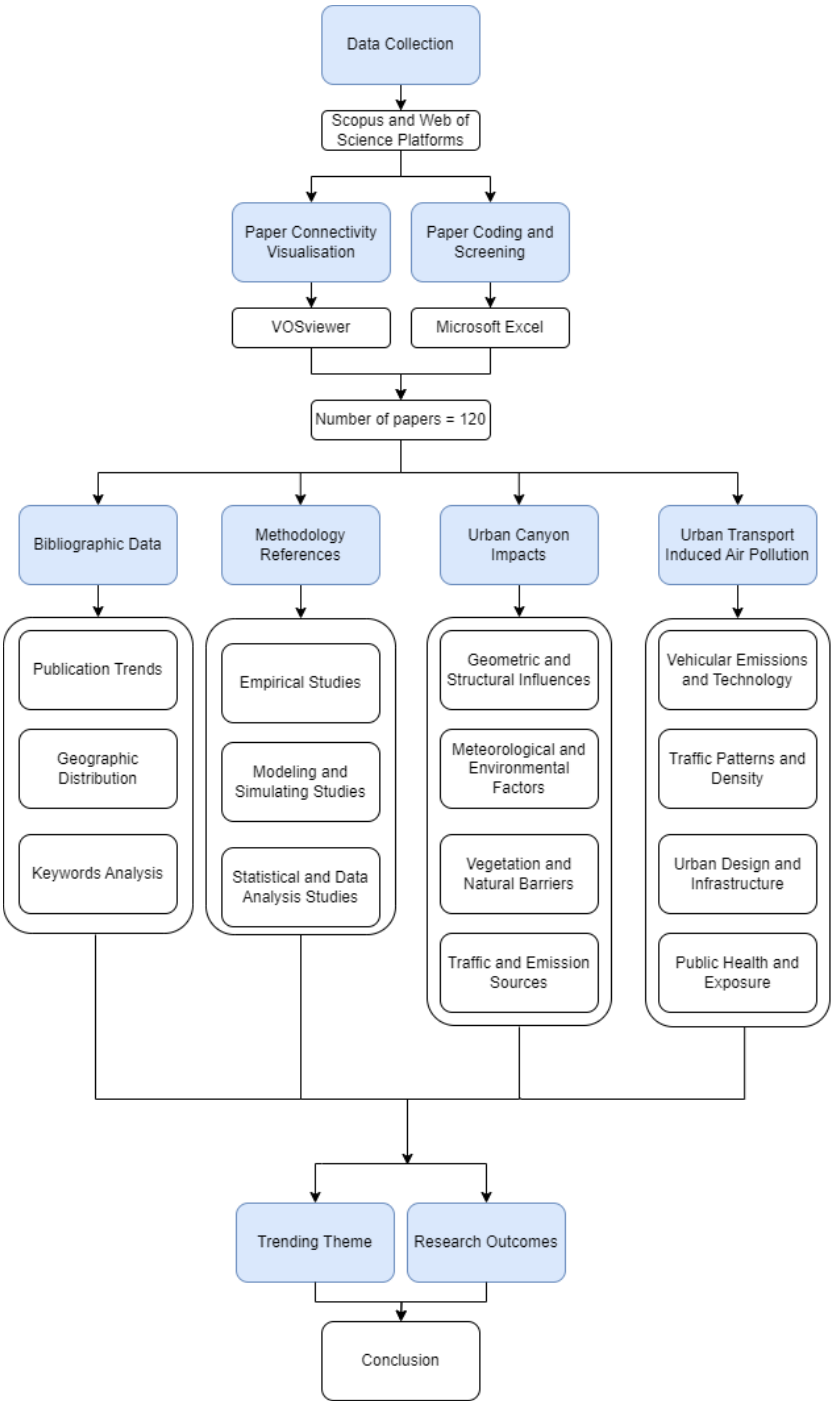


Figure 1:Methodology flowchart of the systematic Literature review

Database search

A thorough exploration of the literature was carried out using a prominent electronic database, Scopus, to pinpoint relevant articles. The literature search strategy involved the systematic use of keywords such as, transport-induced pollution, urban heat island, air pollution and human health, transport hub, urban air, air particles, air pollutants, urban canyons, in various combinations.

A thorough exploration of the literature was carried out using prominent electronic databases, Scopus and Web of Science, to pinpoint relevant articles (Figure 2). The literature search strategy involved the systematic use of keywords such as, transport-induced pollution, urban heat island, air pollution and human health, transport hub, urban air, air particles, air pollutants, urban canyons, in various combinations.

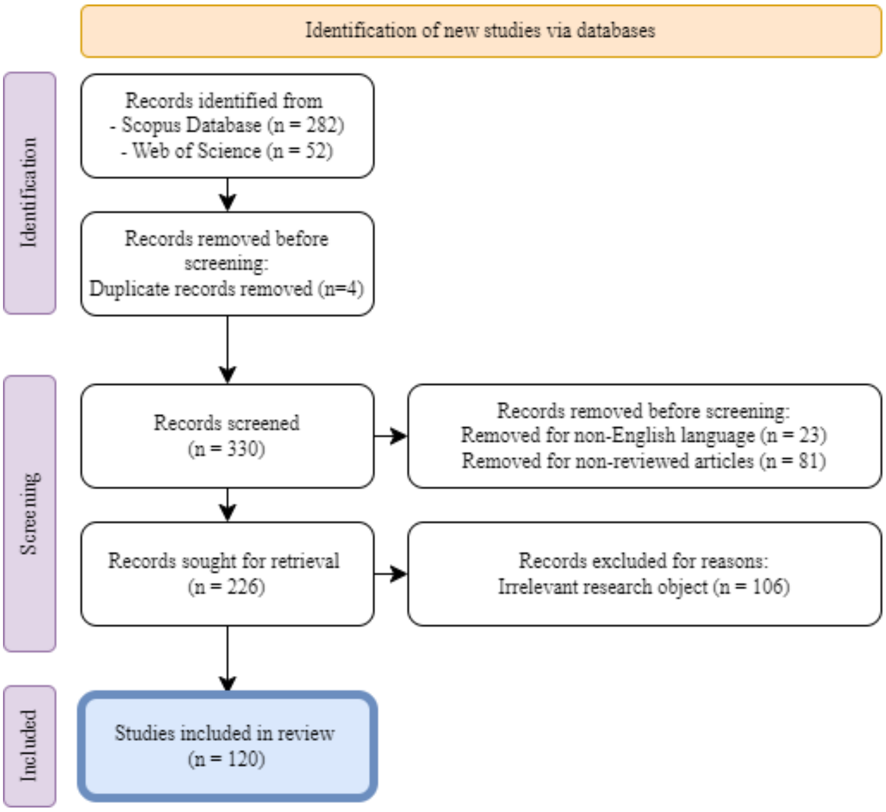


Figure 2: Flow diagram for screening

To ensure the relevant articles and avoid duplications, we followed specific the inclusion and exclusion criteria (see Table 1). Only empirical studies conducted on transport induced air pollution and urban configurations and recommendations were included in this review. Additionally, our study included only peer-reviewed articles published in English globally, while non-English articles and documents were excluded. There are no temporal limitations in this study.

Table 1: Inclusion/Exclusion Criteria

Criteria	Included	Excluded
Geographical area mentioned in the article	Global	N/A
Publication date	1986-2024	N/A
Language of publication	Peer reviewed journal articles written in English	Non-English articles
Types of articles	Only peer reviewed articles	Non-peer reviewed journals
Accessibility of articles	Articles accessible through the electronic databases (Scopus)	Not accessible through these database

Main theme of the articles	Articles specifically focusing on the urban transport or urban canyon and their relationship with urban pollution	Articles that did not specifically focus on the urban transport or urban canyon and their relationship with urban pollution

Analysis Stage

VOS viewer and Microsoft Excel are two prominent and widely used software. This study incorporates these softwares for bibliometric analysis and visualising a wide range of connectivity (clusters) between different papers to indicate the intrinsic meaning of the paper database. These programs enable the creation of bibliographic data maps that are colour-coded and provide an insightful representation of the underlying data. Additionally, the keywords co-occurrence analysis identifies clusters of keywords and creates networks of co-occurring keywords. As a result, critical keywords in papers can be revealed, along with trending topics and concepts throughout the entire research field.

Results

VOS Viewer keywords analysis

VOS Viewer software is used for the keywords analysis. Full counting method was used at a minimum occurrence of 4. The analysis resulted in 98/1137 keywords in All Keywords, 11/268 keywords in Author Keywords and 87/987 keywords in Index Keywords (See Figures 3 - 5).

The visualisation of keyword networks reveals the presence of four distinct clusters (see Figure 3). The first cluster (Cluster 1) is characterised by terms such as "street canyon," "urban canyon," "air quality," "pollutant transport," and "pollutant dispersion." The second cluster (Cluster 2) encompasses keywords such as "atmospheric pollution," "air pollution," "urban area," and "particulate matter." In Cluster 3, keywords like "air pollutants," "exhaust gas," and "vehicle emissions" are prominent. Finally, Cluster 4 is composed of keywords such as "priority journal," "dispersion," "traffic emission," and "mathematical models". The colour of the items and lines determine the cluster in which they belong to. The strongest co-citation links between the keywords are also indicated by lines.

- **Cluster 1** (Red) focuses on the physical aspects of urban environments, emphasising factors like street and urban canyons that influence air quality through pollutant transport and dispersion.
- **Cluster 2** (Green) centres around broader terms related to atmospheric pollution, particularly focusing on air quality issues within urban areas and the presence of particulate matter.
- **Cluster 3** (Blue) delves deeper into the sources of air pollution, specifically highlighting exhaust gas and vehicle emissions as significant contributors to urban pollution.
- **Cluster 4** (Yellow) appears to concentrate on methodological and research-related keywords, including references to priority journals, dispersion models, traffic emissions, and mathematical modelling techniques. This cluster suggests a focus on academic research methodologies and analytical frameworks within the context of urban pollution studies.

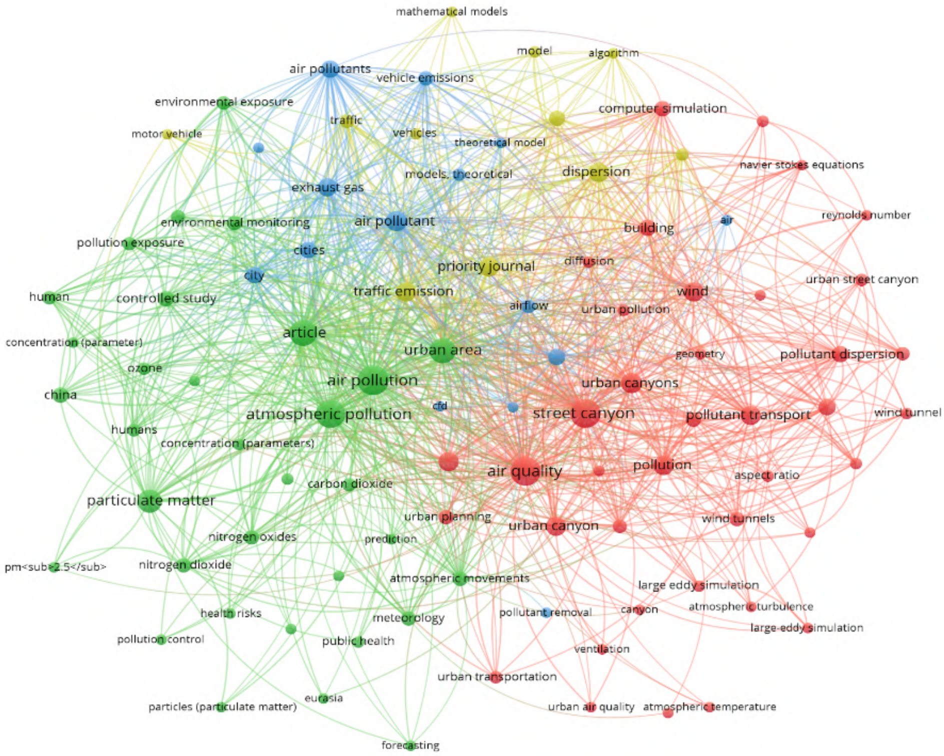


Figure 3:Network Visualisation of All Keywords (Source: VOS Viewer)

The author keywords are organised into four distinct clusters, as illustrated in Figure (4). Cluster 1 is primarily associated with the keywords "air pollution" and "PM2.5". Cluster 2 encompasses terms such as "street canyon" and "pollutant dispersion". Cluster 3 is characterised by keywords including "urban canyon," "air quality," and "large-eddy simulation". Cluster 4 comprises keywords like "urban street canyon," "urban air quality," and "particulate matter".

- **Cluster 1** appears to focus on general aspects of air pollution, particularly emphasising PM2.5, which is a specific type of particulate matter known for its adverse health effects.
- **Cluster 2** seems to delve into the dynamics of pollutant dispersion within street canyons, indicating a specific interest in understanding how pollutants are transported and dispersed in urban environments.
- **Cluster 3** suggests a focus on more detailed modelling approaches, incorporating concepts like urban canyons and large-eddy simulation techniques to study air quality dynamics.
- **Cluster 4** expands on the previous clusters by focusing on specific urban contexts, such as street canyons, and their implications for urban air quality, particularly concerning particulate matter concentrations.

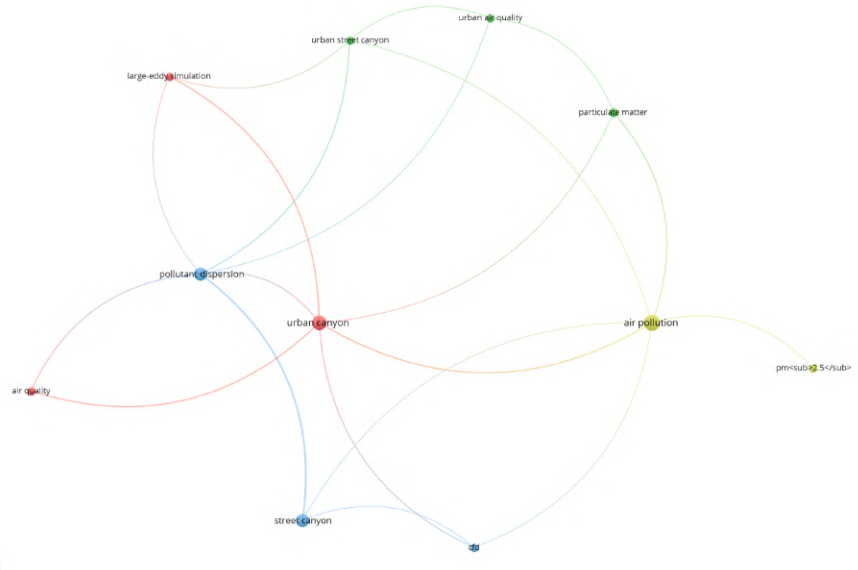


Figure 4:Network Visualisation of Author Keywords (Source: VOS Viewer)

When analysing the index keywords, prominent terms such as "air quality," "street canyon," "air pollution," "atmospheric pollution," "pollutant transport," and "urban pollution" emerge as significant. These keywords are organised into five distinct clusters, as depicted in Figure (5).

Cluster 1 encompasses terms related to modelling, traffic, and mathematical models, indicating a focus on analytical approaches and traffic-related dynamics. Cluster 2 includes keywords associated with air pollution, atmospheric pollution, particulate matter, and prediction, suggesting a concentration on forecasting and understanding the dynamics of atmospheric pollutants. Cluster 3 comprises terms such as atmospheric pollution, pollution exposure, controlled study, and exhaust gas, indicating a focus on investigating pollution exposure and its impacts through controlled studies. Cluster 4 is characterised by keywords related to air quality, street canyon, and pollutant transport, highlighting a focus on understanding the dynamics of pollutants within urban environments, particularly within street canyons. Cluster 5 (Purple) focuses specifically on urban canyons, indicating a specialised interest in the unique atmospheric conditions found within urban landscapes. Additionally, terms like pollution, priority journal, dispersion, and roads and streets are dispersed across these clusters, suggesting broader contextual elements and methodological considerations within the scope of the research.

- The presence of multiple clusters focusing on air quality, air pollution, and pollutant transport highlights the complexity and multidimensionality of these topics within urban environments.
- The inclusion of modelling-related terms emphasises the importance of mathematical models in studying and predicting urban air quality dynamics and pollutant dispersion.
- The emphasis on controlled studies and pollution exposure in Cluster 3 suggests a focus on empirical research aimed at understanding the direct impacts of pollution on human health and the environment.
- The specific focus on urban canyons in Cluster 5 indicates a specialised interest in the unique atmospheric conditions and pollutant concentrations found within these urban microenvironments.

The overlay visualisation of All Keywords provides insights into the temporal evolution of keyword usage within the research. Notably, certain keywords emerged earlier, while others appeared more recently (Figure 4). In the early stages of research, around 2010, keywords such as "dispersion," "wind," "model," "urban street canyons," and "pollutant transport" were prevalent. This suggests a focus on understanding the dynamics of pollutant dispersion within urban environments and the role of atmospheric processes such as wind in pollutant movement.

As research progressed, new keywords emerged, reflecting evolving interests and methodologies. For instance, by 2020, terms like "ventilation," "atmospheric movements," "cities," and "pollution exposure" became prominent. This shift indicates a growing emphasis on factors influencing urban air quality, including ventilation patterns and the exposure of urban populations to pollution.

Figure 5:Network Visualisation of Index Keywords (Source: VOS Viewer)

Interestingly, certain keywords maintained their relevance throughout the years. For instance, "urban area," "street canyon," and "air pollution" were already significant in 2012 and remained so over time. This continuity suggests enduring interest and ongoing research into fundamental aspects of urban air quality and pollution dynamics.

- The temporal evolution of keywords reflects changing research priorities and methodologies within the field of urban air quality and pollutant transport.
- Early research focused on understanding the physical processes driving pollutant dispersion, such as wind patterns and street canyon effects.
- Over time, there has been a shift towards investigating broader factors influencing urban air quality, including ventilation dynamics and pollution exposure.
- Certain keywords have maintained their importance throughout the years, indicating ongoing interest and research into fundamental aspects of urban air pollution.

The density visualisation described utilises a colour gradient ranging from blue to green to yellow, which serves as a representation of keyword density within the selected papers. In this gradient, blue signifies areas of lower density, while yellow indicates higher density. Analysis of the density visualisation of All Keywords reveals that terms such as "air pollution," "atmospheric pollution," "air quality," and "street canyon" exhibit the highest density among the selected papers. Following closely are keywords like "pollutant transport," "traffic emission," "particulate matter," and "pollutant dispersion."

Conversely, terms such as "mathematical models," "pollution control," "forecasting," and "atmospheric temperature" are noted to have lower density, suggesting they may receive comparatively less emphasis or exploration in the literature. This visual representation facilitates the rapid identification of key themes and areas of focus within the literature on urban air pollution. It contributes to a nuanced understanding of the research landscape by highlighting which topics receive more attention and which may warrant further investigation or development.

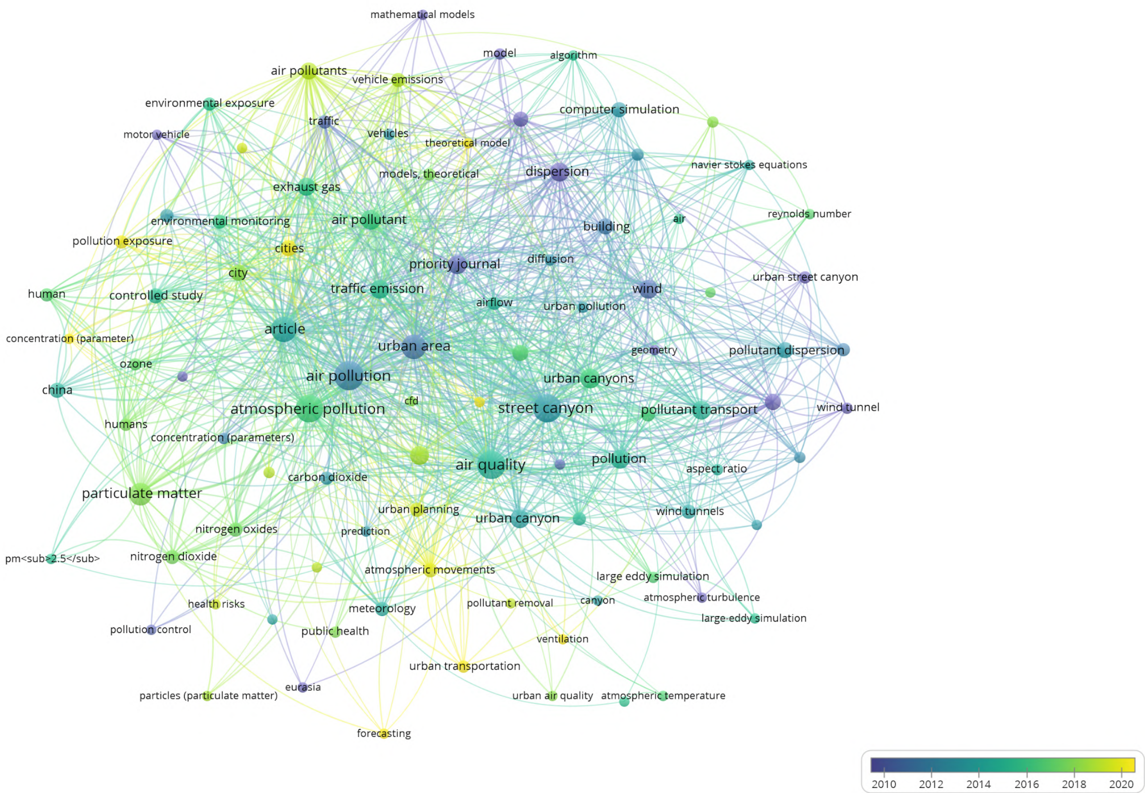


Figure 6: Overlay Visualisation of All Keywords (Source: VOS Viewer)

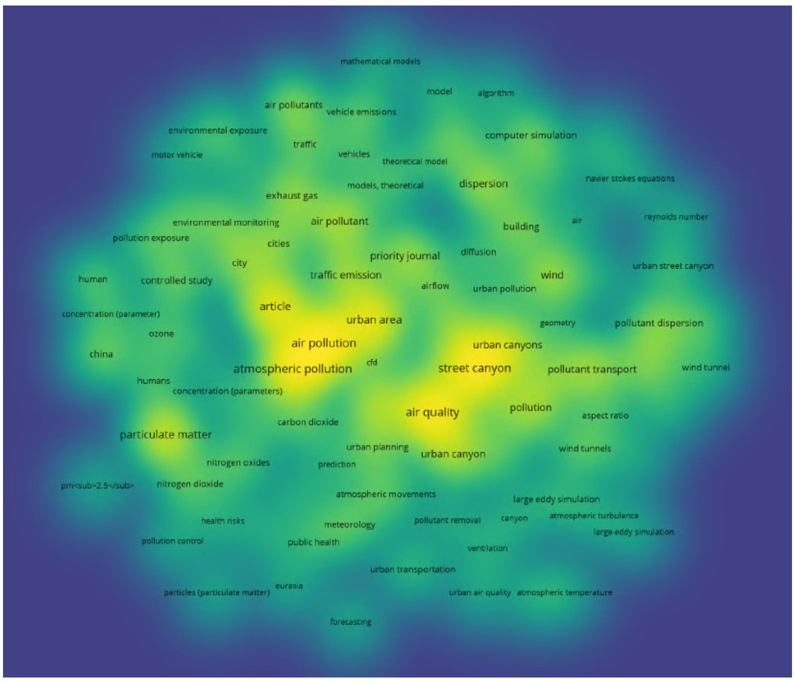


Figure 7:Density Visualisation of All Keywords (Source: VOSViewer)

Bibliographic analysis

The noticeable uptick in published documents post-2016 suggests a potential surge in interest or awareness surrounding urban pollution issues during that period. This temporal trend could be attributed to various factors, including heightened urbanisation, increased climate awareness, or advancements in research methodologies. The peak in publications occurred in 2022, indicating a particularly prolific year for research output in this field.

Given that the review was conducted in February 2024, it's essential to acknowledge that some papers from 2023 and 2024 may not have been indexed yet. Thus, the full extent of recent research contributions might not be fully represented in the analysis. Figure (6) likely offers a visual representation of how the selected articles are distributed across different years, providing insights into the temporal evolution of urban air pollution research within the region.

- The sharp increase in published documents post-2016 indicates a growing interest and awareness of urban pollution issues, likely influenced by various socio-environmental factors.
- The peak in publications in 2021 suggests a particularly active period for research output, possibly driven by heightened attention to urban environmental challenges.
- The acknowledgment of potential gaps in indexing for recent years underlines the importance of interpreting temporal trends with caution and considering potential limitations in data coverage.
- Figure 8 serves as a valuable tool for visually understanding how research on urban air pollution has evolved over time, offering insights into patterns and trends in scholarly output within the field.

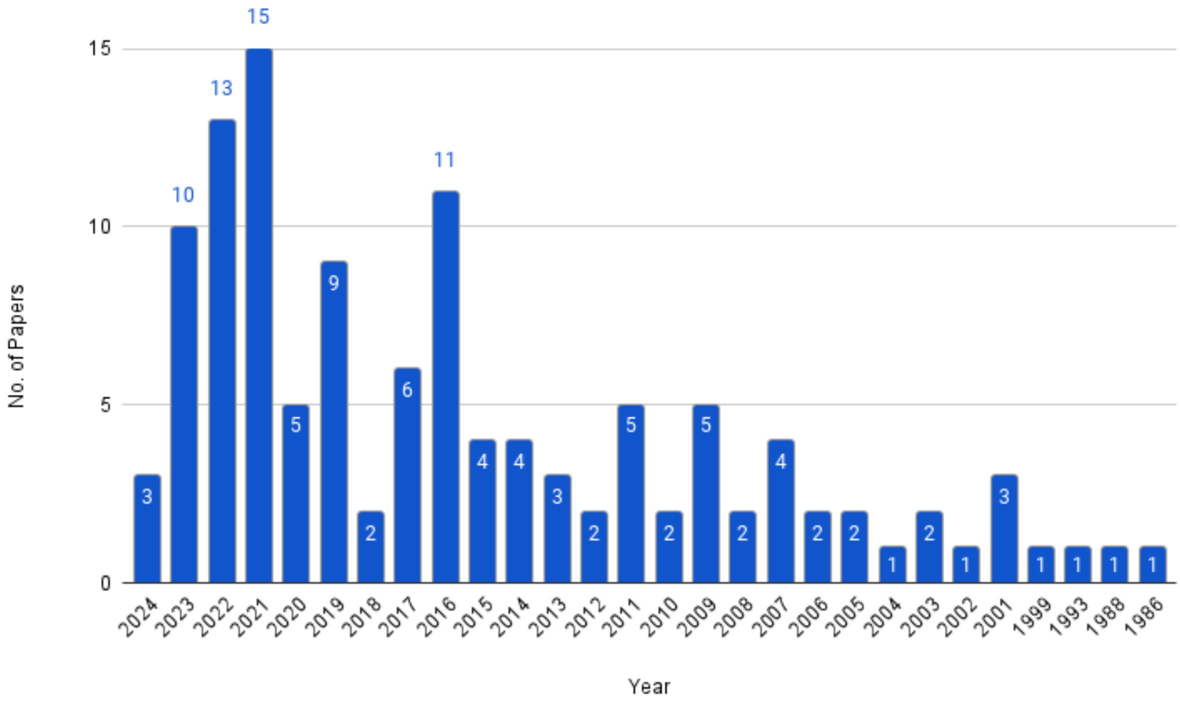


Figure 8:Publications over time in the context of urban canyon and urban transport

The allocation of the documents between countries is described as represented in Figure (9). Research on urban air quality is a course that has Europe as its main contributor as regards the highest number of papers published. This bid shows the region is keen to tackle air pollution issues and also improve the understanding of science in this field. European states have put forth strict air quality standards and have funded research programs focused on dealing with the issue of urban air pollution leading to a solid database on the topic China's publication of urban air quality papers regarding the number of countries is the largest among individual countries. Indeed, this statement shows the present distinguished air pollution problem in China, which is the result of intense industrialization, massive urbanisation, and massive motorization. The Chinese authorities have added air pollution monitoring and control to high-priority development programs, which thus have stimulated more and more research and publication in this field. Interestingly, the lack of papers published from Australia and South America likely means that air quality is not a research priority of the cities in these regions. This could be the low support that researchers are getting to conduct the research, limited institutional capacity, and it could be low public awareness of air pollution related issues. Filling this gap, researchers and policymakers in Australia and South America could make exemplary contributions to the world's discussion on the quality of urban air and be inspired by the best practices that have been implemented in other global cities. Southeast Asia is tagged to be the most lapsed region in the race of urban air pollution research. Hence, this finding indicates that the area has problems in dealing with air pollution problems, regardless of the development that is happening in the urbanisation and the industrialization process. Factors including scarce research infrastructure, scarcity of data, and underdevelopment of institutions can impend research undertakings in Southeast Asia. Increased joint work among researchers, as well as economic resources from States and international organisations, could be a chance to resolve these issues and make progress in urban air quality studies in this region.

The survey of paper distribution between different countries demonstrates the global importance of the issue and shows that to deal with the challenges of air pollution in different regions collaboration is needed. This mapping process would allow to identify the strengths as well as weaknesses in the existing research and would consequently help to better direct future research lines as well as policy intervention aimed at improving the air quality of urban agglomeration globally.

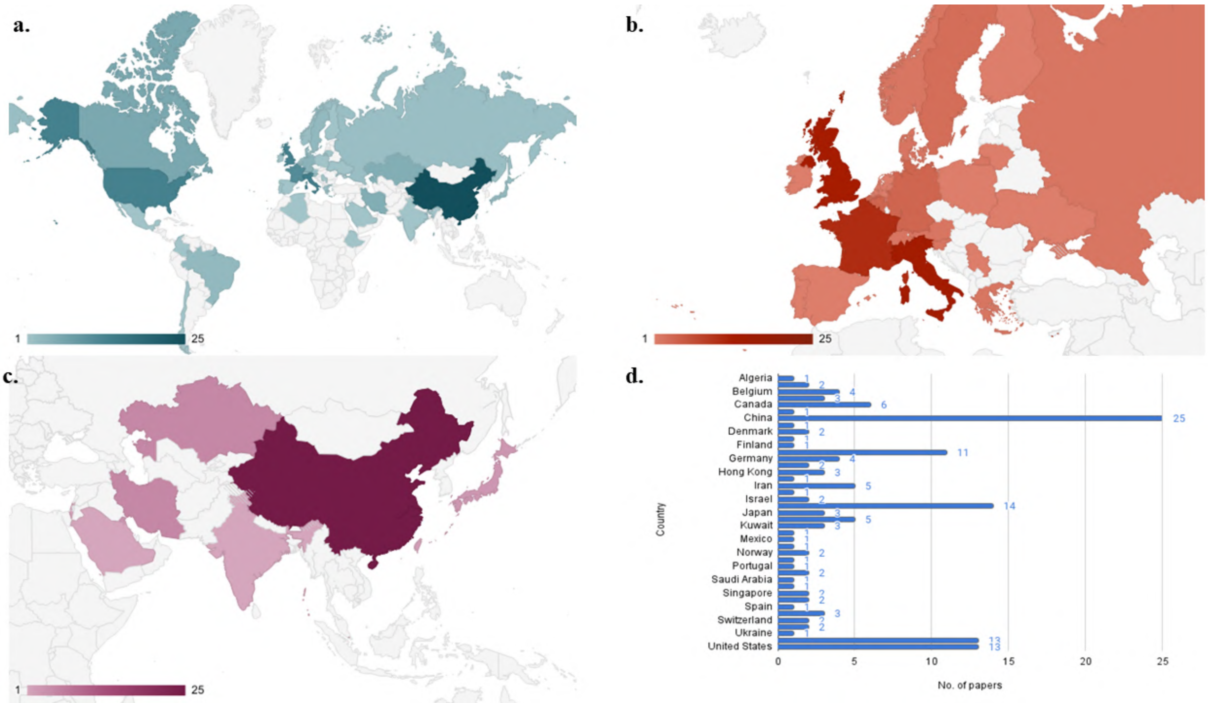


Figure 9:Distribution of papers by countries a. global distribution of papers b. European distribution of papers c. Asian distribution of papers d. total number of papers by country

Abstract & Title Analysis

Methodology References

Bizualem et al., (2023) conducted air quality monitoring in Addis Ababa, Ethiopia, utilising 41 sampling points, employing hand-held portable air test equipment (Model-CW-HAT2005) and Aeroqual Series 500 (2016). (J. Xu et al., 2016) conducted air quality measurements at four sites with varying land use and building characteristics, analysing factors such as traffic volume, meteorological variables, and built environment features. (Wang et al., 2016) conducted roadside NO2 measurements paired with meteorological data and traffic information collected from video cameras at intersections. (Yassin et al., 2008) investigated concentration fields in urban canyons using numerical simulations. (Tang & Wang, 2006) conducted tests in close proximity to vehicles to measure gaseous emissions and particle exposures. (T. Li et al., 2019) investigated the spatial and temporal emission patterns of taxis in Beijing, China, using traffic analysis zones (TAZs) as the analysis unit. (Luo et al., 2017) analysed the energy consumption and emissions of taxis in Shanghai, China, employing big data analysis on GPS data from taxis.

Table 2: Types of methodology references

Type	Key Findings	Reference
Empirical Studies	Measurement of key pollutants Spatial and temporal analysis Policy relevant insights for urban planning and regulation Limited generalisability from single location studies	(Bizualem et al., 2023; Bono, 2001; Carlo et al., 2024; Chan et al., 2003; Perišić et al., 2017; J. Xu et al., 2016)
Modelling and Simulating Studies	Advanced simulation tools are essential for analysing pollutant dispersion in urban environments Use of various simulation models allows for comprehensive analysis under different urban configurations and meteorological conditions Studies often integrate multiple factors including emission sources, chemical reactions and physical processes, providing a holistic view of urban air pollution Validation against experimental data ensures reliability High data and computational requirements Limited generalisability to different urban contexts	(Aliabadi et al., 2017; Baghlad et al., 2019; Baradaran Motie et al., 2023; Chan et al., 2001, 2003; Dai et al., 2022; Gayev & Savory, 1999; Gonzalez Olivardia et al., 2019; Gross, 2016; Issakhov et al., 2020, 2022; Issakhov, Omarova, & Abylkassymova, 2023; Issakhov, Omarova, Mashenkova, et al., 2023; Lauriks et al., 2021; Lee et al., 2022; Librando et al., 2009; Patania et al., 2006; Soulhac et al., 2023; Tang & Wang, 2006; Wang et al., 2016; Yamartino & Wiegand, 1986; Yassin et al., 2008; Zavala-Reyes et al., 2019)
Statistical and Data Analysis Studies	The studies utilise GIS tools to map and analyse spatial emission patterns, enabling a clear visualisation of pollution hotspots and their correlation with urban infrastructure. The identification of specific times with peak emissions provides valuable insights into the dynamics of urban traffic pollution and its association with daily human activities. The studies are regional specific and potentially data biassed as they employed GPS data from taxis in Beijing and Shanghai.	(T. Li et al., 2019; Luo et al., 2017)

Urban Canyon Impacts on Air Pollution

(Cui et al., 2024) investigated the impact of envelope features on pollutant exposure in street canyons. They analysed two geometries, one with a smooth building roof and the other with obstacles atop the upwind building roof. (Issakhov et al., 2022) demonstrated that barrier viaducts play a crucial role in improving air quality in urban canyons. (Carlo et al., 2024) observed that urban canyon attributes such as obstacle height and surface roughness influence pedestrian pollutant exposure. (Gonzalez Olivardia et al., 2019) emphasised the significance of roadside emissions and airflow patterns in determining pollutant concentrations within urban canyons. (Dai et al., 2022) found that peroxyl radical production affects NO2 and O3 levels in deep canyons, underscoring the importance of vertical distribution in health assessments and urban air quality strategy development. (Kandelan et al., 2022) found significant correlations between Air Quality Index rates and green spaces, as well as wind direction.

(Bizualem et al., 2023) obsserved statistically significant differences in pollution levels among sampling locations, indicating significant spatial variation within the study site.

Table 3:Urban canyon impacts on air pollution

Type	Key Findings	Reference
Geometric and Structural Influences	Various geometric elements such as roof-edge roughness elements, barriers, green spaces and building configurations significantly influence airflow patterns and pollutant dispersion within urban canyons. The relationship between airflow patterns and pollutant dispersion change over different times of the day is investigated. The studies validate their numerical models using experimental data, ensuring the accuracy of simulations in representing real world conditions. Numerical simulations rely on certain assumptions and parameters which may influence the accuracy of the results.	(Aliabadi et al., 2017; Baghlad et al., 2019; Baradaran Motie et al., 2023; Buccolieri et al., 2022; Carlo et al., 2024; Chan et al., 2001, 2003; Cintolesi et al., 2021; Costabile & Allegrini, 2007; Hoydysh & Dabberdt, 1988; Y. Huang et al., 2015; Issakhov et al., 2022; Michioka et al., 2011; C. T. Ng & Liu, 2014; Patania et al., 2006; Qin & Kot, 1993; Salmond et al., 2005; Sin et al., 2022; Yassin et al., 2008; Yassin, 2011)
Meteorological and Environmental Factors	Meteorological conditions such as wind speed, wind direction, temperature and atmospheric stability play a crucial role in shaping air quality dynamics and pollutant transport within urban canyons. The interplay between meteorological factors, urban morphology and pollutant sources is complex and varies across different urban settings. Computational fluid dynamics (CFD) modelling and numerical simulations are common methodologies used to study airflow patterns, pollutant dispersion and the impact of urban morphology in air quality.	(Aliabadi et al., 2017; Chan et al., 2003; Costabile & Allegrini, 2007; Dai et al., 2022; Gonzalez Olivardia et al., 2019; Klausner et al., 2021; X. Li, 2008; Marulanda Tobón et al., 2020; Shang et al., 2023; J. Xu et al., 2016; Zhang et al., 2021; Zhou et al., 2019)
Vegetation and Natural Barriers	Green spaces and barriers such as trees and hedge barriers can improve air quality by reducing pollutant concentrations. The type of placement of vegetation have varying effects on thermal comfort and pollution reduction.	(Baradaran Motie et al., 2023; Buccolieri et al., 2022; Carlo et al., 2024; Chan et al., 2003; Kandelan et al., 2022)

Traffic and Emission Sources	Near road concentrations of pollutants exhibit spatial variability influenced by factors such as traffic volume, build environment and meteorological conditions. Wind direction plays a crucial role in determining the dispersion patterns of pollutants emitted from traffic sources. Certain urban areas, particularly those near transport hubs and heavy traffic corridors, are identified as pollution hotspots.	(Baghlad et al., 2019; Bizualem et al., 2023; Bono, 2001; Buccolieri et al., 2022; Carlo et al., 2024; Chan et al., 2003; He et al., 2023; Kholodov et al., 2022; Kosheleva et al., 2019; Lee et al., 2022; Schmeer et al., 2023; Vardoulakis et al., 2002; Wang et al., 2016; Wu et al., 2020; Yassin, 2011, p. 2)

Urban Transport Induced Air Pollution Impacts

Zavala-Reyes et al., (2019) demonstrated that vehicular technology, such as Euro 6 vehicles, significantly reduced exposure to PM2.5 and NOX compared to Euro 5 vehicles. (Luo et al., 2017) analysed the spatial and temporal distribution of energy consumption and emissions in Shanghai, China. (Tang & Wang, 2006) compared emissions from diesel taxis and trucks with those from petrol passenger cars and trucks. (Zhu et al., 2021) measured air pollutant concentrations and meteorological factors in a transport hub over a year. (T. Li et al., 2019) identified patterns in taxi trips and emissions within and between traffic analysis zones (TAZs). (Haynes & Savage, 2007) assessed particulate pollution levels in Kings Cross before and after redevelopment work. (W.-Y. Ng & Chau, 2014) investigated the effectiveness of building separation and setbacks in reducing personal air exposures in urban canyons. (Y. Huang et al., 2015) compared air pollutant exposures and respiratory health outcomes between participants in a transport hub and a park.

Table 4:Urban Transport Induced Air Pollution Impacts

Type	Key Findings	Reference
Vehicular Emissions and Technology	Road dust in urban areas, particularly near traffic polluted sites, contains high concentrations of metals like chromium, zine, lead and copper. Transport hubs in the cities experience high levels of particulate and gaseous pollutants. Implementation of policy measures to reduce vehicular emissions can lead to significant reductions in air pollution.	(Adamiec, 2017; Bizualem et al., 2023; Bono, 2001; Chan et al., 2003; Cheng et al., 2011; Luo et al., 2017; Wang et al., 2016; Zavala-Reyes et al., 2019; Zhao et al., 2022)
Traffic Patterns and Density	There is a positive correlation between road density and emissions. Air pollution levels vary spatially within urban areas with hotspots of pollution concentration observed near major traffic arteries and interactions. The temporal emission patterns align with daily rush hours, highlighting the impact of commuter behaviour on urban air quality.	(Adamiec, 2017; Baghlad et al., 2019; Bizualem et al., 2023; Bono, 2001; Chan et al., 2003; Jia et al., 2020; T. Li et al., 2019; Luo et al., 2017; L. Yang et al., 2022; Zhu et al., 2021)
Urban Design and Infrastructure	Ground heating influences flow patterns and pollutant dispersion in urban street canyons.	(Buccolieri et al., 2022; Carlo et al., 2024; Chan et al., 2003; Haynes & Savage, 2007; C. T. Ng & Liu, 2014)

	Continuous monitoring of air quality parameters is essential for assessing the effectiveness of urban design interventions. Local meteorological conditions play a critical role in pollutant dispersion and air quality management.	
Public Health and Exposure	Exposure to traffic emission pollutants is associated with adverse health effects, including respiratory and cardiovascular diseases. Exposure levels vary based on pedestrian routes, vehicular technologies, traffic velocities and meteorological conditions. Pedestrians and cyclists are exposed to varying levels of particulate matter and nitrogen oxides depending on traffic scenarios. Ultrafine particles emitted from vehicular exhaust and road dust pose significant health risks due to their small size and ability to penetrate deep into the respiratory system.	(Adamiec, 2017; Baradaran Motie et al., 2023; Bizualem et al., 2023; Bono, 2001; Chan et al., 2003; J. Huang et al., 2016; Pardo et al., 2016; Zhang et al., 2021; Zhu et al., 2021)

Discussion

Through grouping and representation of the keywords, we can reach several important conclusions about the subject of scholarly studies in this area as well as their focus and direction. The research finds that the study on urban air pollution covers a wide range of topics, including various lines of focus. The changing overlay of keywords in the temporal evolution section indicates that the priorities of research have been changed during the time. First research focused on explaining dispersion of pollutants and the influence of atmospheric processes like wind on the pollution. On the contrary, newer studies are tending to pay much attention to the factors like ventilation patterns and pollution exposure. This change highlights that urban air pollution is becoming increasingly recognized as multifaceted and a need for collective efforts in its study is emerging.

Keywords like "urban area", "street canyon", and "air pollution" have remained as the central focus throughout the years, which is a result of researchers' effort to find out more in these areas. Besides that, coming words such as "ventilation", "atmospheric movements", and "pollution exposure" show new trends in those studies which are more generalised with environmental and health effects. The grouping of the clusters based on the methodological keywords shows the need for continuous improvement and development of research methods in this field. The fact that mathematical models and dispersion methods are emphasised, it is clear that there is a continuous work on improving the accuracy and dependability of air quality forecasts. Besides, the controlled studies and pollution exposure emphasise the necessity of empirical study to assess the immediate effect of pollution on the health and the environment.

The density map shows the most common topics that are present in the literature, i.e. "air pollution", "atmospheric pollution", "air quality", and "street canyon". These high-density regions are indicators of well-developed research interests. On the other hand, low-frequency keywords, like "mathematical models" and "pollution control" look for research gaps that need to be filled. The same areas might be used as a basis for more in-depth exploration to build a comprehensive knowledge of urban air pollution mitigation.

Distribution of papers by country shows that certain regions are more productive than others in research output. The continent of Europe is the world leader in the number of publications, and China is also among the countries with the highest number of publications. Nevertheless, the regions such as Australia, South America, and South-East Asia are under-represented, which indicates the lack of geographically diverse research activities, and, thus, the need to undertake them in order to cover the global urban air pollution problem adequately.

The studies made in order to understand urban air pollution utilise several methods and techniques, due to the fact that pollution is dynamic. Diverse methods of urban air pollution research are deployed, involving field measurements, computational modelling, big data analytics, and Geographic Information Systems (GIS), collectively addressing pollution and emission problems. Through cross-referencing the outcomes of different studies, it will be easier to identify the merits and demerits associated with each strategy in diverse scenarios, and this will help in enhancing an overview of urban air quality.

Mobile monitoring is also beneficial in terms of acquiring spatial variability data that are key to mapping of pollution sources. Bizualem et al., (2023) conducted air quality sampling and analysis at 41 different sampling points in Addis Ababa using portable air test equipment and Aeroqual Series 500; this proved the possibility of extensive air quality monitoring in urban environments. While mobile monitoring seems like a very efficient method of monitoring due to its resource intensity and coverage it seems to have its limitations particularly in identifying long-term trends. Portable and affordable sensors make air quality monitoring accessible to anyone for mass deployment which allows to collect data at a high granularity. Their integration with other data sources is necessary for reliability, as it was illustrated by J. Xu et al., (2016) who collected air quality data for different types of urban land use, describing the evaluation of pollution sources. These field measurements give us the opportunity to see the local traffic emissions and the meteorological conditions, although possibly the coverage of this data is limited and the resources are very intensive.

By means of computational models we get a powerful toolbox for sensitivity analysis and mitigation assessment, but their accuracy depends on the data source and the assumptions. Numerical simulations are used to elucidate the concentration patterns of urban canyons which in turn guide the understanding of pollutant diffusion in complex urban environments. Numeric simulation allows better analysis of the pollutant behaviour at different situations. They are used to solve complex problems related to the behaviour of systems in urban environments, but the accuracy of the information largely depends on the quality of the input data and the assumptions made. The use of machine learning algorithms is often characterised by high levels of accuracy and is suitable when dealing with large databases. Data analytic forms big data that can identify the pollution sources and the temporal variations which assists in the policy making but also has a limitation with the data processing. Although they are computationally intensive and need considerable subject knowledge, they offer accurate, application-oriented data for air quality management restricted to users with access to or trained in computing.

GIS helps with spatial pattern recognition and urban planning and, hence, it is possible to visualise pollution dispersion and hotspots, and they depend on the accuracy of the input data. Cumulatively, these methodologies present the interrelation of traffic flows, the built environment features, and the weather conditions in the formulation of the urban air pollution dynamics. As the result of observational analysis, modelling, data assimilation, and hybrid studies, the information about the distribution of air pollutants in urban areas is collected. For instance, J. Xu et al., (2016) and Wang et al., (2016) applied observational findings to address the fluctuations of air quality in distinct cities and various time phases, the relation of traffic congestion, meteorological conditions, and the architectural environment. These findings were supported by Tang & Wang, (2006) as well as Yassin et al., (2008) who made targeted measurements and numerical simulations in order to determine action at the individual emission sources as well as dispersion.

It has been established that air pollutants tend to disperse and concentrate differently where they are in urban canyons. It merges with the geometric formations, the flow of vehicles, vegetation, and weather conditions. Modern cities are characterised by large buildings which create urban canyons, and these affect pollution patterns which determine the concentration as well as the distribution of the pollutants. Characteristics such as building arrangement, the presence of barriers or fences and the surface texture of the roads are considered as the key parameters which define the movement of air and spread of pollutants in the canyon street settings. High rise buildings within urban canyons cause considerable build-up of pollutants due to the 'street canyon' effect and contribute to higher concentrations of traffic related pollutants like NOx and CO. This was demonstrated by Fu et al., (2017) who pointed out that even and uneven heights of buildings as a factor that plays a part in pollutant dispersion. In another study by an anonymous author, cool pavement (Zhang et al., 2021), considered the orientation and structural arrangement of streets as key to increasing the temperatures within the local environment as well as affecting pollutant dispersion; for instance, East-West oriented streets were stated to be hotter. This finding has a close connection with Wagner & Schäfer, (2017), where these authors noted that the atmospheric mixing layer height is important for dispersion of pollutants.

These parameters prove crucial in the dispersion of pollutants within the urban canyons. Similarly, Zhang et al., (2021) showed that perpendicular winds improve the quality of the environment as well as the dilution of pollutants since parallel winds tend to retain pollutants and therefore contribute to their increase. This is in agreement with the simulation analysis by Zavala-Reyes et al., (2019) in whose simulation wind velocity and direction affected pollutant concentration in a simple street environment and hence exposure of pedestrians to the emissions. Another aspect that plays a very important role is the vertical distribution of pollutants and thus the problem remains complex and requires both horizontal as well as vertical treatment of pollutants.

Vegetation function in urban canyons is two-fold. According to Salmond et al., (2005), some of the factors that can affect the concentration of the pollutants include dense tree canopies. On the other hand, Pugh et al., (2012) pointed out that the low-level green infrastructures such as the hedges have the potential of improving air quality by acting as a source of deposition and dispersion of pollutants. This was further evidenced by the study on air pollution in Addis Ababa by Bizualem et al., (2023) where vegetation was found to have influenced the local air quality. Proper positioning of green areas and barrier viaducts in a city planning is an acceptable way to influence pathways and concentrations of pollutants to enhance air quality.

These are aspects such as traffic flow and the type of vehicles in use, which are crucial in influencing emission levels in urban areas. In their study, Thaker & Gokhale, (2016) discovered that greater amounts of traffic and diesel vehicle traffic, in particular, lead to increased pollutants. Similarly, in another work written by Zhang et al., (2021), the author made an analysis of personal exposure to small particulate matter (PM) in sample transportation modes during a peak period in China. The facts highlighted during the evaluation pointed out that during the stay in congested places due to rush periods such as the Spring Festival Travel Rush, there is a staggering enhancement of exposure to pollutants, which affirmed the usefulness of traffic patterns in the quality of air in urban areas.

Urban canyons are interesting elements of urban landscapes because they have a substantial effect on the ways the air pollutants can be accumulated and dispersed. It is therefore important that urban designing and layouts must include the effects that building structures will have on the climate, traffic patterns and rate, water bodies and greenery. The integration of observational measurements, computational calculations, and innovations in modelling strategies for air quality in complex canyons can advance the development of effective policy and innovations in urban design for better air quality. The fight against urban pollution requires the use of the principles from architecture, urban planning, meteorology and environmental science, all asserting the need to design and plan for healthier urban built environments.

By adopting an integrative focus, this work harnesses the methods and comprehensive results of the reviewed studies to provide a systematic analysis of the mechanisms of urban air pollution and possible approaches to addressing the issue. The transport centres are precisely the essential areas where automobiles emit significant concentrations of vehicular pollutants; particularly PM2.5, black carbon, and NOx as pollutants that harm the quality of air. This is compounded by the fact that Zhao et al., (2022) carried out in the Central Plains of China revealed large CO2 emissions from Light Duty Gasoline Vehicles (LDGV) and Heavy-Duty Diesel Trucks (HDDT). Similarly, Zavala-Reyes et al., (2019) described how these modern vehicular technologies help in emissions reduction globally; they found out that the Euro 6 cars for example, have slashed their PM2.5 and a 66% reduction of NOx emissions rate compared to Euro 5 vehicles. Similarly, according to such works as Slezakova et al., (2013), the use of electric and hybrid vehicles can significantly reduce emissions of pollutants, as well as greenhouse gases.

Density and flow characteristics affect the concentration of air contaminants surrounding transport facilities. The rate of traffic stream movement especially during rush hours is characterised by high concentration of pollutants. This is in agreement with Luo et al., (2017), who studied the emissions of taxis in one of China's most populous cities, Shanghai, and demonstrated high levels of pollutants during peak traffic density. Zhang et al., (2021) conducted during the Chinese Spring Festival Travel Rush indicated that enhanced traffic flow significantly enhanced individual exposure to PM2. 5, this supports the earlier findings stressing on the necessity to enhance traffic control in order to decrease pollution level. Furthermore, Thaker & Gokhale, (2016) revealed that traffic congestion especially diesel vehicles aggravated emissions and concentration especially on the lee side of urban waters due to entrapment.

Air pollution can be effectively addressed through urban design and associated infrastructure. Chen & Whalley, (2012) study revealed that implementation of urban rail transit systems helped decrease the use of private vehicles hence lowering the emissions. The availability of public transport and pedestrian areas in the urban layout contributes to the effective dispersion of pollution. Also, the implementation of green elements such as trees and green roofs can increase pollutant deposition and ventilation leading to better air quality. The effect of vegetation is two-fold, as put forward by Salmond et al., (2005) and Pugh et al., (2012), where the proper incorporation of GI plantation reduces pollution levels in urban canyons immensely.

This briefing has found that air pollution presents precise threats to public health in transport regions. Scholars have observed that elevated pollutant levels lead to immediate adverse respiratory effects, consequently, extended pollutant exposure results in chronic health problems. J. Huang et al., (2016) noted that people who live in polluted areas characterised by high traffic emission levels suffer from reduced lung capacity. The following measures are important in minimising these risks: measures such as minimising the transport and traffic emanating from semi enclosed transport environments, promoting the use of public transports among others. Zhou et al., (2019) established the effects of high levels of pollution with regards to pollution occurrences in the Yangtze River region and the degree of health hazards which arise from high pollutant concentrations and particular types of meteorological conditions.

Within the transportation sector, transport junctions are one of the key sources of urban air pollution through motor vehicle exhaust, traffic congestion level, and transport structure, which in turn have an adverse effect on human health. Some of the impacts of transportations on environments are as follows. In this regard, measures such as proper planning and organising of city structure, up-to-date emission control technologies, and better traffic and transport control can play significant roles. Multidisciplinary methods using both experimental and computational methods such as observational investigations and numerical simulations employing systematic modelling approaches offer good prospects for evolving comprehensive insights into the coordinated phenomenon of air quality pollution of urban centres.

One research topic of interest is the impact of urban air quality on health which is more of concern in the densely populated cities where transport emissions are largely a major source of pollutants. A review of the articles like the one done by J. Huang et al., (2016) shows that high levels of traffic related pollutants found in transport hubs affect not only the acute health of the individuals exposed to it but also the chronic health of the people, this includes asthma, lung cancer, and cardiovascular disease. A closer look at urban canyons also shows that the geometry and heights of buildings within these areas tends to further disrupt the flow of pollutants by trapping them hence increasing the density of NOx and CO with possible effects on the health of individuals in these areas as pointed out by Fu et al., (2017). Further, the findings of the study indicate that traffic congestion and fumes during rush hour greatly increase the rate of emission of pollutants because stationary vehicles emit more pollutants per distance covered in contrast to moving vehicles Luo et al., (2017). Some of the modern emission control technologies for instance, hybrid, and electric vehicles have been demonstrated to reduce these emissions as well as enhance the quality of the air hence the need for society to embrace cleaner modes of transport in order to guarantee health of citizens Slezakova et al., (2013). Even that the vegetation and urban planning could effectively reduce the exposure levels and pollutant dispersion, and suggest the importance of integrating multiple disciplines in urban designing and environmental management to safeguard public health (J. Huang et al., 2016; Pugh et al., 2012). In general, it is crucial to implement multifaceted strategies in the spheres of traffic regulation, emission reductions, and urban planning to reduce the adverse effects of urban air pollution on health and create better conditions for urban citizens.

The research conducted by many scholars shows that the intricate link between urban traffic, air pollution, and public health is a complex matter. The report points to the dominant role of automobile technology, emissions, and urban planning in the distribution and exposure of pollution levels. Having a grasp of these dynamics is of paramount importance for the development of effective strategies to deal with air pollution and its adverse health effects in the urban context. The findings demonstrate the necessity of combining transport planning, urban design, and air quality management to achieve lasting and sustainable healthier cities. Furthermore, they highlight the necessity of site-specific interventions and programs that target pollution sources and decrease human exposure in different urban settings.

Key findings from the literature review process

This research offers a detailed exploration of the complex links between urban design characteristics, transport emissions and air pollution concentrations. Major conclusions show the role of automobile exhausts and movements in polluting air, stressing the importance of post-modern emission reduction technologies and traffic flow controls. With regards to the urban canyon geometry, the study shows how factors like street orientation and building height affect pollutant dispersion and concentration and this calls for a proper planning to improve air quality. Moreover, a significant level of disparity between regions is evidenced from the study, hence the need for international cooperation in tackling urban air pollution. Analysing the presented case studies, methodological discrepancies in evaluating the spatial distribution of pollutants in cities are defined, and the necessity of utilizing accurate and unified techniques is revealed. The relative impact of urban design features and transportation systems on air pollution behaviour is also demonstrated, revealing the need for systematic research in this field.

The findings of this study provide policy makers and urban planners with the important and useful information about the nature and factors of urban air pollution to develop the improved and healthful metropolitan environments. Closing the indicated research gaps requires interdisciplinarity and comprehensiveness, which can effectively reduce the transport-caused air pollution influence on the population and the environment. In conclusion, this study highlights the importance of a multifaceted approach to tackling urban air pollution. By integrating advanced technologies, efficient urban planning, and public health strategies, we can achieve significant improvements in air quality and public health in urban environments. Future research should continue to refine these methodologies and explore innovative solutions to sustain urban air quality improvements.

Innovative Approach and Health Impacts:

The project integrates diverse parameters such as transport patterns, air pollution levels, traffic speed, demographic variations, and climate conditions to mitigate the health effects of transport-induced air pollution (Kan et al., 2012). Focusing on societal and behavioural dimensions in policy effectiveness, especially in regions like Yangon where empirical environmental data may be scarce (Sabel et al., 2016), the project offers a holistic view of the relationship between urban transport, air quality, and public health.

Urban Canyon Impacts

The difference between sampling locations was statistically significant ($p < 0.05$), suggesting that there is significant spatial variation between different parts of the study site. Individual comparisons, however, revealed that they are not significantly different from one another on some sites. The hotspot analysis also confirmed that there are hot and cold spots in the distribution of pollution over space and time. (Bizualem et al., 2022).

Cui et al. (2024) provides valuable insights into the impact of envelope features on pollutant exposure in street canyons. Two geometries are analysed: one with a smooth building roof, the other having a series of solid obstacles atop the upwind building roof. The pollutant is released at the street level. The simulations are successfully validated against laboratory and numerical datasets, and the primary vortex displacement detected in some laboratory experiments is discussed. The turbulence triggered by the obstacles destroys the sharp shear layer that separates the canyon and the surrounding flow, increasing the mixing. Greater vertical turbulent mass fluxes and more frequent ejection events near the upwind building (where pollution accumulates) are detected. Overall, the obstacles lead to a reduction in the pollution concentration within the canyon of about 34 % (Cintolesi et al., 2021).
The simulation results show that Air Quality Index rates correlate significantly with green spaces and wind direction, and the optimised scenario could decrease the PM2.5 ambient concentrations up to 33% at the level 1.75 m above the ground, in which people breathe, throw dispersion and deposition of the pollutants. In terms of prediction objectives, regression models were developed to represent the importance of variables and the prediction model of PM2.5 concentrations in the ambient conditions. The accuracy of the optimised predictive model is 97.5% (Kandelan et al., 2022).

Urban Transport Impacts on Air Pollution

Vehicular technology had a large influence on exposure: Heavy duty-Euro 6 vehicles decreased 86% the exposure to PM2.5 and 66% to NOX with respect to Euro 5. The proposed computational system provides information on how wind velocity influenced the inhomogeneous pollutant distribution in the street-canyon, causing exposure to be dependent on pedestrian route location. (Zavala-Reyes et al., 2019)

We measure air pollutant concentrations and meteorological factors on 6 days throughout a year in different areas of the hub. We explore the spatial and temporal distribution of air pollutants within the hub and apply General Additive Models to assess the relationship between air pollution, meteorological factors, and location attributes. We find that motor vehicles including taxis and parking vehicles are a major source of air pollutants in the hub. (Zhu et al., 2021)

The results demonstrated that (1) the highest taxi trips during the day occur at 10:00, 16:00 and 20:00. (2) The variations of the 4 pollutants within and between TAZs are similar. The emissions of TAZs with business centres, entertainment centres and transportation hubs are obviously higher than others. For TAZs within the 5th Ring Road, the northern emissions are stronger than the southern. Emission patterns can be divided into 3 types, corresponding to the time periods of 0:00–3:00, 3:00–6:00 and 6:00–24:00. (3) There is a positive relationship between emissions within and between TAZs and road densities. (Li et al., 2019)

Air Pollution Impact on Health

Exposure to air pollution, whether it is for a short period of time or for an extended period, has the potential to cause a broad variety of ailments. These disorders include stroke, chronic obstructive pulmonary disease, malignancies of the trachea, bronchus, and lung, enhanced asthma, and lower respiratory infections. Following a comprehensive analysis of the most recent scientific data indicating the negative effects of air pollution on human health, the World Health Organization (WHO) announced new recommendations for air quality in the year 2021. As part of the regulations governing ambient air quality, the European Union (EU) has also established criteria for the most important air contaminants. In the European Green Deal, the European Commission made a commitment to making additional improvements to air quality and to harmonising the criteria for air quality in the European Union with the recommendations of the World Health Organization. This dedication was reflected in the zero-pollution action plan, which established a goal for the year 2050 to bring the levels of pollution in the air, water, and soil down to a point where they are no longer regarded to be hazardous to human health and natural ecosystems.

Community engagement in Yangon

Air pollution is a major threat to public health. Numerous epidemiological studies showed that a correlation between air quality and adverse health impacts emphasising a significant role of air pollution in the disease impact to the general population stretching from clinical effects to premature death. According to the World Health Organization (WHO), ambient outdoor air pollution causes 4.2 million of human lives lost every year (Anenberg et al., 2017). Increased mortality and reduced life expectancy has recently arisen due to the exposures to the particulate material (PM) for the long term and short term (Apte et al., 2015). Furthermore, PM10 also triggers carcinogenic effects on individuals. Additional health risks of the major pollutants including oxides of sulphur (SOx) and oxides of nitrogen (NOx), Ozone are also associated with respiratory, circulatory diseases and mortalities, chronic respiratory diseases, and asthma (Estarlich et al., 2011). Therefore, the exposure of these air pollutants in both individuals, and community levels requires investigation thoroughly for measuring the current measures and concurrently, enhancing the community awareness of transport related health issues.

In order to become effective, decisions and an action plan on air quality policy is required to be developed through community engagement. This implies that the local vulnerability and health impacts need to be assessed and investigated through focus group discussions (FGD), surveys and key informant interviews. This intends to explore community awareness of transport-related health issues and air pollution in their vicinity. As stated upon the engagement modalities, 6 focus group discussions, survey targeting 314 respondents and 9 key informant interviews have been encompassed.

Concretely, applying mixed method research methodology, this has been conducted according to the conceptual framework adapted from Noël et al. (2021). The questionnaires of both focus group discussions and surveys were conducted according to the conceptual framework to improve the validity and reliability of the data collected and furthermore, cross validation can be accomplished. Starting with the geographical location of the participants, they are likely to respond and share their risk perception of air pollution.

Geographical setting is important to understand the perception upon air pollution and their mode of commutes, associated with temporal experiences of air pollution. This leads to exploring their exposures over air pollution and identifying the sources of air pollution with addition to transport induced pollution. For example, the person who lives near the transport hub may experience air pollution more than those who live on the street where there are only a few fossil-fuelled vehicles operating. Additionally, this setting may provide the understanding of a wide range of transport modes in different areas and its impact on air pollution. Furthermore, mode of commuting is also pivotal that associated with their mode of commuting, the environmental exposures of the commuters may be exacerbated through temporal experience and level of comfort.

Risk perceptions are described as including people's beliefs, attitudes, judgements, and feelings and furthermore, the broader cultural and social tendencies they accept towards exposures and their benefits (Pidgeon et al., 1992, p. 89). To understand the risk perception, The correlation between environmental exposure upon air pollution and well-being (for example, respiratory effects or chronic stress) is mediated by perceptions of the "exposure" (Noël et al., 2021). The inherent formation of an attitude derived from understanding a risk, leads to subsequent behaviour and effects to the psycho-social behaviours and well-being. For example, due to inhaling unpleasant smells for a certain period of time, a negative attitude may be formed and reflect the levels of distress in particular people. The temporal experiences may affect the increase of chronic stress and distress over exposure to an unhealthy environment. These exposures intricately transform behaviours and responses which may impact their mental and well-being. Moreover, air pollution-related knowledge has been assessed through the adapted model of four dimensions of action-oriented knowledge towards the environmental problem of air pollution (see Fig 6). These particular measures unfold the understanding (Why), the causes of the problem (What), the root causes of the environmental issue (Where) and what can be performed (How) to mitigate or prevent the problem. This can assess the intrinsic knowledge of air pollution and the willingness to adopt the measures of current adaptation upon air pollution and improvement developed by the community. To observe this experiment, the conceptual framework can be formed as Figure 5.

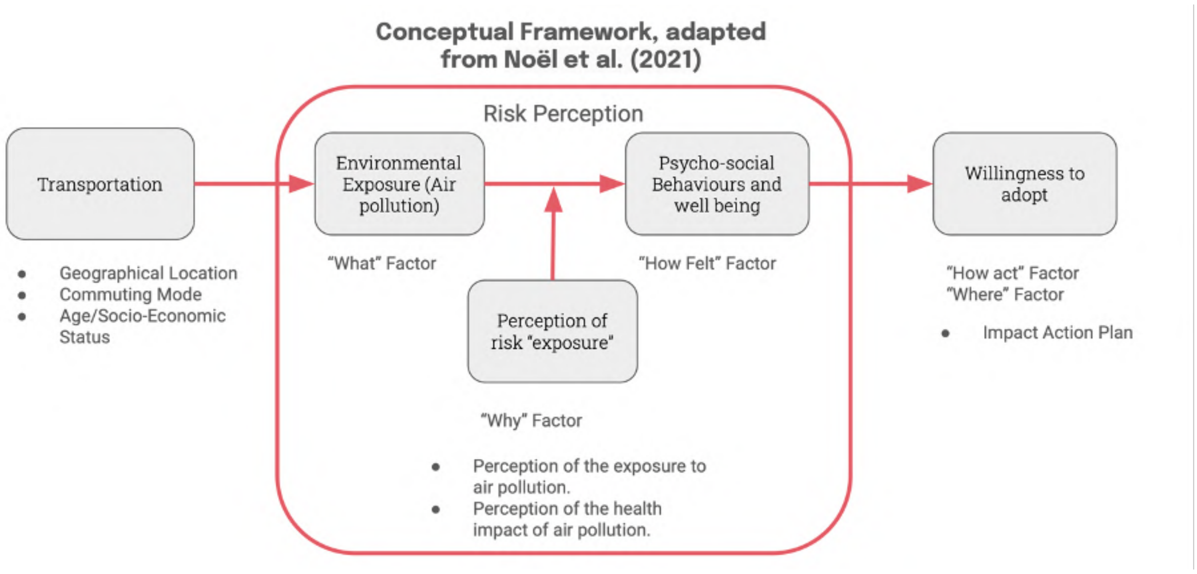


Figure 10: Conceptual Framework adapted from Noel et al. (2021)

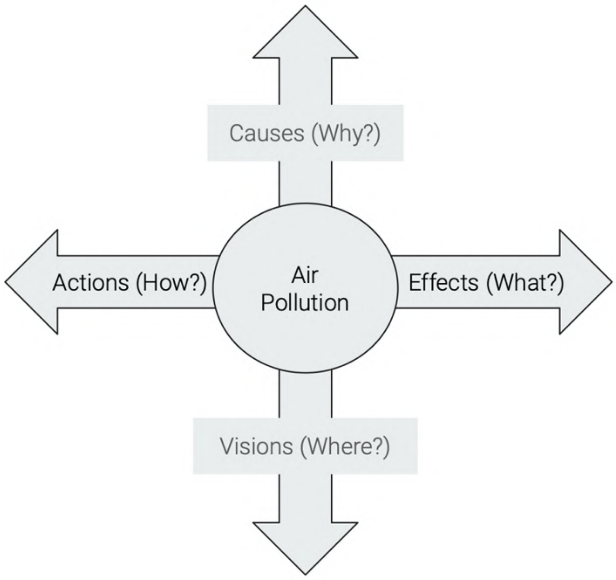


Figure 11: Four dimensions of air pollution-related knowledge, adapted from Jensen (2002)

Data Collection and Technological Novelty:

The project's technological innovation lies in its use of integrating sensor technology, data analytics, and spatiotemporal modelling. This includes the deployment of IoT-enabled sensors for real-time air quality monitoring with heat stress data and the development of interactive platforms for data dissemination.

Air Quality Sensor Data Collection

Urban air pollution represents one of the most pressing environmental challenges of our time, particularly in densely populated cities worldwide as evidenced from the systematic literature review conducted. It demands a refined understanding of its primary constituents and their impact on human health and the environment with PM2.5, PM10, COx, and NOx contributing significantly to this dilemma. These pollutants, emanating predominantly from transportation and industrial activities, not only degrade air quality but also pose severe risks to public health. PM2.5 and PM10, due to their ability to penetrate deep into the lungs and even enter the bloodstream, are closely associated with an array of adverse health outcomes, including respiratory and cardiovascular diseases, and premature mortality. Similarly, COx and NOx are key contributors to urban smog and acid rain, exacerbating respiratory conditions and altering the ecological balance.

The BREATHE-Cities project's comprehensive approach to data collection, encompassing both quantitative measurements and qualitative community insights, sets a precedent for how urban areas can tackle the multifaceted challenge of air pollution. By focusing on the specific pollutants of PM2.5, PM10, COx, and NOx, the project not only aims to highlight their immediate health impacts but also to shed light on their broader implications for urban sustainability and resilience.

The relevance of collecting data on these pollutants cannot be overstated. It provides the empirical foundation necessary for understanding the spatial and temporal patterns of air pollution, identifying hotspots, and assessing the effectiveness of existing policies and interventions. Moreover, this data is instrumental in modelling the potential impact of future urban planning and transport policies on air quality, thereby offering a roadmap for mitigating pollution at its source.

The project focuses on Manchester, Bangkok, and Yangon and the preliminary results included in this report offer a simple visualization of how urban transportation contributes to air pollution levels. The findings underscore the urgent need for a paradigm shift towards smarter, more sustainable urban transport and planning strategies. Notably, the project leverages novel sensor technologies and innovative data collection methodologies to provide a detailed analysis of pollution patterns, thereby establishing a robust proof of concept for the integration of advanced technological solutions in urban environmental health research.

The collected data on PM2.5 and PM10, pivotal due to their ability to penetrate deep into the lungs and bloodstream, highlight the acute and chronic health risks posed by fine particulate matter. Similarly, measurements of COx and NOx offer insights into the contribution of vehicle emissions and industrial activities to urban smog, acid rain, and respiratory ailments. Incorporating RH and climate data into our analysis allows us to understand the environmental conditions that exacerbate or mitigate air pollution levels, providing a holistic view of the challenges at hand.

Particulate Matter 2.5 (PM2.5) refers to fine inhalable particles, with diameters that are 2.5 micrometres and smaller. PM2.5 poses significant health risks because of its ability to bypass the nose and throat and get deep into the lungs (EPA, 2023). Some particles may even reach the circulatory system. The health effects linked to exposure to PM2.5 include premature death in individuals with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, and increased respiratory symptoms such as irritation of the airways, coughing, or difficulty breathing.

Those most at risk from PM2.5 exposure include people with heart or lung diseases, children, and older adults (EPA, 2023). Long-term exposure to PM2.5 has been associated with major health impacts worldwide, contributing to over 4 million deaths in 2019 (State of Global Air[1], 2023). Health issues attributed to long-term exposure to PM2.5 include ischemic heart disease, lung cancer, chronic obstructive pulmonary disease (COPD), lower-respiratory infections, stroke, type 2 diabetes, and adverse birth outcomes. The global mortality burden from PM2.5 is significant, with Asia and Africa experiencing the highest rates of death attributable to PM2.5 due to a combination of high death rates and large populations (Fig. 7, State of Global Air[1], 2023). WHO (2021) guidelines state that the annual average concentrations of PM2.5 should not exceed 5 µg/m3, while 24-hour average exposures should not exceed 15 µg/m3 more than 3 - 4 days per year (WHO, 2021).

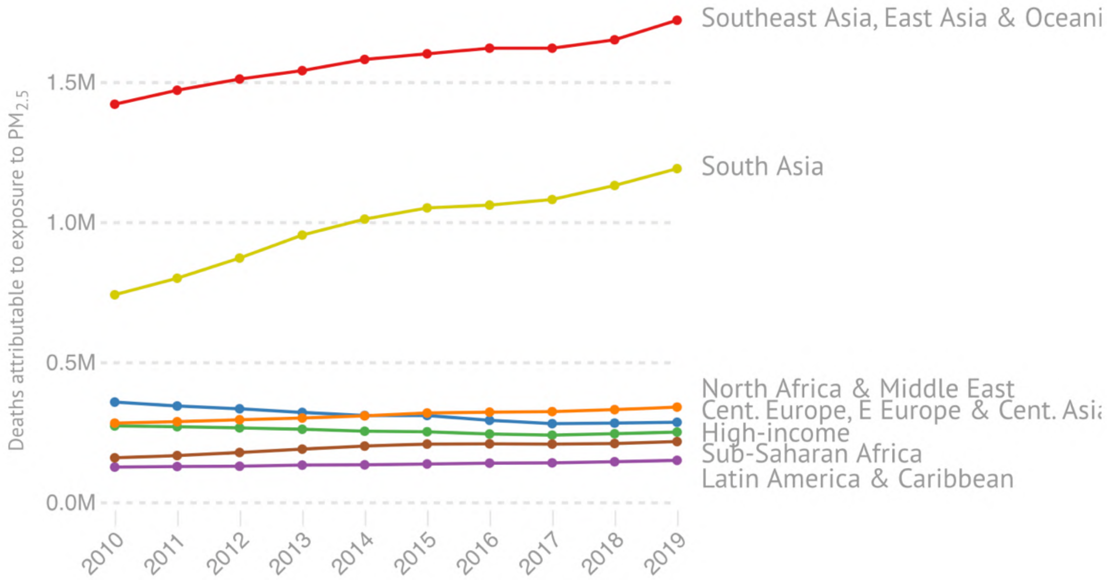


Figure 12: Trends in total deaths attributable to PM2.5 globally and in the GBD Super Regions, (State of Global Air 2023).

To reduce exposure to PM2.5 and its associated health risks, it's important to monitor air quality levels and take preventive actions when levels are high. This can include limiting outdoor activities during days with high PM2.5 levels and using air purifiers indoors to reduce particulate matter in the air.

[1] https://www.stateofglobalair.org/health/pm,

Particulate Matter 10 (PM10) refers to particles that are 10 micrometres in diameter or smaller. These particles are inhalable into the lungs and can cause various health problems due to their size allowing them to penetrate deep into the respiratory system. PM10 can be composed of several components, including nitrates, sulphates, organic chemicals, metals, soil, dust particles, and allergens. Sources of PM10 include motor vehicles, wood-burning heaters, industry, construction sites, landfills, agriculture, wildfires, and industrial sources. During events like bushfires or dust storms, PM10 levels can spike to extremely high concentrations (CA. Gov, 2024; NSW, 2024) .

The health effects of PM10 are significant and multifaceted. Short-term exposure to PM10 can exacerbate respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD), leading to hospitalization and emergency department visits. Additionally, it can irritate the eyes, nose, and throat, and in individuals with heart disease, it can trigger heart attacks and arrhythmias. Long-term exposure to PM10, although less clear than PM2.5, suggests a link to respiratory mortality and potentially to the development and progression of cardiovascular and respiratory diseases. The International Agency for Research on Cancer (IARC) has noted that particulate matter in outdoor air pollution, including PM10, is carcinogenic, particularly causing lung cancer (CA. Gov, 2024).

Those most at risk from PM10 exposure include older adults with chronic heart or lung diseases, children, and asthmatics. Children are especially vulnerable because they breathe more air relative to their body weight than adults, spend more time outdoors, and have developing respiratory systems. Research has shown that children living in areas with high levels of PM2.5 and PM10 have slower lung growth and smaller lung capacities by age 18 compared to those in areas with lower levels of pollution. To mitigate the health risks associated with PM10 exposure, it is important to monitor air quality levels and reduce exposure on days when PM10 levels are high. This can include staying indoors, using air purifiers, and avoiding strenuous outdoor activities (NSW, 2024).

Collecting data on PM2.5, PM10, COx (Carbon Oxides), NOx (Nitrogen Oxides), temperature, and relative humidity, and cross-referencing it with climate data, is crucial for understanding and mitigating air pollution's impact on urban areas, public health, and the environment. Each of these pollutants and environmental parameters plays a distinct role in air quality and climate dynamics:
As mentioned, PM2.5 and PM10 are particulate matter with diameters less than 2.5 micrometres and 10 micrometres, respectively (WHO, 2024). They can penetrate deep into the lungs and even enter the bloodstream, causing respiratory and cardiovascular diseases, as well as other health problems.

- COx, including carbon monoxide (CO) and carbon dioxide (CO2), arises from the incomplete combustion of carbon-containing fuels. CO is a poisonous gas to humans even at low levels, while CO2 is a significant greenhouse gas contributing to climate change (EPA, 2023).
- NOx, a term for nitrogen oxides including NO and NO2, is primarily produced from vehicle emissions and industrial activities. NOx contributes to the formation of smog and acid rain and can lead to respiratory problems (EPA, 2023).
- Temperature and relative humidity influence the concentration and chemical reactions of air pollutants (EEA, 2024). They also affect human comfort and health directly.
- Climate data provides context for long-term environmental changes and can help identify trends in air pollution, enabling more effective planning and response strategies (WHO, 2024; The World Bank, 2022; IPCC, 2022).

Integrating these data points allows for a comprehensive understanding of air quality and its interaction with climate change. For example, higher temperatures can increase the rate of ozone formation from NOx and volatile organic compounds, while relative humidity can affect the formation and deposition of particulate matter. Cross-referencing pollution data with climate information helps in predicting air quality, assessing public health risks, and developing mitigation strategies.

These pollutants underscore the complexity of air quality management and the importance of integrated environmental monitoring and policy-making to address the intertwined challenges of pollution and climate change.

Data Collection Process

Monitoring air quality

Applying the Transit-Oriented Development (TOD) and the 15-Minute City concepts to the challenge of identifying air pollution hotspots involved a strategic approach to urban planning and environmental monitoring. By focusing on geographical identification of transport hubs and nodes, and triangulating this information with existing air pollution data from satellite sources, enabled to pinpoint areas with potentially high levels of PM2.5, PM10, COx, NOx, relative humidity (RH), temperature, and other climate-related data. This methodology offers a comprehensive view of how urban infrastructure and mobility patterns contribute to air quality issues. The following process was implemented in Manchester, Bangkok, and Yangon:

Step 1: Identifying Transport Hubs and Nodes
Transport hubs (major transit stations, airports, etc.) and nodes (intersections of major traffic flows) are critical areas of focus. These locations often experience higher pollution levels due to the concentration of vehicle emissions, making them logical starting points for air quality monitoring.
Step 2: Utilizing Satellite Air Pollution Data
Websites like IQAir Earth, NASA Earthdata, the World Air Quality Index (WAQI), and BreezoMeter provide near-real-time air quality data, including satellite imagery and ground-level monitoring of pollutants like PM2.5 and PM10. By overlaying this data with the geographical locations of transport hubs and nodes, we can identify areas with elevated pollution levels.
Step 3: Data Collection
For each city, five locations near major transport hubs and nodes are selected based on their potential as air pollution hotspots. These locations are then monitored for specific pollutants (PM2.5, PM10, COx, NOx) and environmental conditions (RH, temperature) that contribute to overall air quality. This targeted approach allows for the efficient allocation of monitoring resources and more effective data collection strategies.
Step 4: Analysis and Application
The collected data is analysed to understand the relationship between transport infrastructure and air pollution within the context of TOD and 15-Minute City planning principles. This analysis can inform urban development and mobility strategies aimed at reducing pollution levels, such as enhancing public transport options, creating pedestrian-friendly zones, and implementing green infrastructure projects.

Applied Resources:
IQAir Earth: Provides a visual map of global air quality in real-time, highlighting areas with high concentrations of PM2.5 and PM10. https://www.iqair.com/earth
NASA Earthdata: Offers satellite imagery and data related to air quality and other environmental parameters, useful for identifying pollution trends over time.
https://www.earthdata.nasa.gov/learn/find-data/near-real-time/hazards-and-disasters/air-quality,
World Air Quality Index (WAQI): Features real-time air quality information from around the world, with detailed data on various pollutants. https://waqi.info
BreezoMeter: Delivers air quality data, including specific pollutant levels and health recommendations, based on real-time monitoring. https://BreezoMater.com

The integration of advanced sensor technologies and innovative data collection methodologies, as outlined in the BREATHE-Cities project, not only enhances the accuracy of pollution monitoring but also enriches the understanding of its impact on urban environments. By identifying transport hubs and nodes as critical points for monitoring, the project leverages the Transit-Oriented Development (TOD) and the 15-Minute City concepts to pinpoint pollution hotspots. This strategic approach allows for a more focused analysis of how urban infrastructure and mobility patterns contribute to air quality issues, paving the way for informed urban planning and policy-making.

Manchester, United Kingdom

Locations

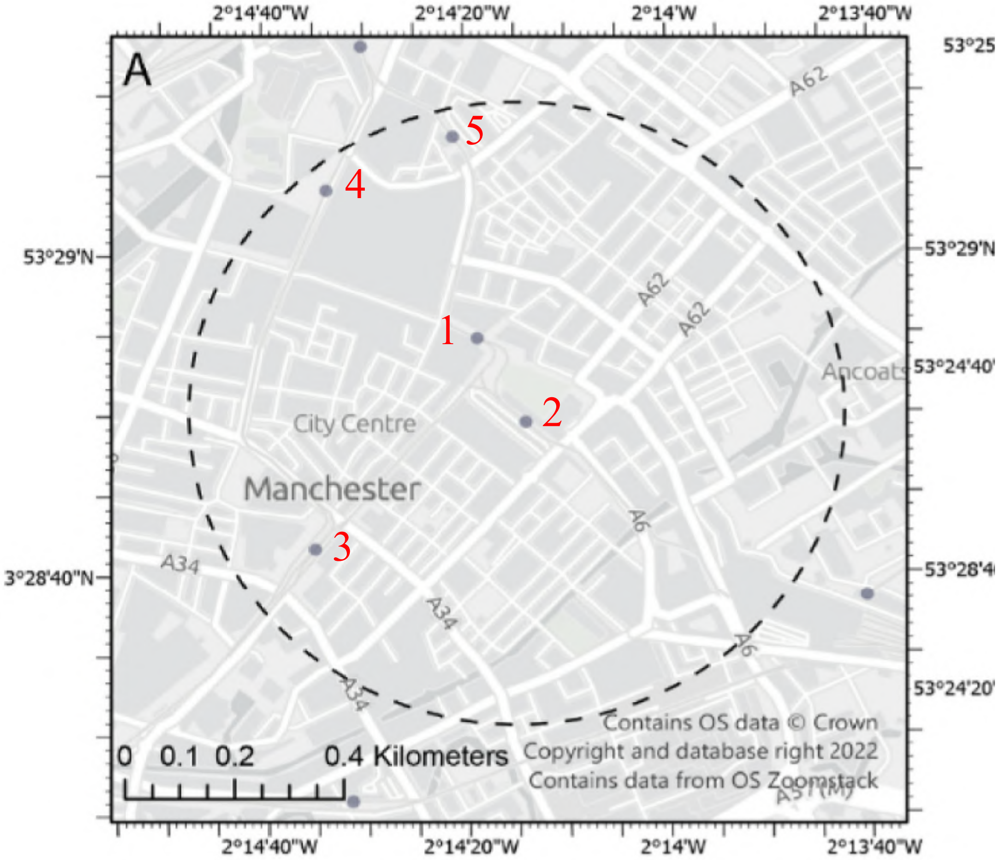


Figure 13:Map of the hotspots measured in Manchester, UK

1. Market street station
2. Market street bus station
3. St Peter Square
4. Manchester Victoria
5. Shudehill bus station

Measurement:

PM10, PM2.5, Cox, NOx, Four times on a weekday 8:00 – 12:00 – 17:00 – 21:00
VoC, Temperature, RH Four times on a Sunday 8:00 – 12:00 – 17:00 – 21:00

The tabulated data for the hotspots in Manchester is included in Appendix 1 of the present report.

Bangkok, Thailand

Locations

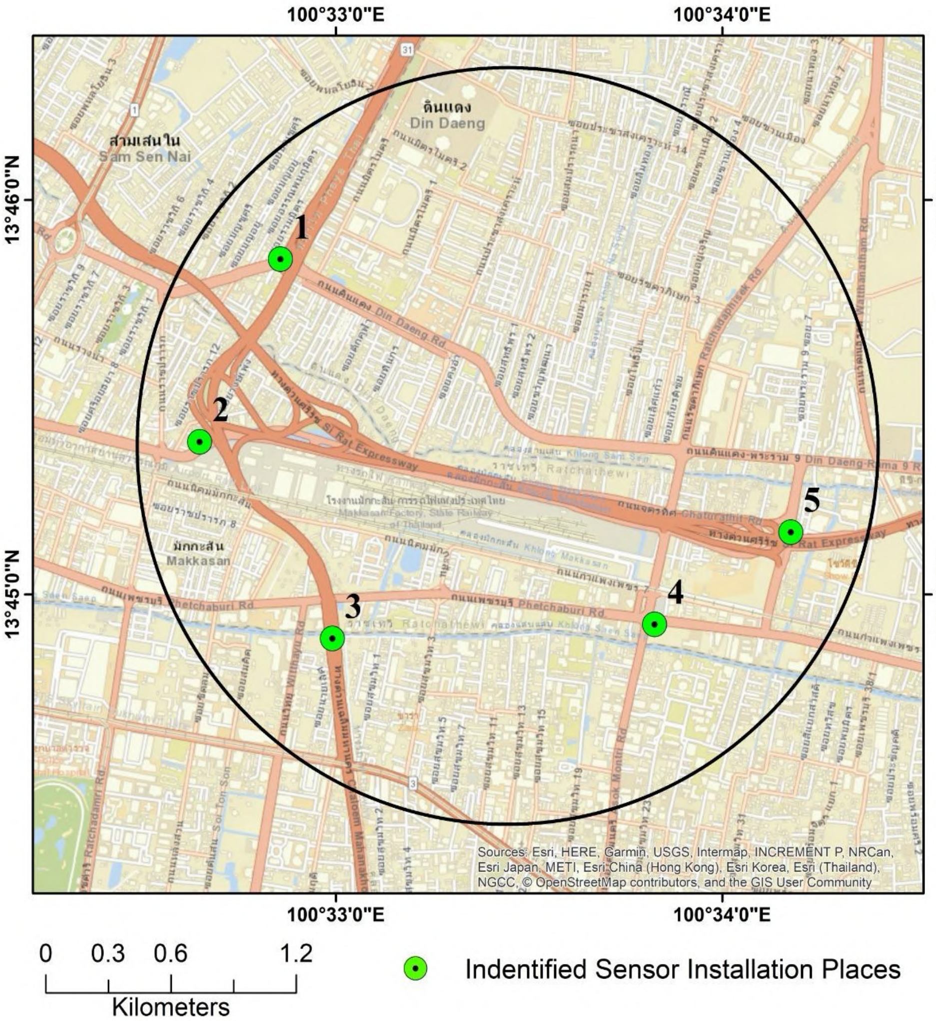


Figure 14: Map of the hotspots initially measured in Bangkok, Thailand

1. Pracha intersection
2. Disvan place apartments
3. Petchaburi expressway
4. Momin cafe
5. CPM capital co.

Measurement:
PM10, PM2.5, Cox, NOx, Two times on a weekday 8:00 – 12:00 – 17:00 – 21:00
VoC, Temperature, RH Two times on a Sunday 8:00 – 12:00 – 17:00 – 21:00

The tabulated data for the initial measured air quality in the hotspots in Bangkok is included in Appendix 2 of the present report.

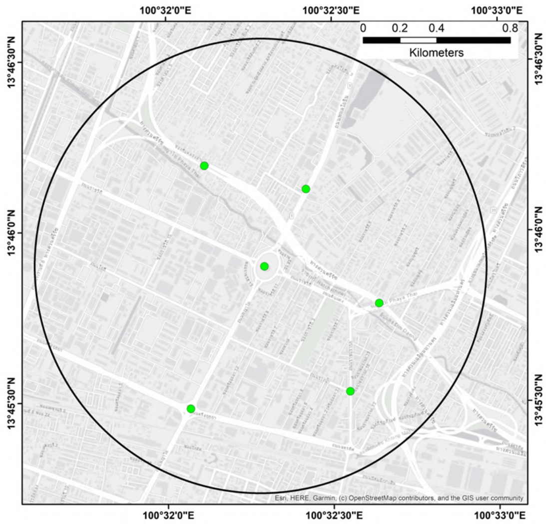


Figure 15: Map of the hotspots to be measured in Bangkok, Thailand following the initial pilot analysis.

For the piloting, five points considering 15-minute walking distance but due to heavy traffic on weekdays it was not possible to measure 4 times for data collection in the selected hotspots in Bangkok including the absence of a transport hub. Therefore, the new plan to reconsider 2 points north-wards and equal-spaced from the transport hub to include 4 data collection phases in Bangkok as unique pollution hotspots which will be considered in the upcoming final data collection process.

Yangon, Myanmar

Locations

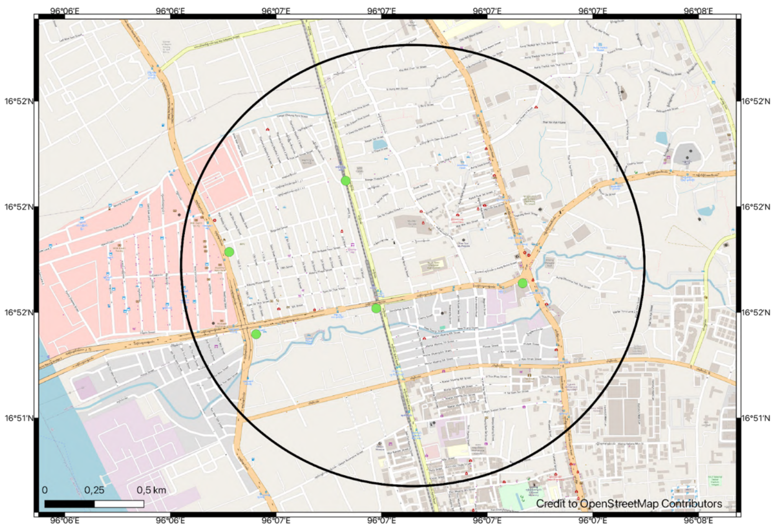


Figure 16: Map of the hotspots to be measured in Yangon, Myanmar

1. Hyundai Motor Myanmar
2. SuThiNainKarGya Mosque
3. LanSone Restaurant
4. Ba Yint Naung Market
5. New Thamine Township Train Stop

Measurement:

PM10, PM2.5, Cox, NOx, Four times on a weekday 8:00 – 12:00 – 17:00 – 21:00
VoC, Temperature, RH Four times on a Sunday 8:00 – 12:00 – 17:00 – 21:00

Following the comments, we received from the FCDO regarding the lack of quantitative data collection in Myanmar, during our stay and work on the community engagement part of the project, we conducted a two days pilot data collection using movable air quality sensors. These were conducted on a weekend and weekday four times a day as in the remaining case studies. This data has not been processed yet and the tabulation data is included in Appendix 3 of the current report. It will be analysed, processed, and triangulated for the final draft report with the community engagement data collected in Yangon.

The project's methodology, utilising satellite air pollution data and ground-level monitoring, exemplifies a scalable and effective framework for urban air quality assessment. This approach not only aids in identifying air pollution hotspots but also in evaluating the effectiveness of existing policies and interventions. It underscores the importance of an integrated approach to environmental monitoring, combining technological advancements with community insights to address the complex challenge of urban air pollution.
In essence, the BREATHE-Cities project contributes significantly to the ongoing discourse on urban sustainability and public health. By highlighting the severe implications of PM2.5, PM10, COx, and NOx pollution, and employing a comprehensive data collection and analysis strategy, the project offers valuable insights into the pathways for mitigating urban air pollution. It stands as a testament to the potential of collaborative research and innovative methodologies in paving the way for healthier, more resilient urban environments.

Data Collection for Community Engagement in Yangon

Strategy

The project's objective is to explore resilient and sustainable urban transport strategies that mitigate transport-induced pollution's repercussions which emphasises community engagement focusing on developing the implementing policies that are informed by community needs and preferences, leading to more effective and accepted interventions. This also aims to address the unique health needs and challenges of each urban setting, striving to mitigate the severe health effects of transport-induced air pollution through refined, context-specific interventions and preventative measures. Therefore, this project's research can be considered as both exploratory and explanatory to investigate the psycho-social behaviours and well-being and current measures and improvement adopted by the community through participatory approaches. To comprehend the context-specific interventions, engagement modalities had been performed with (1) street vendors, (2) people who live in informal settlement areas and (3) residents in a transport hotspot. These specific groups are assumed that they occupy greater temporal and physical experiences and are actively involved in outdoor activities since their functions are operating externally. In terms of socio-economic status, **street vendors** and **people who live in informal settlements** are likely to be greater deprived than others. Additionally, **residents who live in the transport hotspot** tend to experience air pollution induced by transport since their outdoor and indoor activities are greatly operating in polluted areas.

Focus Groups

Street vendors can be defined as the communities who are actively doing commercial activities on the streets. They are significantly involved in creating social activities around the transport hub by retailing their goods and services. Furthermore, activities can create both air pollution by performing social and economic activities, for example, grilling meats and baking paratha which are heavily involved to contribute pungent smoke. At the same time, they are affected by the air pollution every day due to the core locations actively working, mostly **around 9 am to 8 pm for 11 hours**.

People who live in informal settlements are also likely to be affected by the air pollution as most of them are located on the street where traffic congestion occurs frequently. They may either contribute to air pollution by undertaking environmentally polluted actions, for example, burning waste on the street. Most of them are migrating from rural regions or neighbouring cities and growing organically nearby economic areas where they can offer economic opportunities in their daily lives. Additionally, they are settling randomly with basic infrastructures to fulfil their basic needs rather than having proper air ventilation in their households. Thus, air pollution can affect their well-being and worsen their living conditions from day-to-day life.

Residents who live in the transport hotspot can be considered as the communities who settled on the congested roads where most of the transports are passing by. Those may be vulnerable to air pollution as the temporal experiences are likely to take longer as their homes are located near the polluted area induced by the transport. They tend to contribute to commercial activities by establishing small groceries stores, maintenance services, restaurants, tea shops and so on.

Data Collection Instruments (Focus Group Discussion and Survey and Interviews)

This research applied both qualitative data derived from focus-group discussions and key informant interviews and quantitative data resulting from surveys. The aim is to analyse communities' perceptions towards transport-induced air pollution and additional sources such as burning waste, lack of proper waste management and so on. The data collection method relied on focus-group discussions with identified vulnerable communities encompassing street vendors, residents who live in the transport hub and informal settlement. The participants were mobilised through Doh Eain's Yangon Neighbourhood Network members to reach vulnerable stakeholders at the grass-root level. Participatory design has been incorporated to enable the formulation of more inclusive and effective transport strategies. Members of the Yangon Neighbourhood Network also play a key role to gather participants to join the focus group sessions. Furthermore, the community mobilized in their neighbourhoods for performing the key informant interviews. Snowball sampling has been applied which was useful to retain insights for a specific target group (Stockemer, 2019). To obtain more insights derived from the specialists who are working on this particular field, the interviewees were invited online to perform the in-depth interviews. Overview of the engagement methodology with the community and experts is displayed in Figure 12.

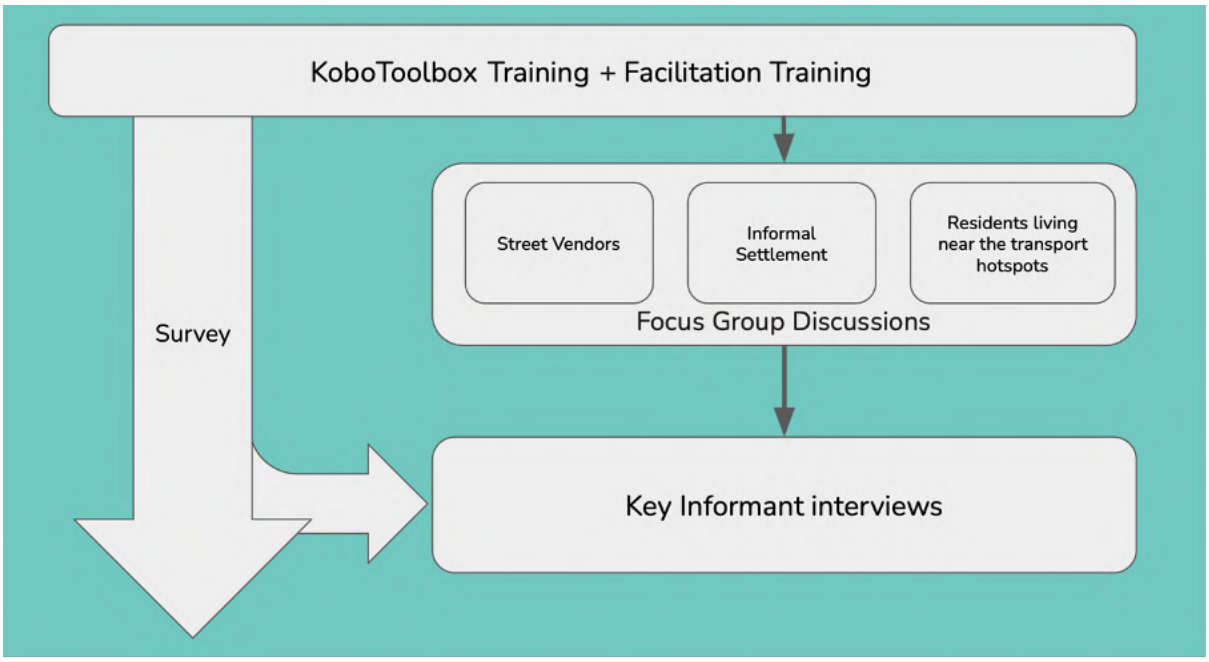


Figure 17:The workflow for community engagement.

Each participatory focus group discussion composes **three interactive activities** entailing mapping the geographical location and social activities and their perception and environmental awareness upon their surroundings and general knowledge of the impact of air pollution. Incorporating these activities, a focus group discussion has been lasting two and half hours and it will be happening every weekend depending on the availability of the participants as they are usually working during the weekdays. Six to twelve participants have joined for each focus group discussion with the balanced ratio of male and female. Participatory mapping incorporated in the first activity to identify the settlement and workplace or where they usually commute in Yangon. This leads to performing participatory GIS as the locations have been located when compiling the geo-data. This can also assess the perception and experiences of the community who contribute commercial or social activities near the defined area, associated with the spatial modelling, derived from previous output 3.

The project is to explore the stakeholder collaboration and community engagement which enhance the implementation and sustainability of air quality initiatives, and to assess the efficacy and impacts of existing transport strategies on vulnerable communities. Furthermore, these findings aim to address transport-induced pollution with actionable steps for immediate and long-term interventions gauging grassroots-level perspectives, enabling the formulation of more inclusive and effective transport strategies. This intends to reveal areas that require attention and improvement through the understanding of perception and exposure towards polluted area. As described in methodology, the research unfolds both qualitative and quantitative research to analyse and explore the grass-root perspectives composing perception, needs and challenges to mitigate the transport induced air pollution in their vicinity throughout the day. The numbers of participants to the focus group discussions, key informant interviews and respondents through survey were shown in **Table 2**.

Table 5: Type and volume of engagement sessions

Mode of Engagement	Sample sizes	Type of Engagement
6 Focus Group Discussions	60 participants	In-person
Survey	314 respondents	In-person
Key Informant Interviews	10 interviewees	Online / In-person

Selected study area:
Among the activities, the communities had been mobilised through Yangon Neighbourhood Network to understand the grass-root level perspectives, associated with air pollution in Yangon. Based on the time availability of members of Yangon Neighbourhood Network and the identified locations where sensor installation was undertaken, the study site has been selected as shown in Figure 18. Those are

(1) Near Bayli bridge and Pinlon road at North Dagon township.
(2) Thumingalar Road and in front of Nandawin local market at South Okkalapa Township
(3) Thamine junction and Ba Yint Naung Construction Market at Insein and Mayangone Township.

These three sites can be identified as the busy areas where social and commercial activities are undertaken with a high-density population. Concurrently, the locations hold a wide range of transport modes transiting continuously which enhances the social activities in the vicinity. Due to the presence of local markets where people nearby depend on buying groceries and equipment for their households.

Figure 18:Three locations where focus group discussions and survey collection took place.

ANALYSIS and RESULTS

The initial findings reveal significant variations in air quality levels around major transport hubs and nodes across the three cities, underlining the critical impact of urban transport on air pollution. In Manchester and Bangkok, the deployment of cutting-edge air quality sensors has provided a granular view of pollution dynamics, revealing peak pollution times closely tied to traffic patterns. This data is instrumental in identifying hotspots for targeted interventions. Meanwhile, in Yangon, where political instability and resource constraints have limited traditional data collection, which was only possible for two days with a mobile air quality monitoring device, innovative community-based approaches have yielded valuable insights into the socio-economic factors exacerbating air pollution exposure and health vulnerabilities.

1.4.4.1. Manchester, United Kingdom

Despite the relative low air qualities in Manchester in comparison to the resto of urban areas in UK, the City could still be considered a ‘good’ reference for comparison to both Bangkok and Yangon. While many variables contribute to urban air quality, the level of air pollution (particularly PM2.5, PM 10) in Manchester city centre is largely related to volume and speed of traffic. 28.98% and 12.90% of all PM10 and PM2.5 are directly related to transport in the City.

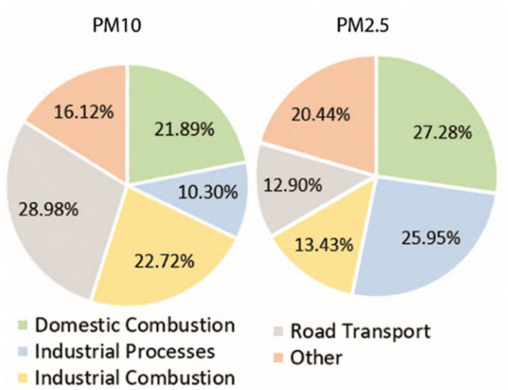


Figure 19: Classification of pollutant sources in Manchester, 2024

Manchester city centre also offered a variety of place configuration that impact on concentration and dispersion of air pollution. Research by ELmarakby and Elkadi (2023) shows strong correlation between levels of PM2.5 and PM10 and urban canyon ratio.

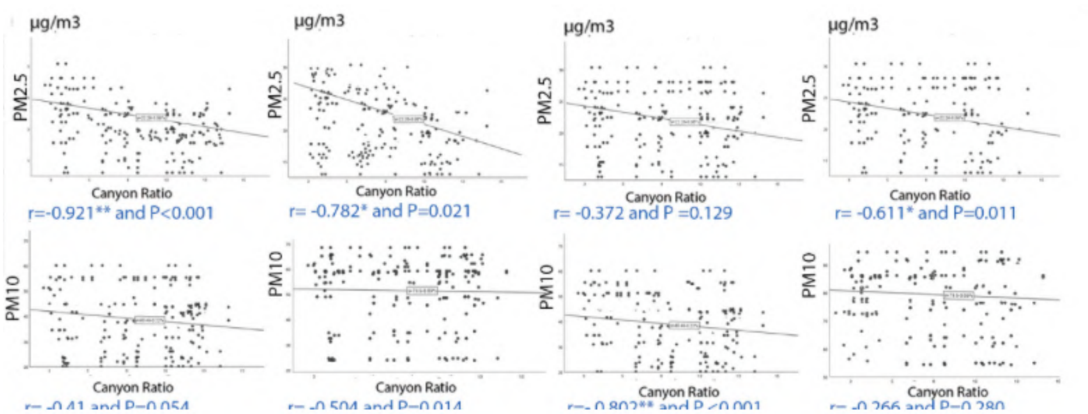


Figure 20: (after Elmarakby and Elkadi, 2023)

Manchester city centre also provide an excellent example of interconnected transport modes and transformed levels of land use, volume of traffic, and differentiated modal split; accordingly, a textbook example of the transformation as a result of ToD approach.

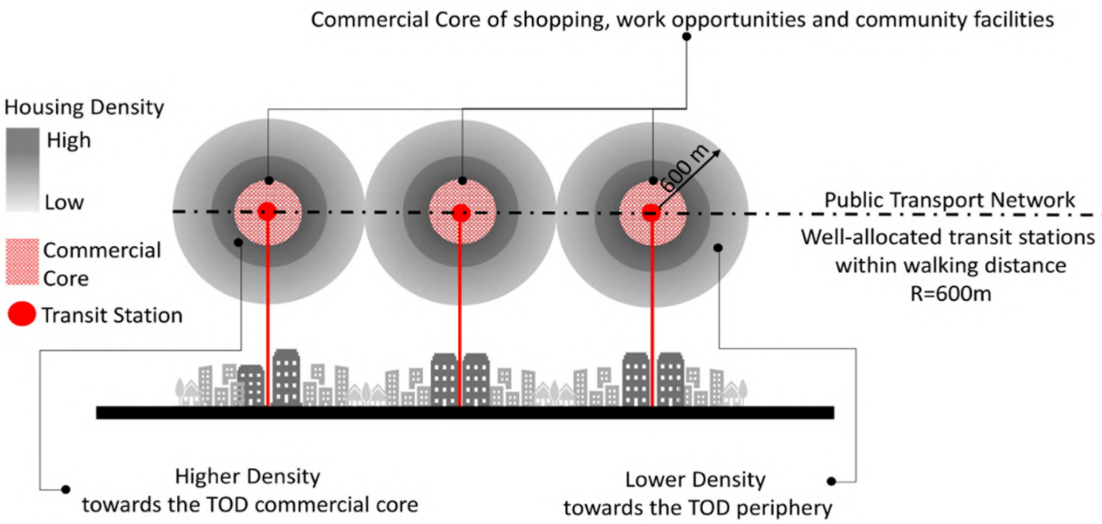


Figure 21: (after Elmarakby and Elkadi, 2023)

In more in-depth field measurements in this project showed a clear pattern of changes in various pollution levels at different points in the selected area at different times of the day. The average of different locations shows a clear distribution for PM2.5 and 10 throughout the day for both weekdays and weekends. Gaseous pollution levels (CO2 and NOx) seem to be steadily accumulated through the day.

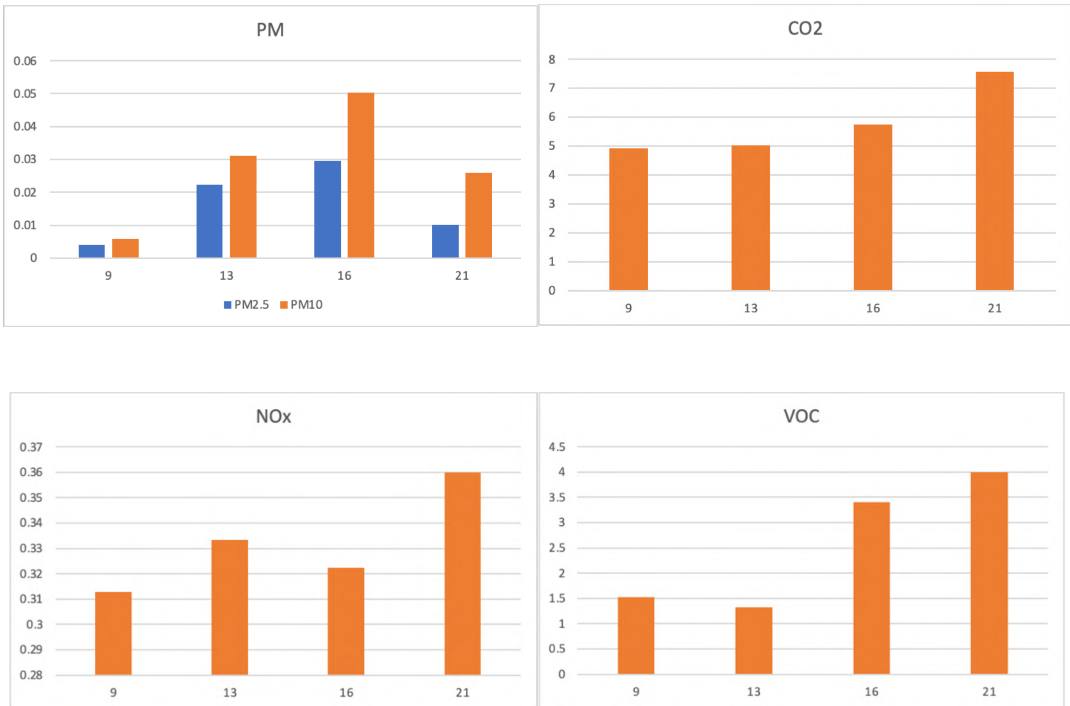


Figure 22:Distribution of different pollution during different ties of a weekday in Manchester City Centre

Different patterns are recorded during a weekend day (Sunday). A high level of pollution was recorded in the early morning. It is to be noted that this recorded Sunday coincided with the Chinese New Year celebration that morning with substantial increase of traffic volume that morning. The level of PM2.5 and PM10 pollution was dramatically reduced for all pollutants as the day progressed.

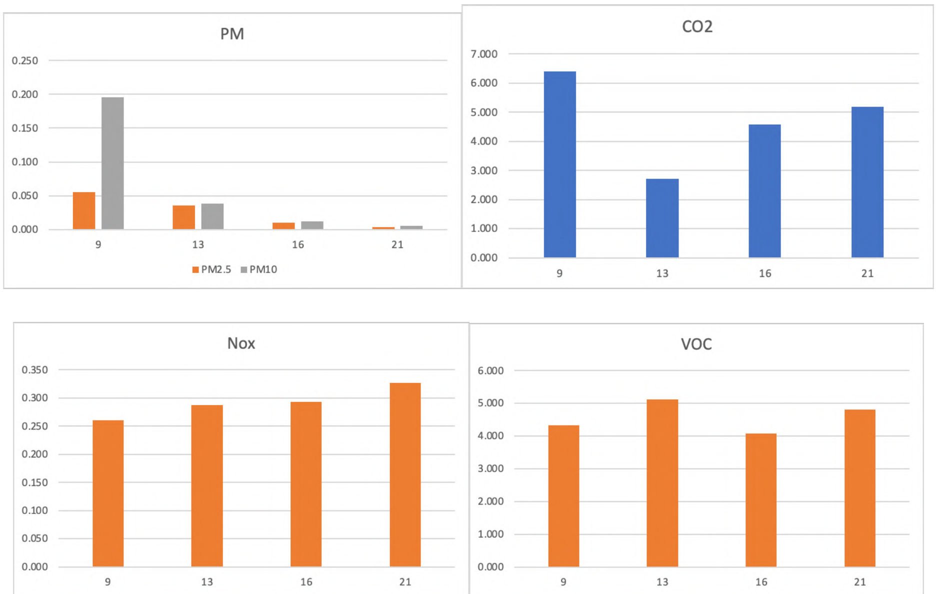


Figure 23: Distribution of different pollution during different ties of a weekend in Manchester City Centre

Further analysis of collected data is underway for the patterns in different 5 locations of the city centre with relation to the Urban Heat Island characteristics in each location (Canyon ratio analysis as well as Heat Maps).

Figure 24:Urban Heat Islands in the study area (weekday and weekend)

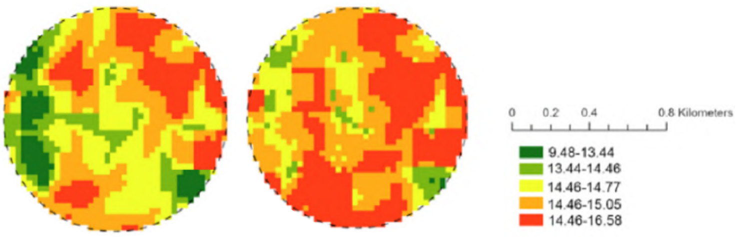


Figure 25: Land Surface Temperature (LST) in the study area (weekday and weekend)

Figure 26: Images of the data collection points in Manchester, February 2024

Level of the pollutants on the weekend in Bangkok's hotspots

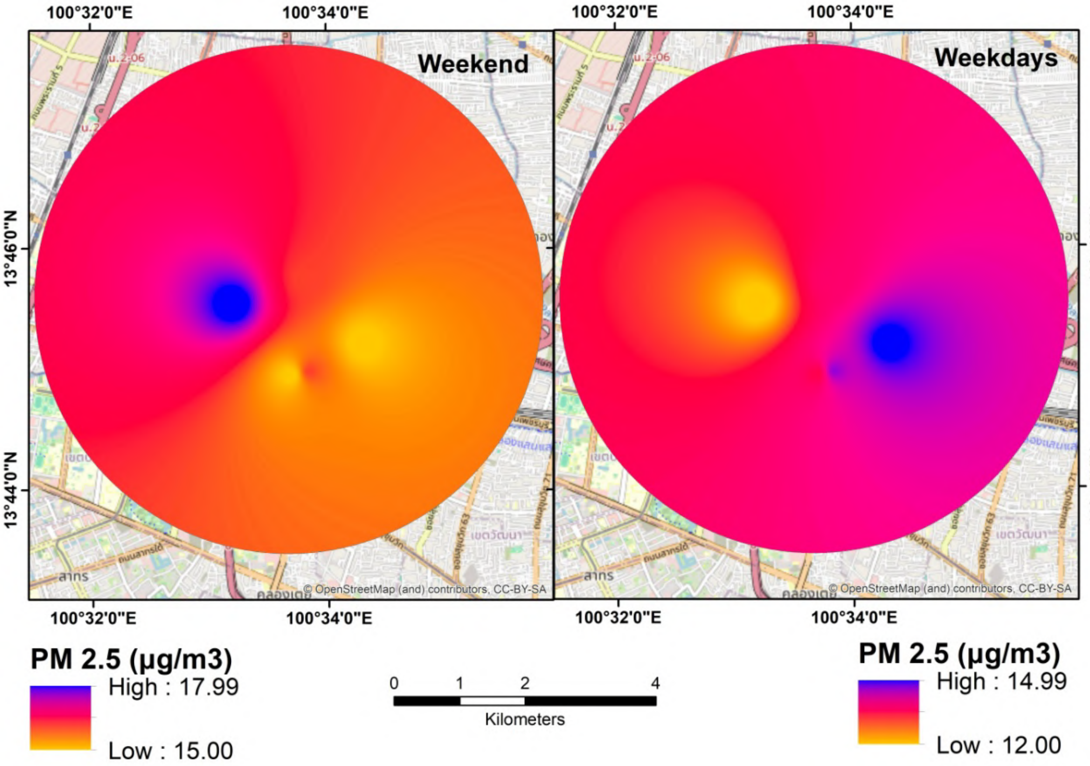


Figure 27: Spatial distribution of PM 2.5 in Bangkok

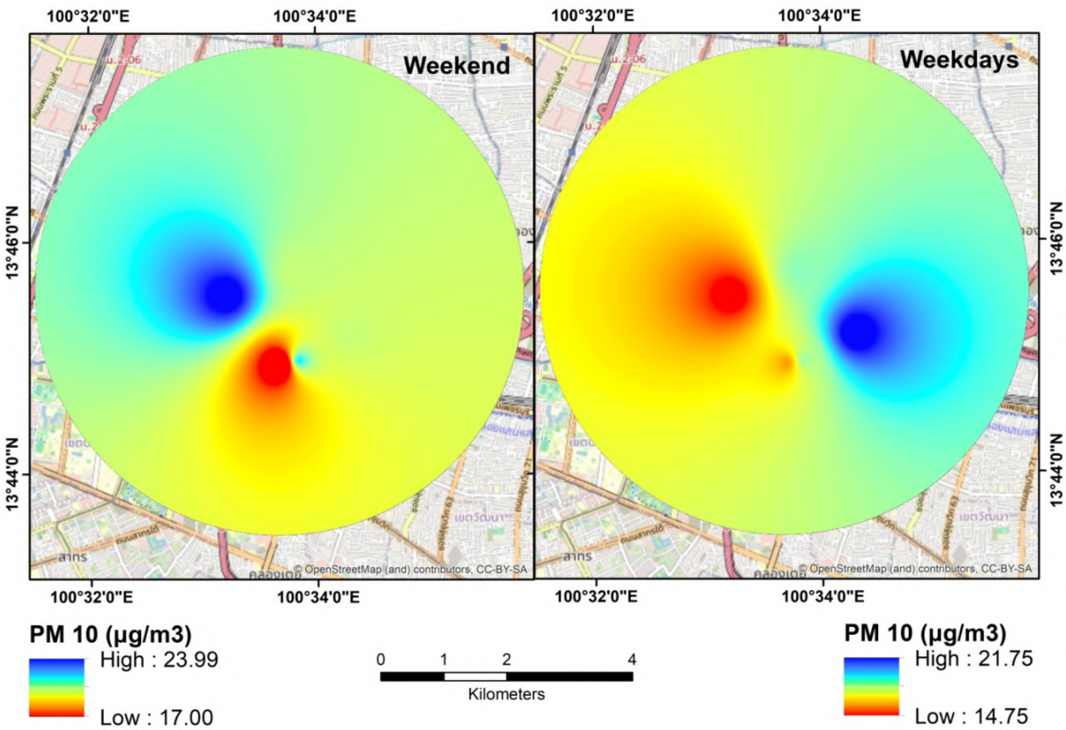


Figure 28: Spatial distribution of PM 10 in Bangkok

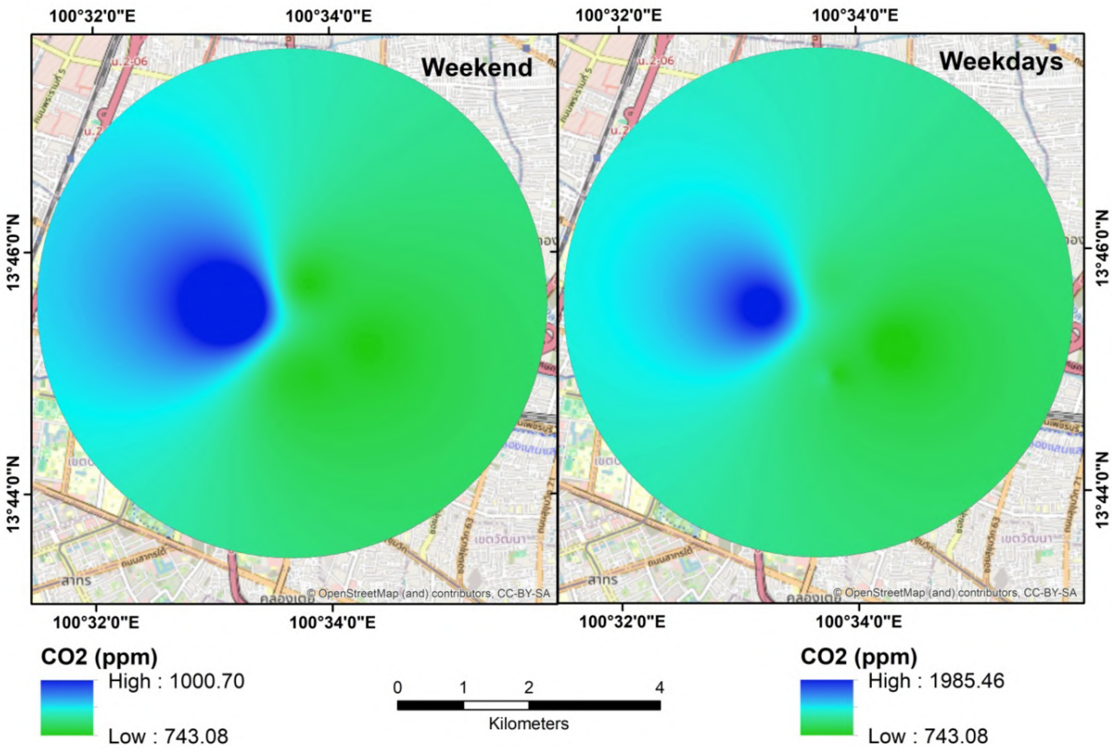


Figure 29: Spatial distribution of CO2 in Bangkok

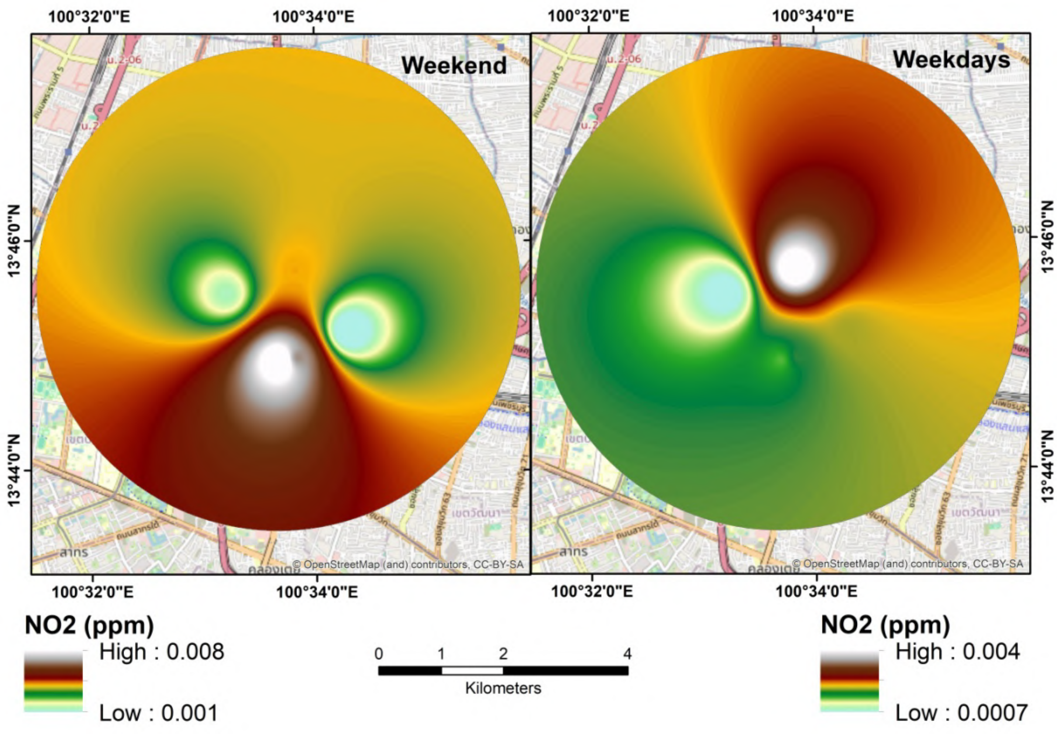


Figure 30: Spatial distribution of NO2 in Bangkok

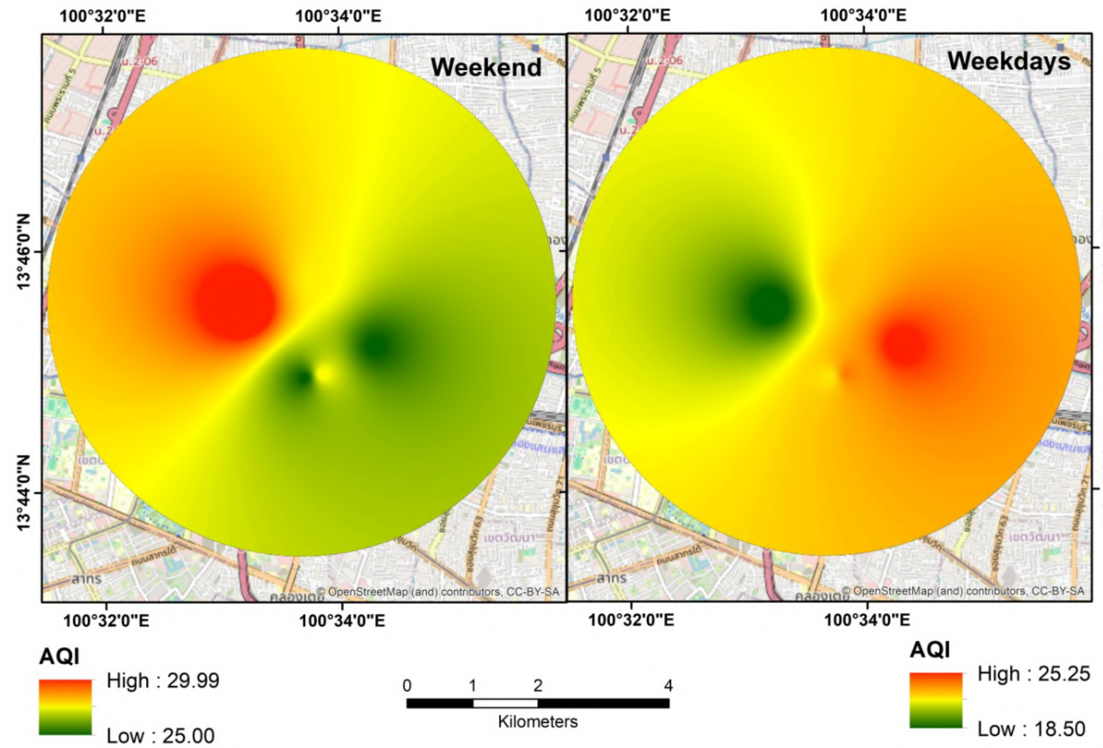


Figure 31: Spatial distribution of AQI in Bangkok

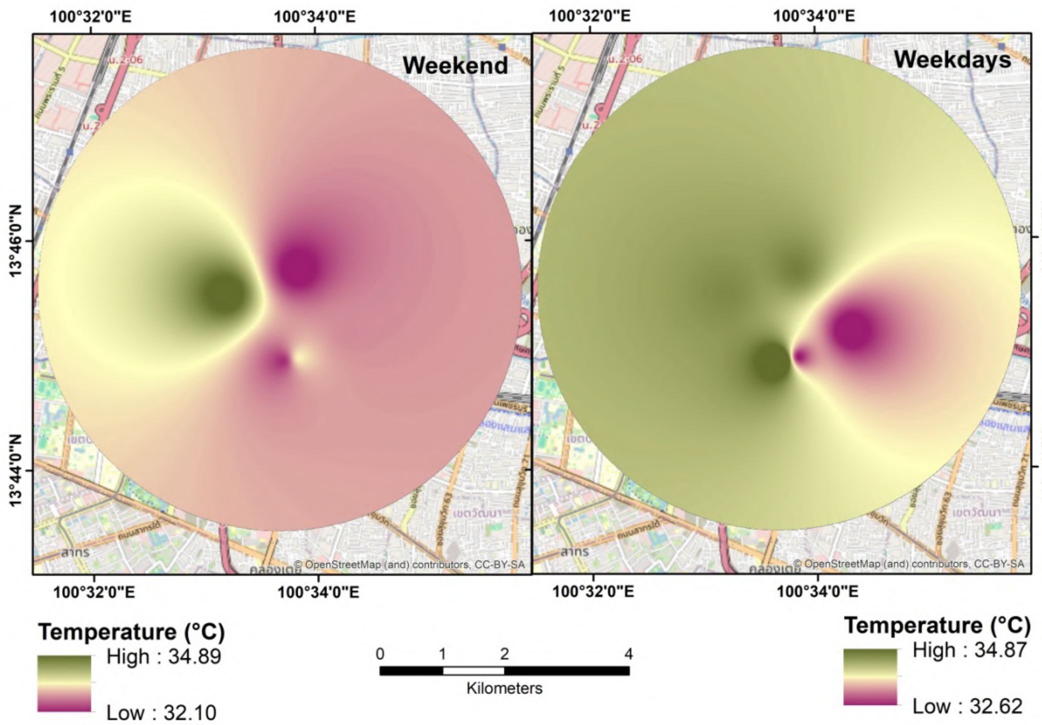


Figure 32: Spatial distribution of Temperature in Bangkok

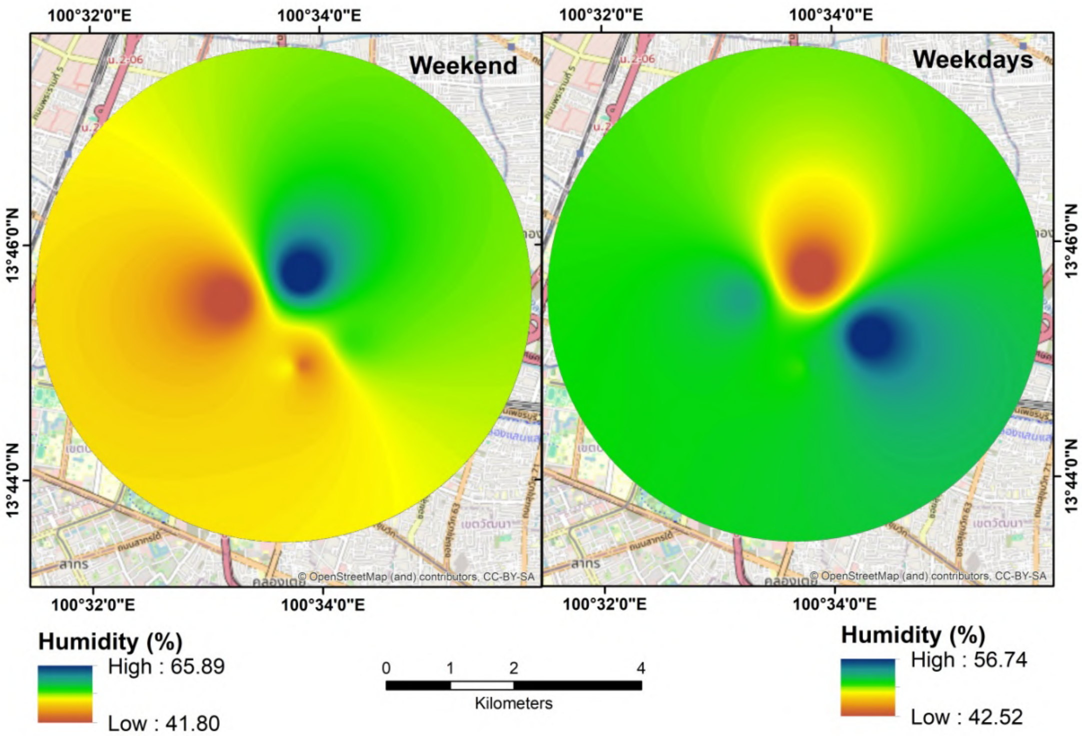


Figure 33: Spatial distribution of Humidity in Bangkok

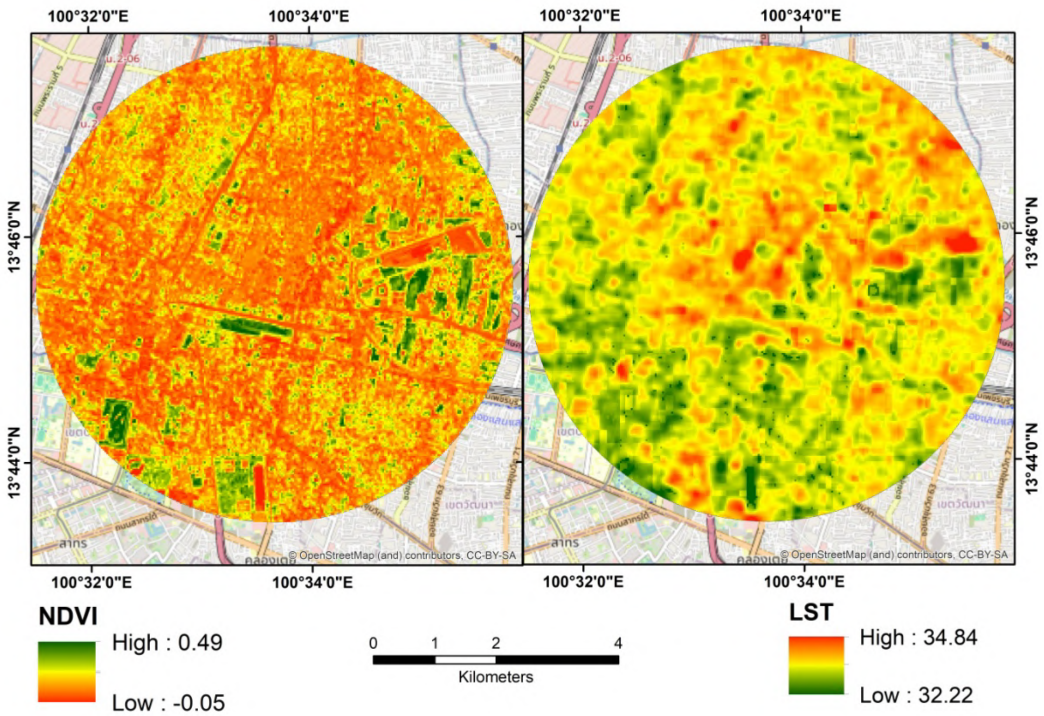


Figure 34: Spatial distribution of NDVI and LST in Bangkok

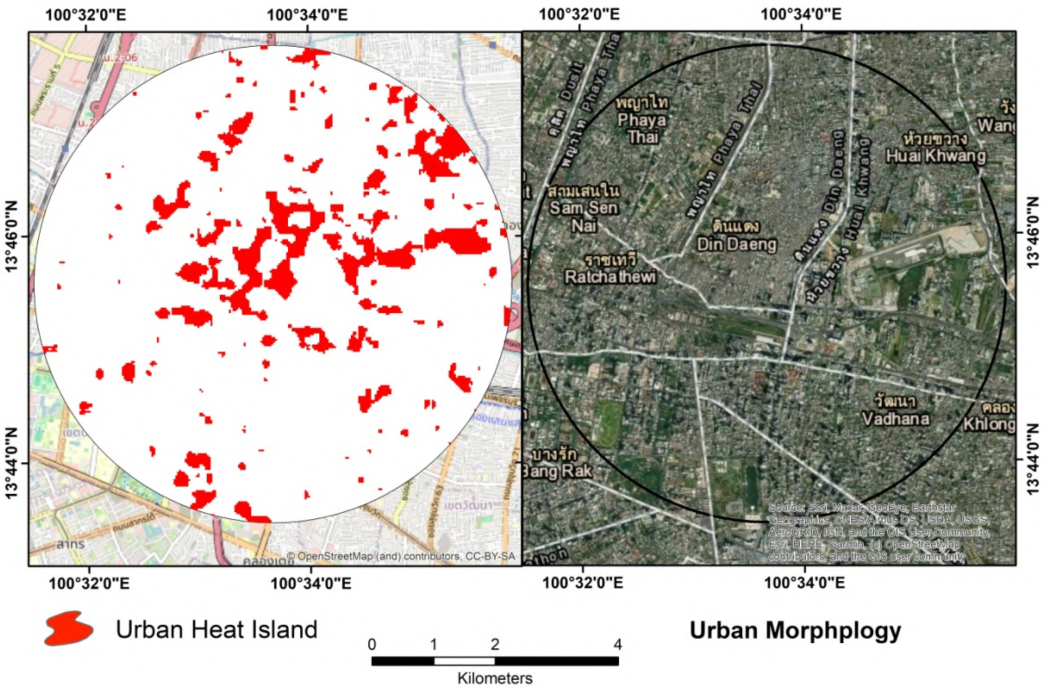


Figure 35: Spatial distribution of urban heat island and urban morphology in Bangkok.

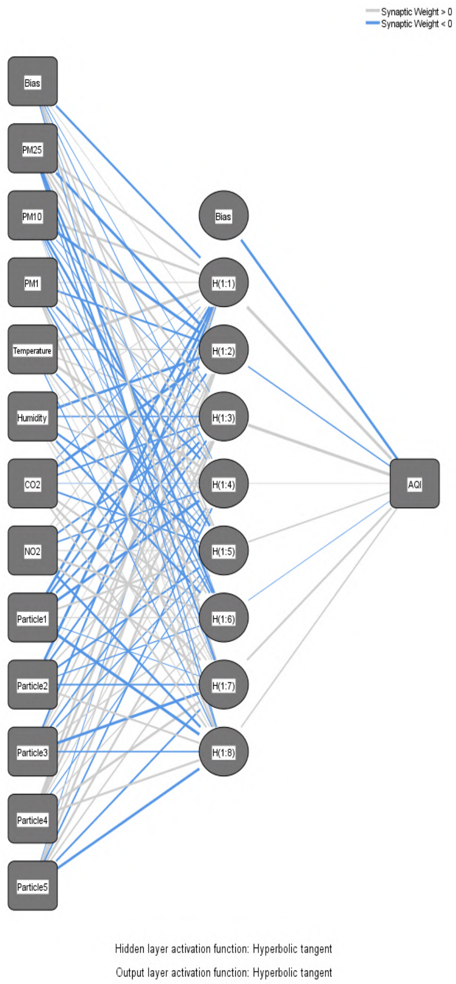


Figure 36: Activation function layer in ANN model considering the weekend datasets in Bangkok.

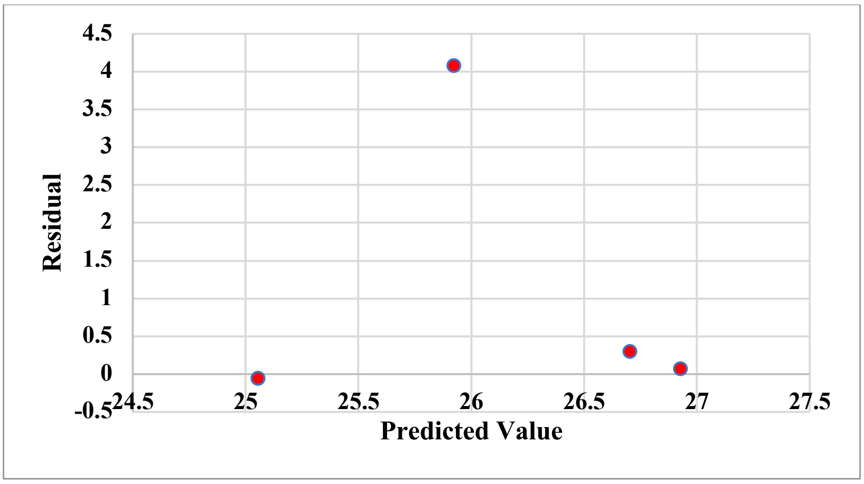


Figure 37: Residuals of the predicted values in ANN model considering the weekend datasets in Bangkok.

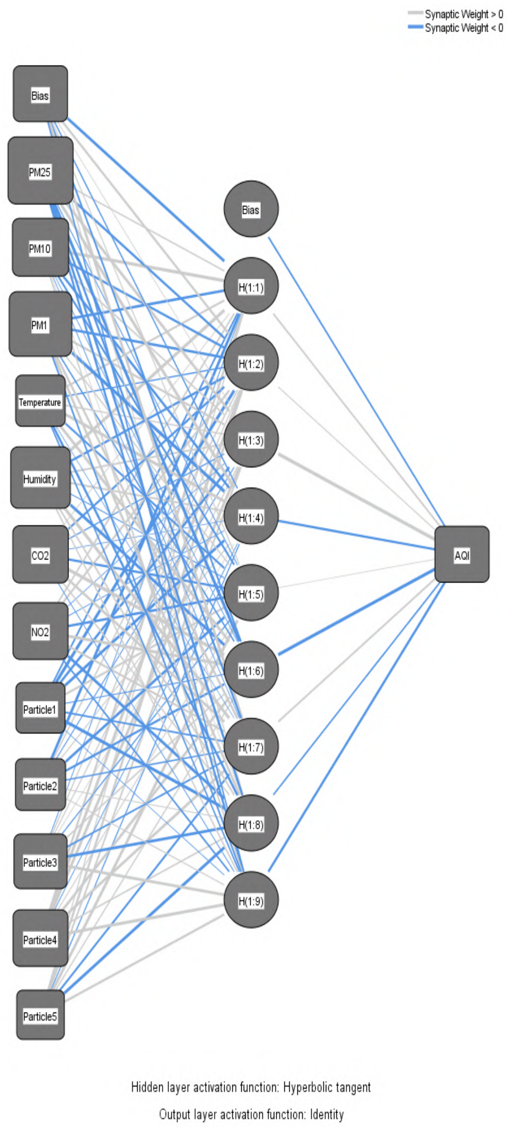


Figure 38: Activation function layer in ANN model considering the weekday datasets in Bangkok

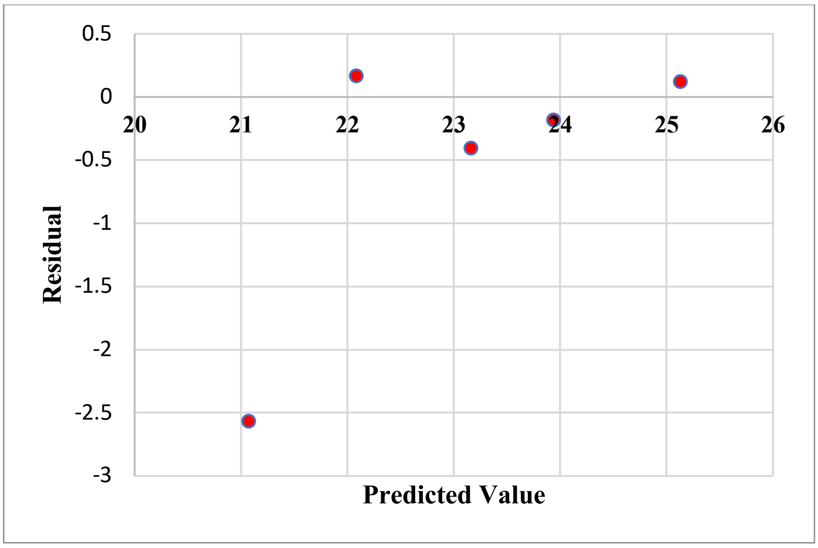


Figure 39: Residuals of the predicted values in ANN model considering the weekday datasets in Bangkok

An Analytical/artificial Neural Network (ANN) model was applied here to estimate the trend of pollutants in Air Quality. The activation function layer and its associated hidden layers are shown above. The optimal capacity of the model in estimating the air quality is high and which indicated the clear-cut short-term prediction in adequate accuracy.

Findings from the weekend

The selection of the points has been done by considering different urban morphology and various transport networks. The highest values of PM 2.5 are found in collector roads. The same scenario has been observed in the case of PM 10. The highest value of CO_2 is mainly found in Principal Arterial Road characterised by multiple highways and intersections. The same scenario has been observed in regard with NO_2. The values of urban heat island for Collector Road (Small Business Center), Local Road (Residential), Principal Arterial Road (Multiple Highways, Intersection), Minor Arterial Road (Business Logistics) and Principal Arterial Road (Commercial Houses) are 32.1, 33.18, 34.41, 34.08 and 23.3 respectively. Apart from this all the points have been considered with the basis of population density pattern, i.e., High Density, High Rise Building, High Rise Residential, Moderate Density, and Medium Size Buildings. The NDVI values for Collector Road (Small Business Center), Local Road (Residential), Principal Arterial Road (Multiple Highways, Intersection), Minor Arterial Road (Business Logistics) and Principal Arterial Road (Commercial Houses) are 0.15, 0.06, 0.05, 0.04 and 0.04 respectively.

Figure 40: Images from the data collection in Bangkok, weekday, February 2024

For estimating the trend of pollutants in air quality, we have used an Artificial Neural Network (ANN) model. In the above figure, we can see the activation function layer as well as the hidden layers that are related to it. The model has a high ideal capacity for evaluating the air quality, which suggests that it can make a clear-cut forecast in the near term with appropriate accuracy.

Findings from weekdays

A variety of urban morphologies and transportation networks were taken into consideration during the selection process for the spots. In the Principal Arterial Road, the PM 2.5 concentrations are reported to be at their most significant. On the other hand, the situation has been seen to be the same with PM 10. Collector Road, which is defined by a Small Business Centre, is the primary location where the highest level of CO2 may be detected. Local Road, which is defined by some settlement area, has the highest amount of NO2 that can be discovered elsewhere. It is important to note that the values of urban heat island for Collector Road (Small Business Centre), Local Road (Residential), Principal Arterial Road (Multiple Highways, Intersection), Minor Arterial Road (Business Logistics), and Principal Arterial Road (Commercial Houses) are as follows: 32.1, 33.18, 34.41, 34.08, and 23.3 respectively. Aside from this, every single point has been taken into consideration with regard to the pattern of population density, which includes High-Density, High-Rise Building, High Rise Residential, Moderate Density, and Medium Size Buildings. Collector Road (Small Business Centre), Local Road (Residential), Principal Arterial Road (Multiple Highways, Intersection), Minor Arterial Road (Business Logistics), and Principal Arterial Road (Commercial Houses) each have NDVI values of 0.15, 0.06, 0.05, and 0.04 accordingly.

Spatial Analysis of Air Quality and Temperature in Yangon, Myanmar

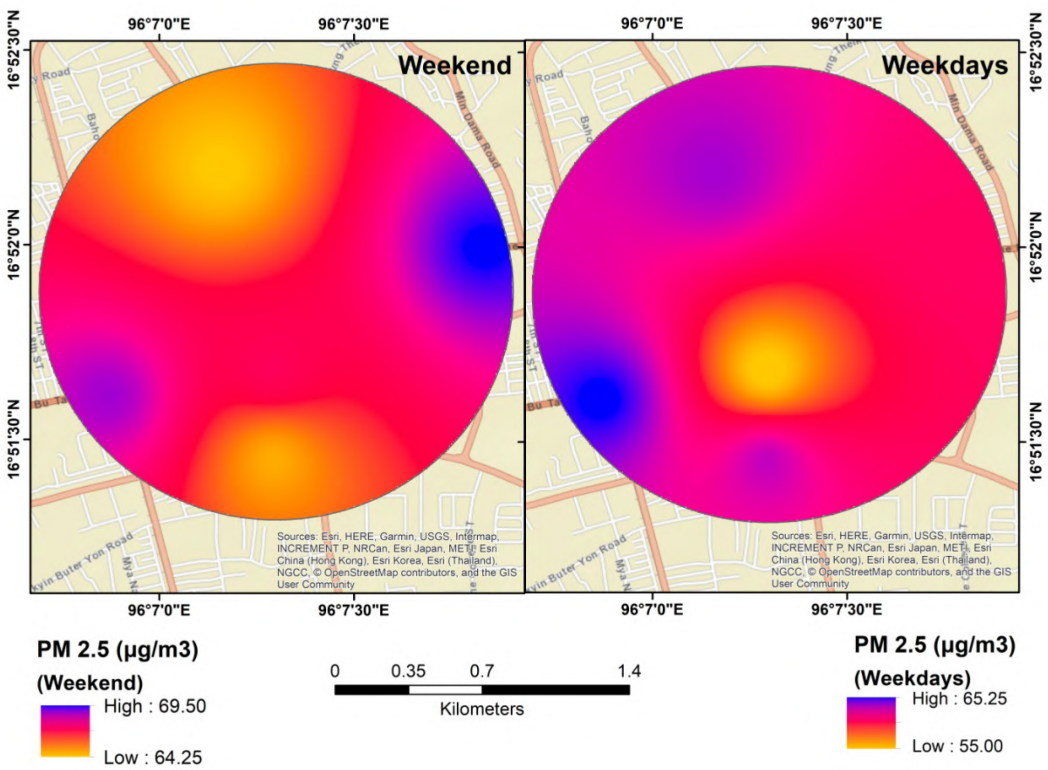


Figure 41: Spatial distribution of PM 2.5 in Yangon

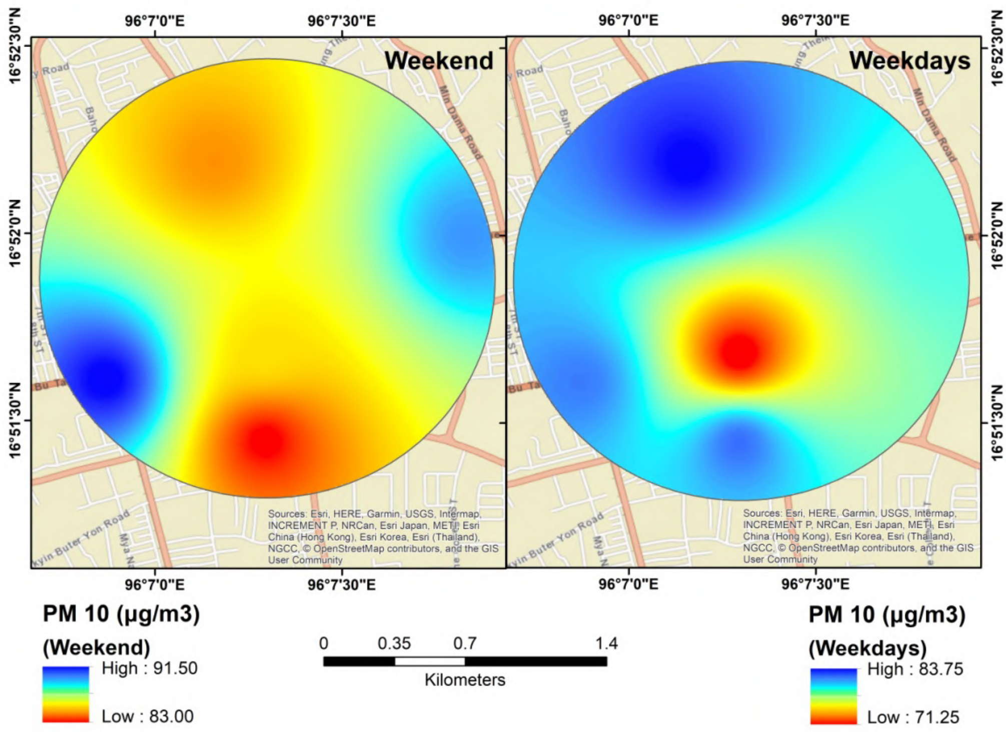


Figure 42: Spatial distribution of PM 10 in Yangon

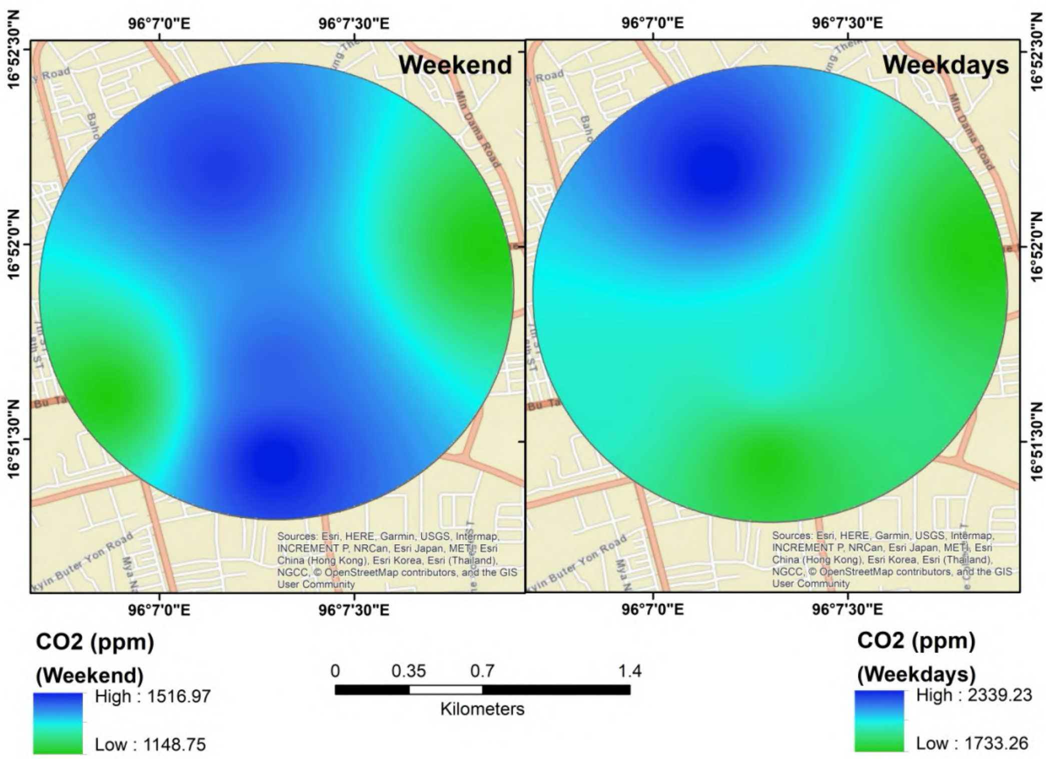


Figure 43: Spatial distribution of CO2 in Yangon

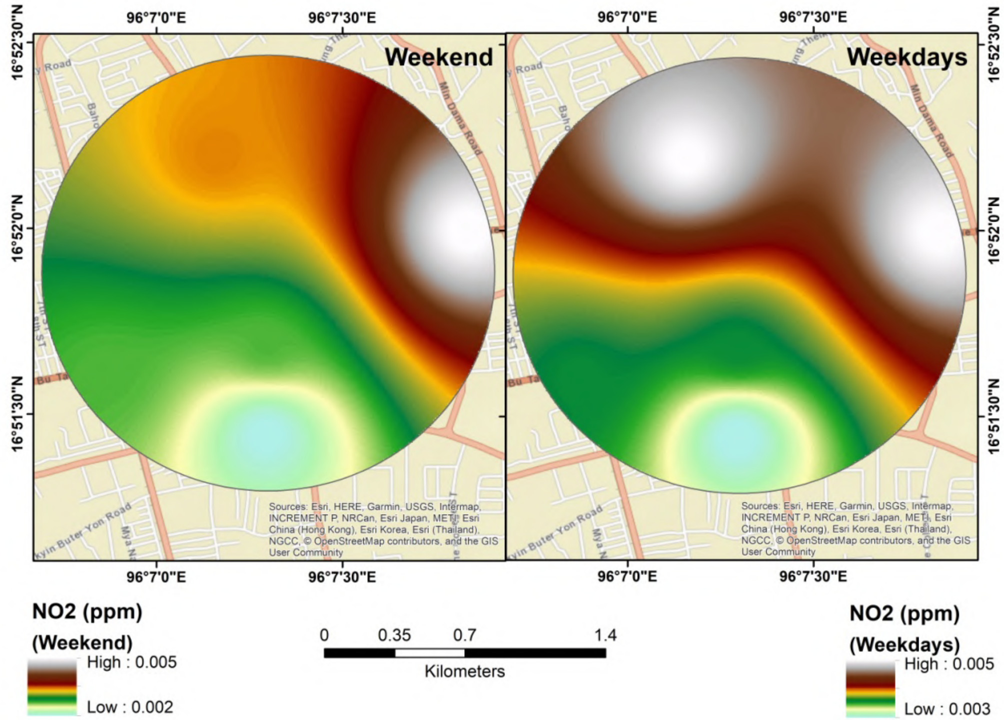


Figure 44: Spatial distribution of NO2 in Yangon

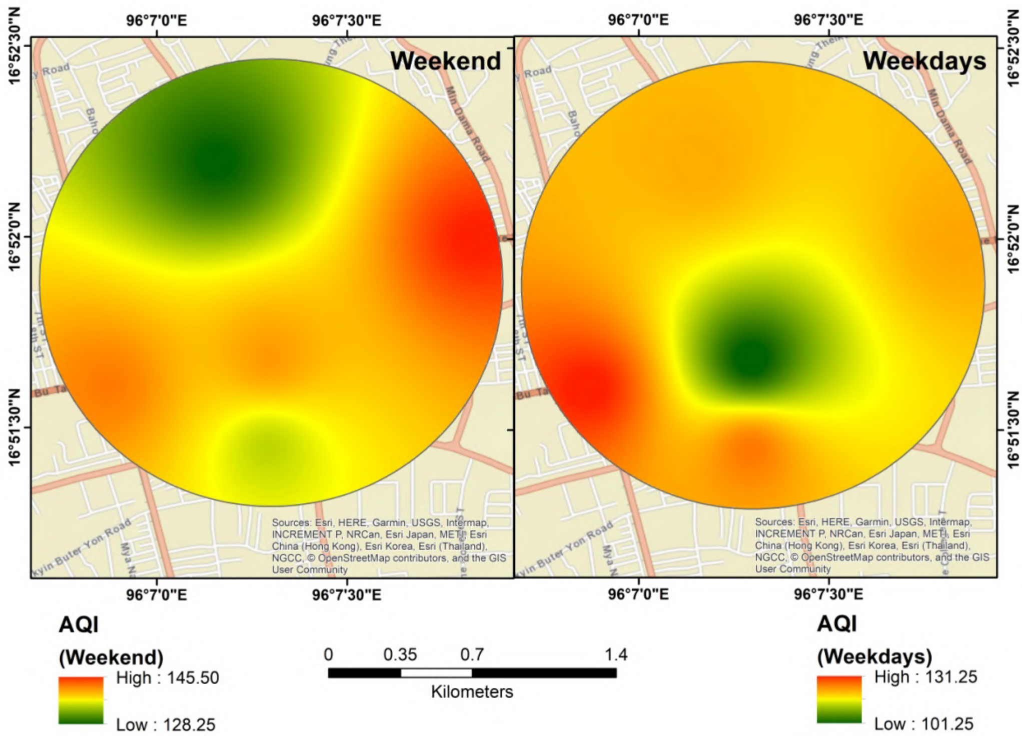


Figure 45: Spatial distribution of AQI in Yangon

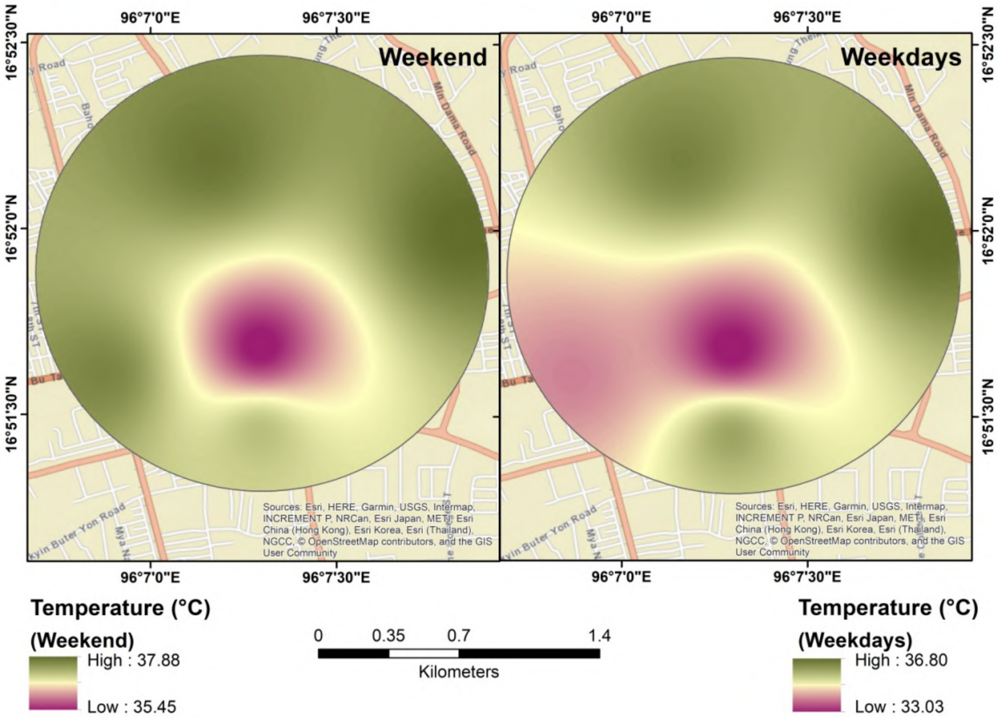


Figure 46: Spatial distribution of Temperature in Yangon

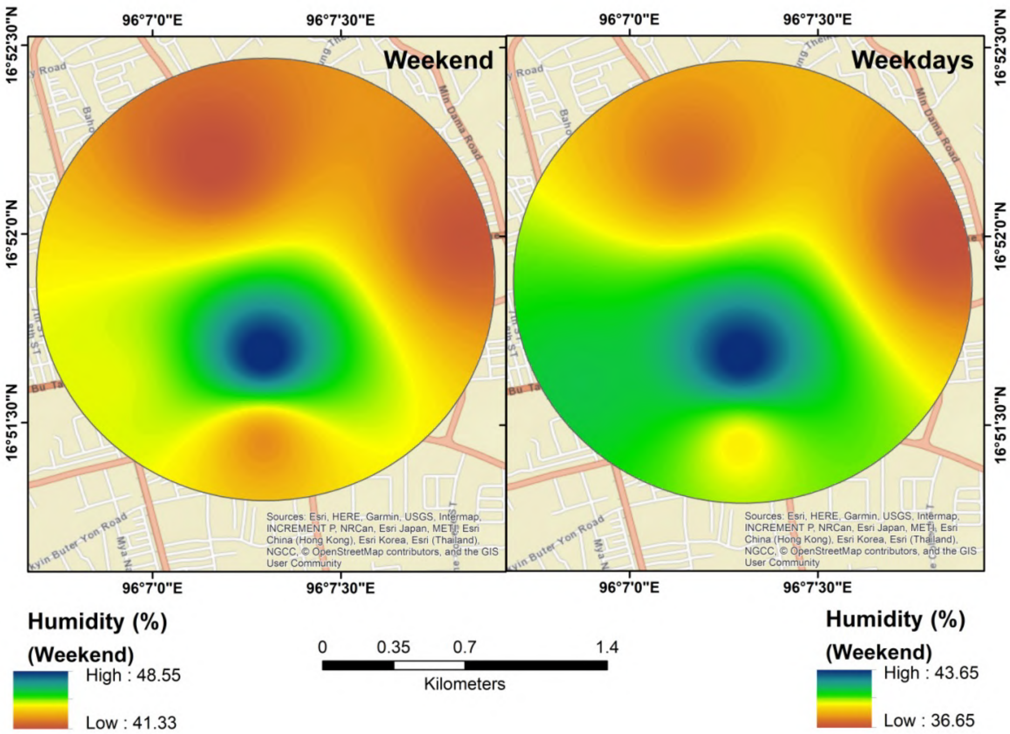


Figure 47: Spatial distribution of Humidity in Yangon

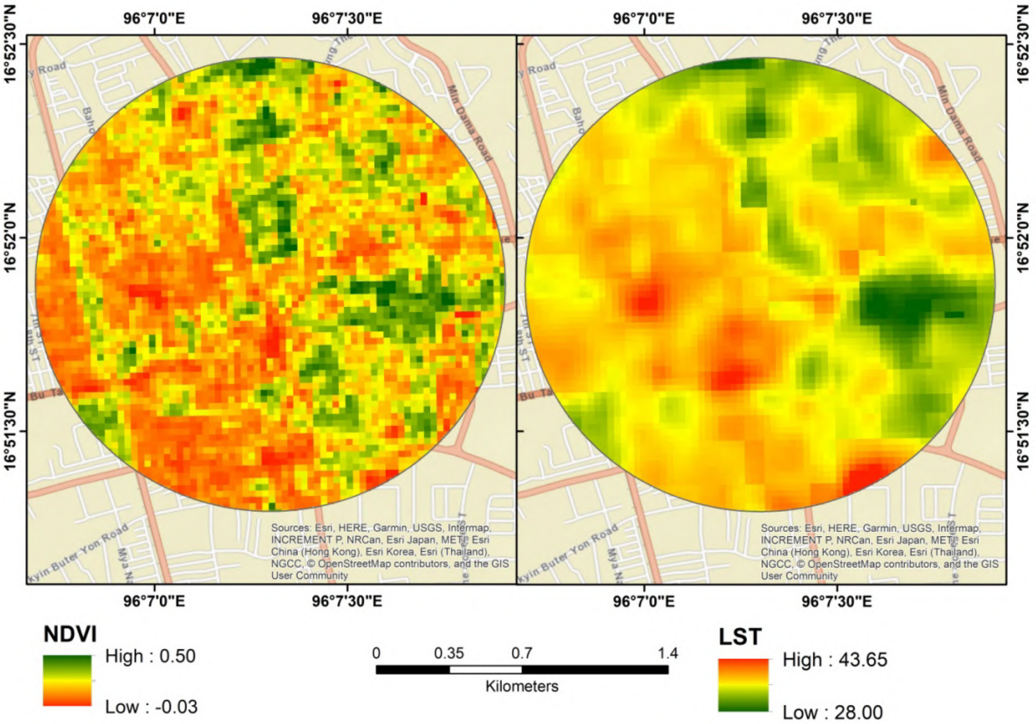


Figure 48: Spatial distribution of NDVI and LST in Yangon

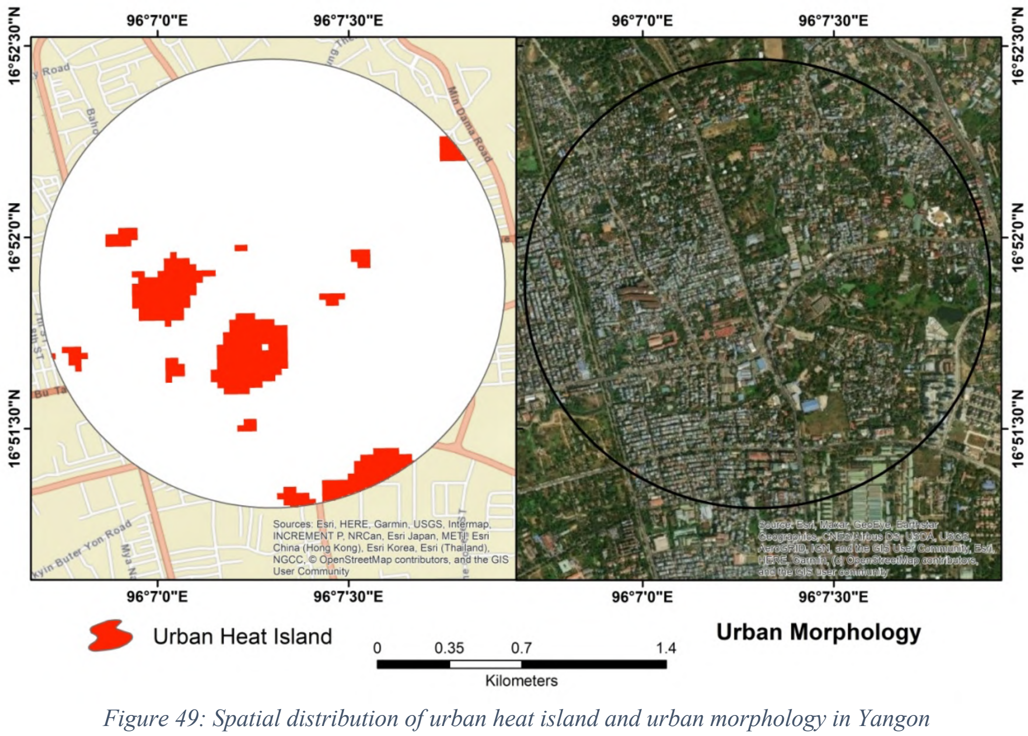


Figure 49: Spatial distribution of urban heat island and urban morphology in Yangon

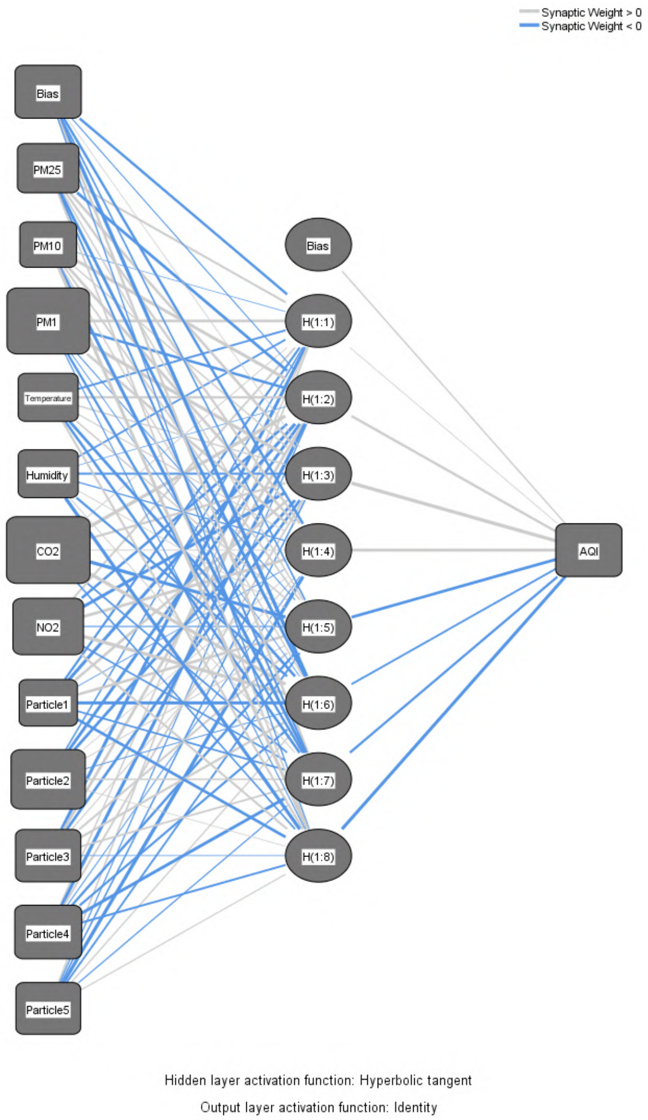


Figure 50: Activation function layer in ANN model considering the weekend datasets in Yangon

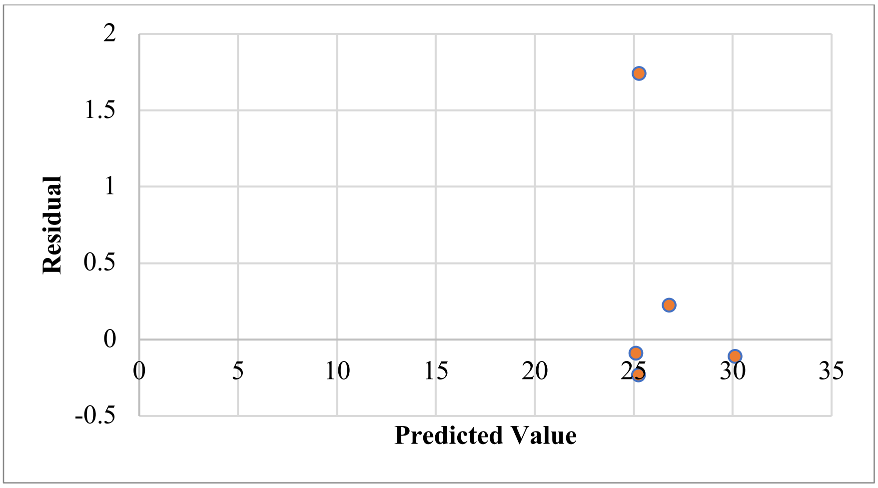


Figure 51: Residuals of the predicted values in ANN model considering the weekend datasets in Yangon

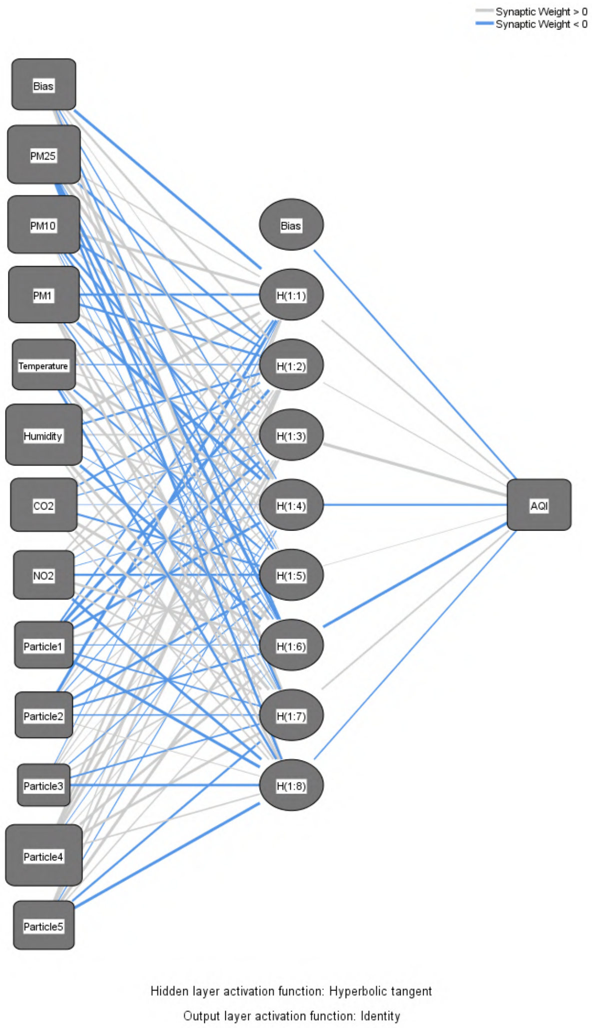


Figure 52: Activation function layer in ANN model considering the weekday datasets in Yangon

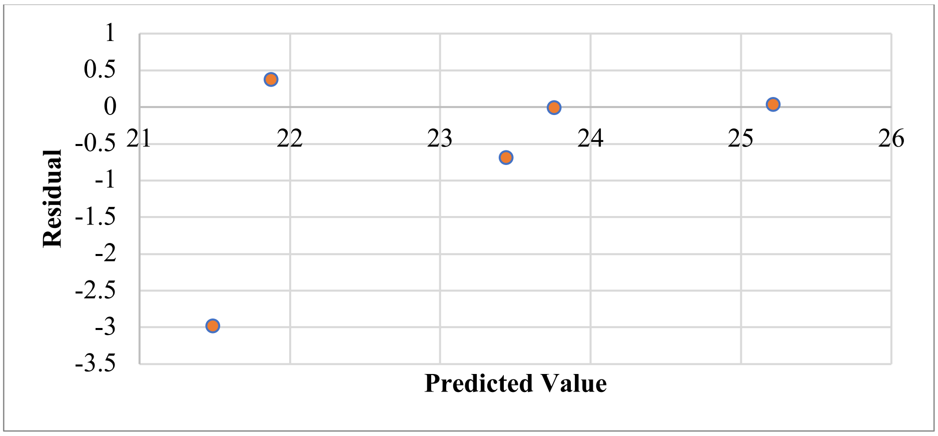


Figure 53: Residuals of the predicted values in ANN model considering the weekday datasets in Yangon

Visual analysis

- Levels of air quality varied considerably between weekdays and weekends in the three selected cities. The difference was less noticeable in Manchester as the dates of weekend measurement coincided with the celebration of the Chinese New Year with large influx of visitors to the Piccadilly areas. Other studies in Manchester, however, show differences in air quality between weekdays and weekends.
- Unlike Manchester, higher air quality levels have completely spatially reversed in the weekend in Bangkok and Yangon. This indicates a very different mobility patterns during the weekend because of the dispersion of leisure and business sites.
- The analysis shows that Bangkok, with its high urban canyon ratios, higher measured temperature coincided with higher levels of air PMx pollutants. This was not the case in Yangon with its very low urban canyon ratios. The results highlight the importance of considering urban morphology in air quality studies and related health risks, particularly in Southeast Asian cities with their high density and high urban canyon ratios.
- The analysis confirms the corelation between the flow of traffic and air quality indicators in both Bangkok and Yangon as previously established in Manchester City Centre (Elmarakby and Elkadi, 2024)

Visual analysis of collected data in the selected areas

Air Quality Index has been calculated using a variety of attributes related to various air pollutants. AQI is generally calculated based on data related to CO, Ozone, NO2, SO2, PM2.5 and 10. The equation used is (EPA, 2018):

$$I^{b} = \frac{\mathrm{Bb}^{HI} - \mathrm{Bb}^{\Gamma o}}{I^{H!} - I^{\Gamma o}}(C^{b} - \mathrm{Bb}^{\Gamma o}) + I^{\Gamma o}.$$

Where Ip- the index for pollutant p

Cp= the truncated concentration of pollutant p

BPHi= the concentration breakpoint that is greater than or equal to Cp

BPLo= the concentration breakpoint that is less than or equal to Cp

IHi = the AQI value corresponding to BPHi

ILO= the AQI the value corresponding to BPLo

Several attempts have been made since to accurately develop indices of pollution based on the epidemiological dose-response function associated with each pollutant (e.g. Khanna, 2000). However, such efforts were not applied to the specifity of densities and morphology of inner cities where intense land use activities combined with urban heat island effects impact on concentration or dispersion of pollutants.

The BREATHE-Cities project examines the reliability of methodology used to determine 'Air Quality' in highly dense inner cities. Due to a combination of intense activities, urban morphology, and UHI effects, the actual risk to health could be widely varied in inner cities situations. A series of visual interpretations of collected data from weekdays and weekends were compared, layering different air quality, temperature, and Urban Heat Island (UHI)variables. An example is given in Figure 54 for data collected in Bangkok (Figure 54).

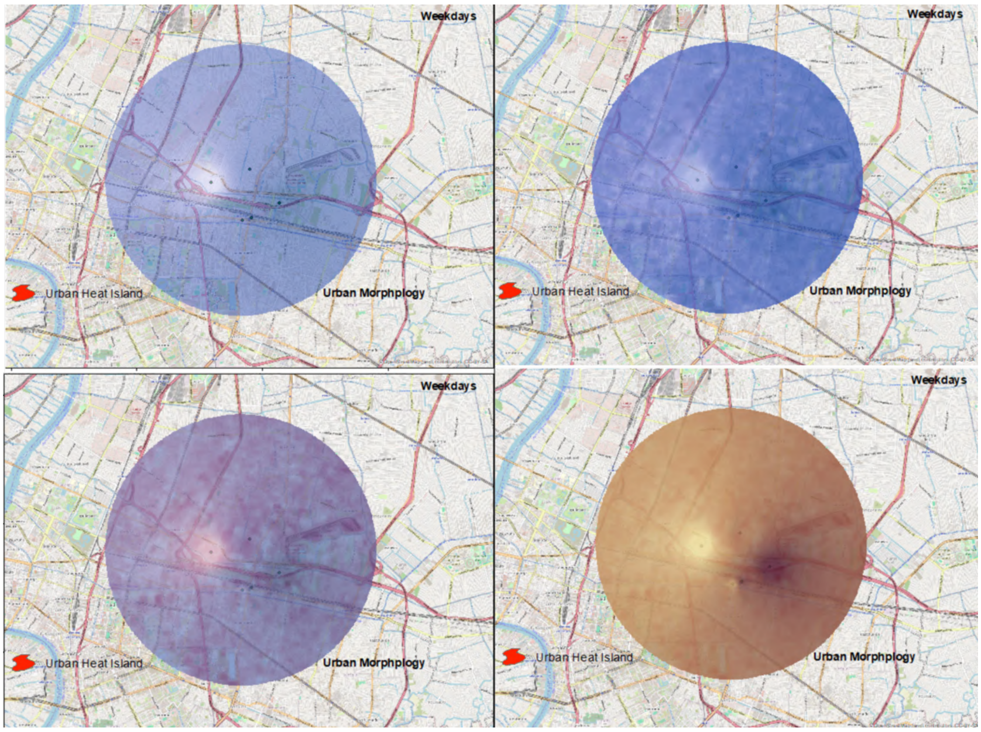


Figure 54: Visual analysis of layers of collected data in Bangkok (Weekdays)

The project initial analysis shows slight differences between visual data of air quality spatial (AQ) distribution and those when combined with Urban Heat Island (UHI) effects. The combined risk seems generally to be much higher than the AQ methodology indicates (Figure 55Figure 56).

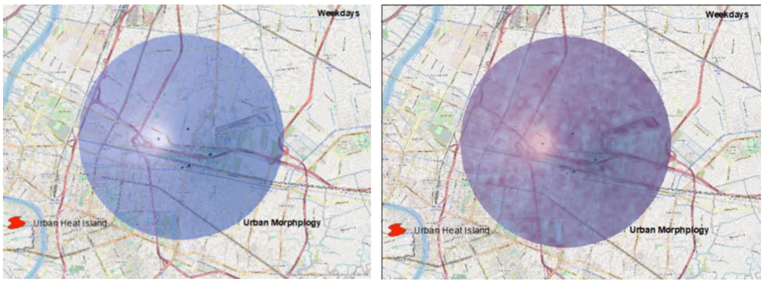


Figure 55: AQ in Bangkok (weekdays) *AQ+UHI in Bangkok (weekdays)*

Figure 56: AQ in Bangkok (weekends) *AQ+UHI in Bangkok (weekends)*

The differences seem to be more noticeable during weekends as displayed for Bangkok (Figure 56) and Yangon (Figure 57).

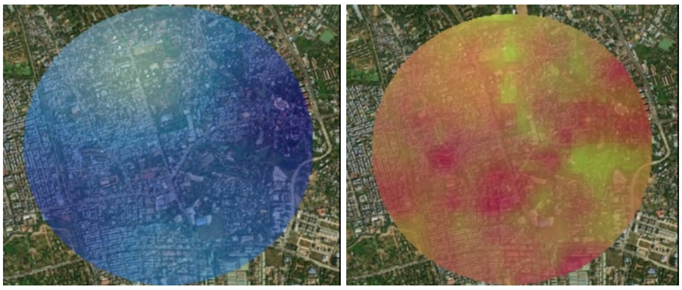


Figure 57: AQ in Yangon (weekends) AQ+UHI in Yangon (weekends)

In order to assess the level of risk for the inner city population, data related to demographic characteristics (population) and urban morphology (urban configuration, land use, ..) were analysed using variety of raster and vector GIS layers for the three cities (Figure 58).

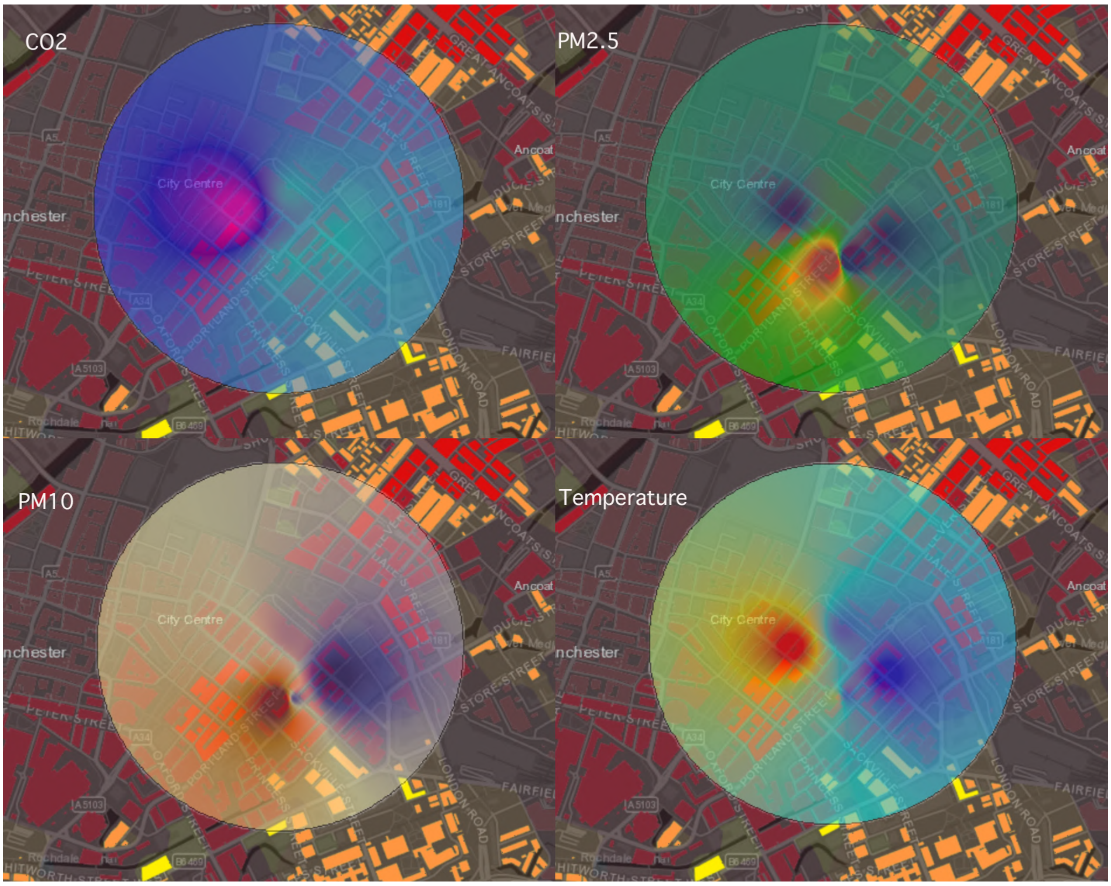


Figure 58: GIS mapping of measured data with urban density in Manchester

Analysis of Public Engagement in Yangon

Collection of survey was taking place for one and a half month in three selected locations seen - Fig (60). Estimated 5-6 volunteers have been operating to collect surveys lasting 15-20 mins with the balanced gender ratio (45% female & 55% male) ranging from various age groups and income levels as shown in Fig (61, 62, 63, 64). In total, there are **314 respondents** so that they respond to the survey questions while they are commuting to their workplace or home. Regarding focus group discussions, there are **6 workshops** in total holding **60 participants** over the three locations with the communities who are settling. **Eight Interviewees** were gathered after workshops and conducted the in-depth interviews to explore and identify the challenges and needs of the vulnerable communities. Two interviewees have been conducted online to enhance the recommendations and current measures and improvement from the perspectives of environmental and health experts.

Socio-economic and commuting mode

Through the survey, **the monthly income of the average respondents** is around 2 Lakhs to 3 Lakhs (estimated around 200 USD). Only a few people (1 percent) indicate that they retain more than 10 Lakhs as a monthly income. Regarding their employment status, 69 percent of the respondents are having full-time jobs while 23.6% holding part-time jobs. These part-time jobs include working at the construction sites, delivery couriers, and retailed workers who require to use physical capabilities. The average age ranges from 35 to 55 years old regarded as early adults in this survey. This shows that the mean income of people who are contributing their social activities such as waiting for buses, having meals, etc, are experiencing air pollution in that area and transport hub in their daily lives.

Regarding **the time that is spent outside** (Fig 65), the average hours that the respondents spent 10 to 12 hours outside their homes. The average commuting time to their workplace is less than 15 mins while only 6% of respondents' time consumes 1 to 2 hours daily. Among these respondents, **the main earners travel to work now by bus or train** by 26% whereas 61% of the respondents travel **by cycling or walking**. Only 2% of the respondents travel by private car to their work. This indicates that the respondents who experience air pollution in the targeted area are less likely to be considered as the main contributor of emitting carbon emissions based on their commuting mode.

From the Focus Groups Discussions, some participants reveal that

"I use sometimes, trishaw or sidecars to carry my groceries. This is accessible to move around with heavy items since I cannot afford taxi fares,"

"Using trishaw or sidecars is conformable compared to public transport, as the travel distance to the grocery shop (market) is close to my house estimating 15 mins travel by trishaw or sidecars,"

" As I am a (taxi) driver who has to bring passengers to their destination, I usually spend my time outside," (see figure 59)

Figure 59:A statement depicting the representative's outdoor time consumption

These particular participants work at home or even some of them are opening their own grocery shops in front of their homes. Therefore, they are required to travel to markets every day and restock the foods and beverages for their grocery shops or stores. Trishaws and sidecars are commonly used by the locals who commute to the shorter distance (around 1 to 2 kilometres). Trishaws are bicycles attached to a pavilion that can hold 1 to 2 persons on it whereas sidecars are motorcycles operated over fossil fuels. Sidecars are emerging in recent years to travel the greater distance without physical efforts (cycling) and can carry a decent number of weights. This implies that the by-product of this emergent pattern can enhance the level of air pollution not only on the main roads but also on the narrow streets.

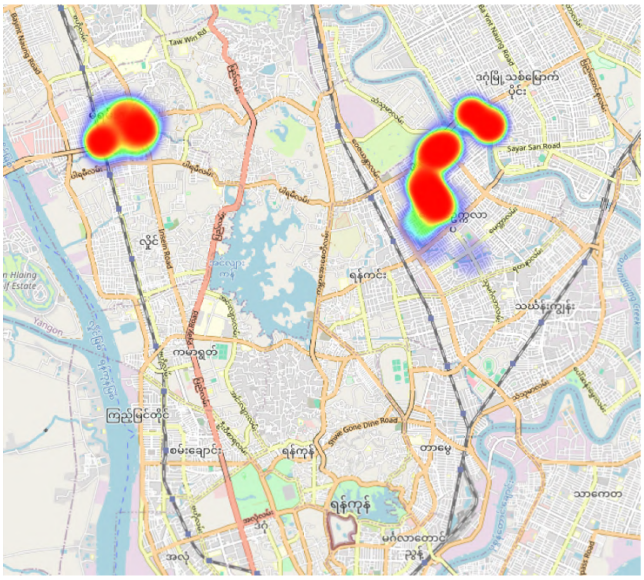


Figure 60:A heat map indicating the locations of 314 respondents through survey

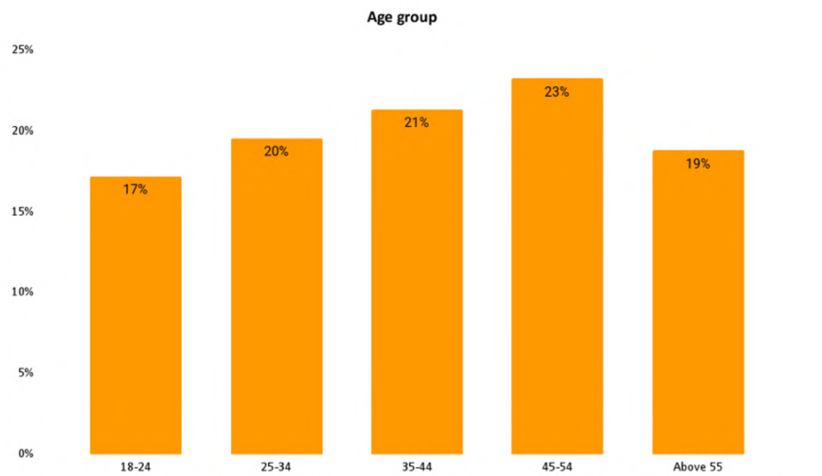


Figure 61: Age of participants in the workshops

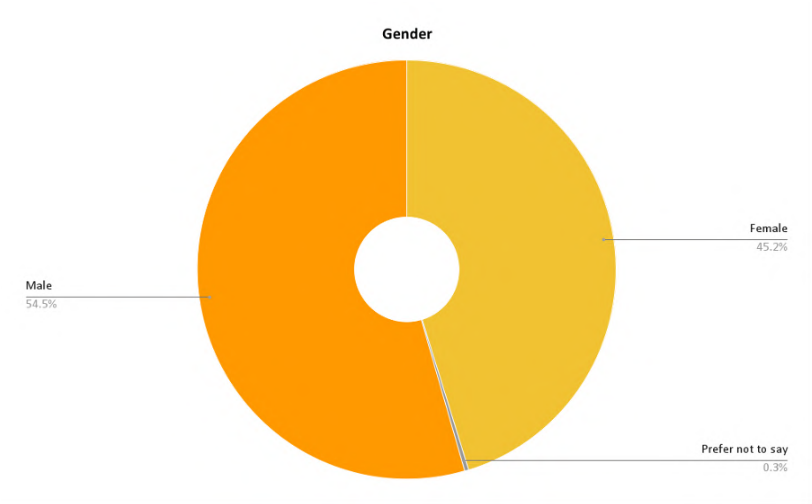


Figure 62: Gender of participants in the workshops

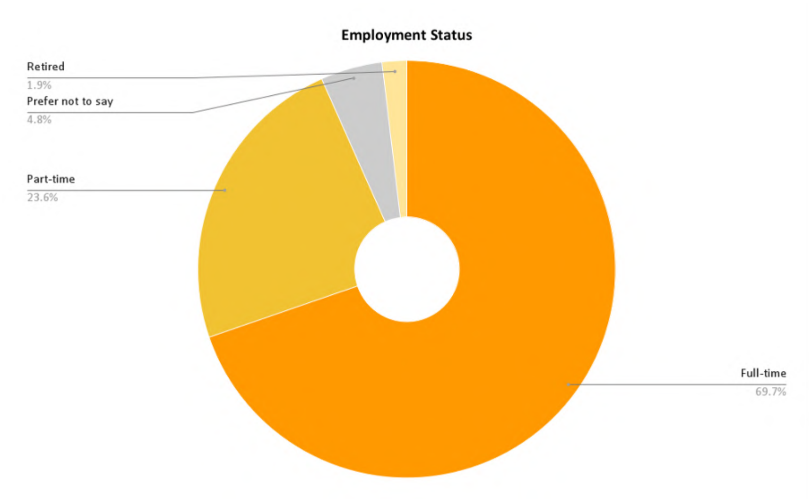


Figure 63: Employment status of participants in the workshops

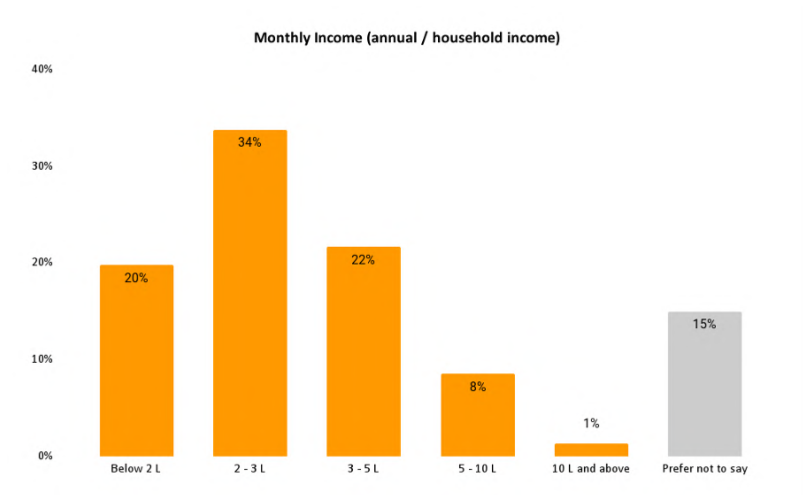


Figure 64: Monthly Income (Annual / Household Income)

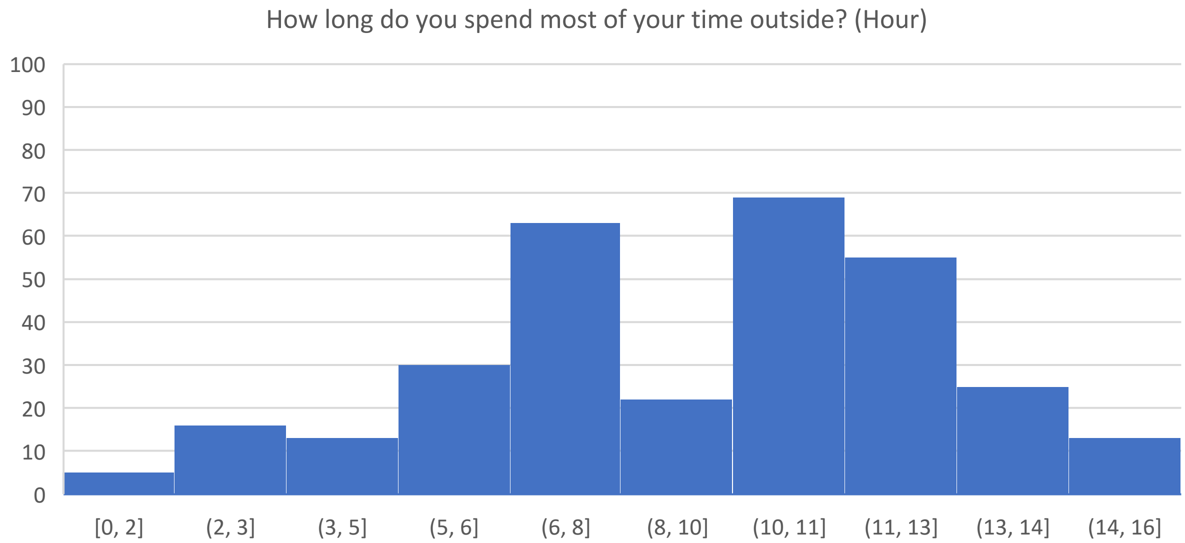


Figure 65: Time consumption outside the respondents' houses'

Perception and Experiences towards air pollution

To assess the **perception of air quality** at their proximity, 66.2% of respondents answered that their surroundings are dusty while 22.3% showed that their environment is clean *(*Fig. 66*)*. Regarding **the perception of air quality while commuting** (Fig 67), 66% of the respondents indicate "unhealthy" whereas 25% reveal "healthy" while commuting to their workplace or home. This also refers to assessing the experience and perception of their comforts, associated with transportation. To understand **the difference of air quality between workplace and home**, 50-60% of respondents reveal that both places are unhealthy. This implies that those are likely to expose air pollution at both workplace and home and cannot differentiate the perception of air pollution among these places.

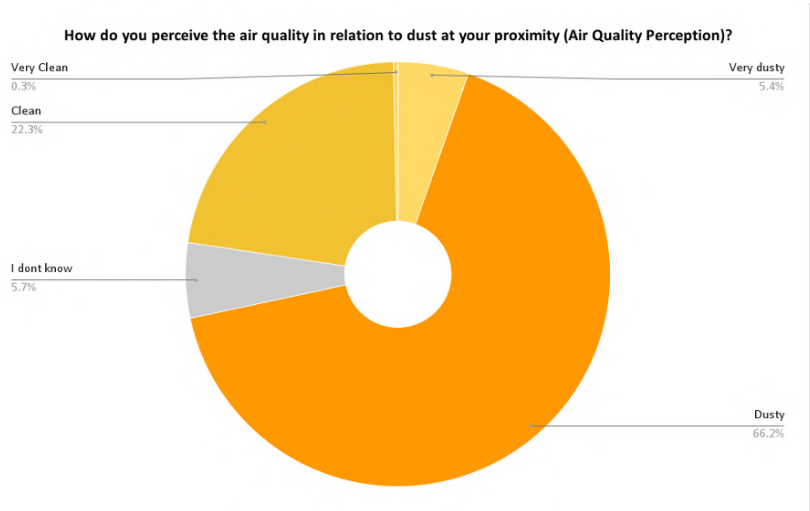
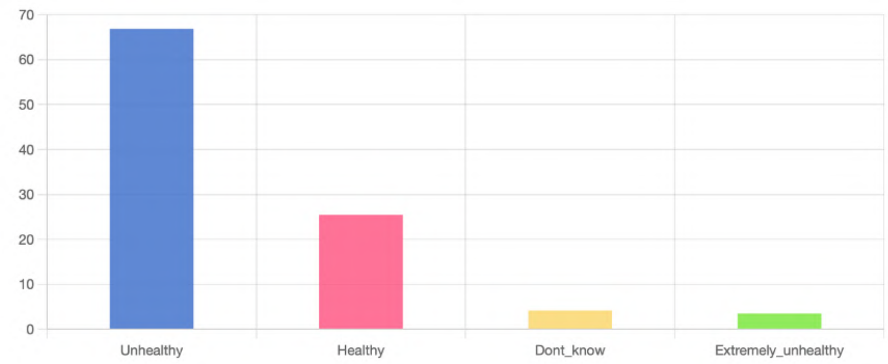


Figure 66: Perception of the levels of air quality among participants of the workshops



Value	Frequency	Percentage
Unhealthy	210	66.88
Healthy	80	25.48
Dont_know	13	4.14
Extremely_unhealthy	11	3.5

Figure 67: Air quality perception while commuting

Associated with the experiences exposed over air pollution, most of the participants at focus group discussions stated headache, dizzy, and nausea. Some participants reflected upon their productivities as well stating that

"After experiencing a disturbing smell over a period of time, I feel less likely to go to work, or even not want to work at all. My morning is ruined and follow to the rest of days,"

"……the smell is disturbing and disgusting. Whenever I eat outside in the midst of polluted air emitted by the car (bus, taxi, mainly), it can ruin my appetite. And Hard to breathe," (see Figure 68)

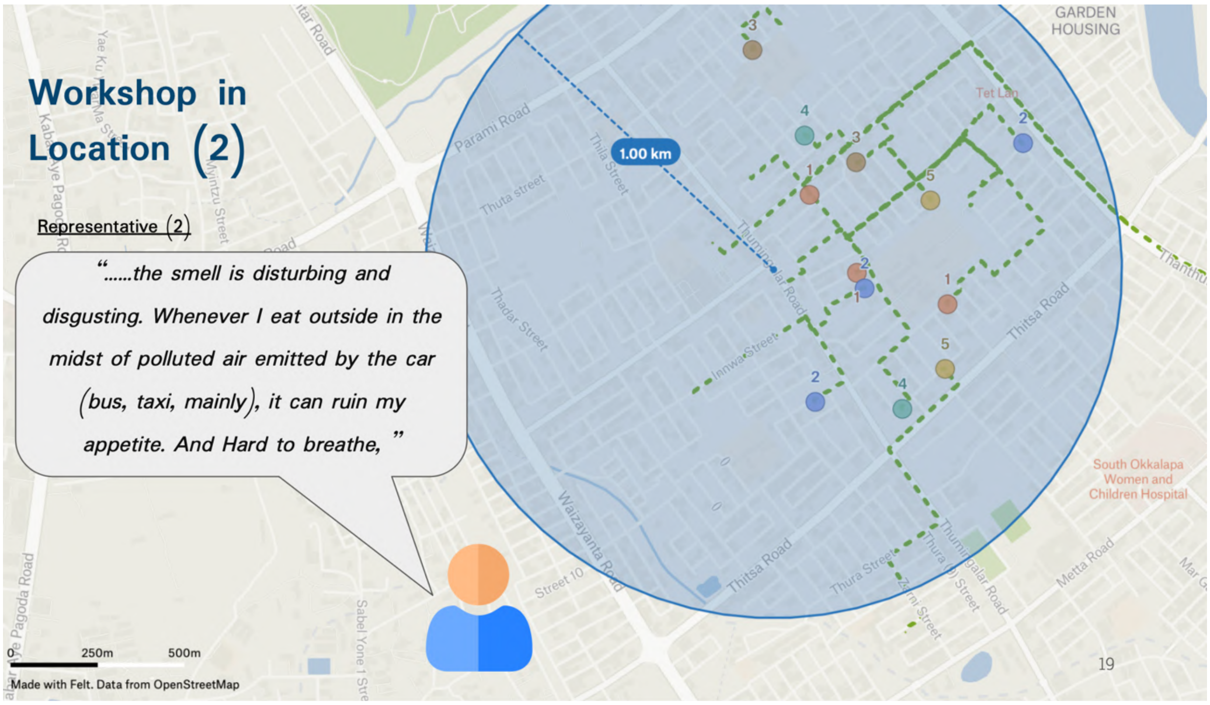


Figure 68: A statement depicting the representative's perception towards air pollution

Social activities entail selling groceries, foods on the street mainly delivered by street vendors and waiting for buses and having meals outside or on the streets. These additional activities exacerbate the air pollution since these generate wastes and well-disciplined manners over disposing waste is very limited in Yangon. Uncoordinated waste management system heightens the level of air pollution in the transport hub. A respondent who usually eat outside during the break time implies that

"…. this pungent and disgusting smell comes to my nose and makes me vomit. Imagine if I am passing by around these locations every day, the rest of the day would be ruined,"

Additionally, most of the participants mentioned that air pollution makes them suffocate, as they are consuming most of their time on the busy road. Street vendors in particular, are deliberately engaging with air pollution regardless of the air pollution as their income is significantly depending on the location (busy roads, transport hub). Few participants stated that

"I feel normal. I don't think the air is polluted. (……) It is our day-to-day life. Nothing special,"

This indicates that experiencing over air pollution or abnormal conditions from time to time normalises into the context. It may even be harmful to the locals' health and their productivities, which are problematic to express their challenges and needs over exposure towards air pollution.

For residents in the transport hub, they are experiencing air pollution emitted by transports by means of the overflow of vehicles in front of their places. Some participants stated that

"My house is full of dust every day and I have to clean it so imagine how much dust my family breathe every day,"

"I see many vehicles in front of my place which makes it unpleasant to live on the busy street. They generate a lot of noises too. It can impact to my relaxed days even during the weekends," (see figure 69)

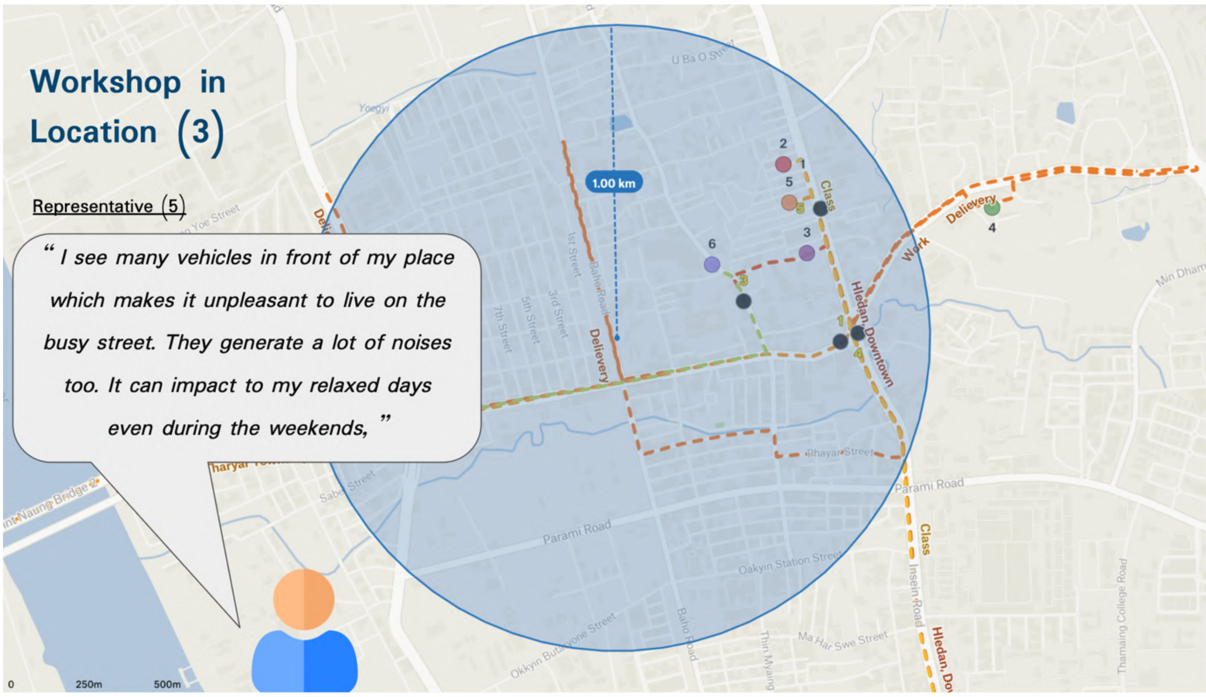


Figure 69: A statement describing the environment in the vicinity

From the key informant interviews, the person who lives next to the bus stop expressed his experiences and exposure towards air pollution induced by the transport.

"When a car stops in front of my place, we experience blackish gases generated from vehicles as their cars are parked facing our house (in front). These gases cannot be avoided and stayed inside our houses for a certain period of time,"

This particular case can occur among the residents who live in the transport hub. Since the parking system is uncoordinated, double, or triple lines of parking systems tends to occur on the street which affects to the residents.

There is **a disconnect** between **perceived health status** and **perceived air quality** (Figure – 70). While 33.1% of respondents consider the air "unhealthy", they self-rate their health as healthy. This could indicate a lack of awareness about the long-term health impacts of air pollution.

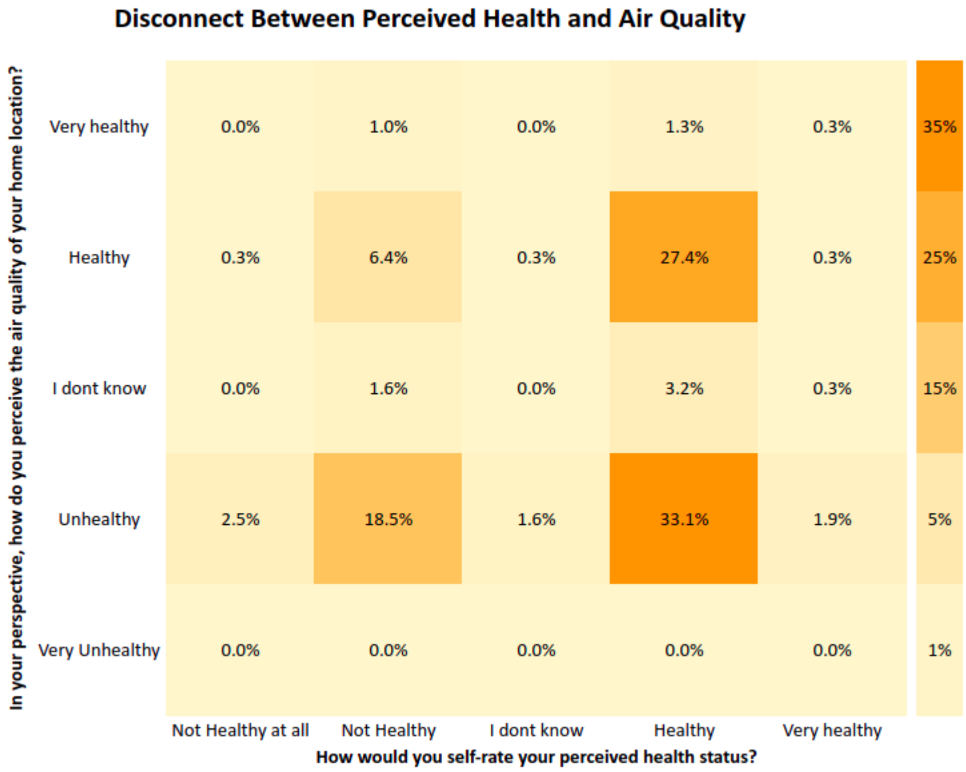


Figure 70: Disconnect between Perceived Health and Air Quality

Digital Heat/ Air Quality Platform

The adopted spatial-temporal model will ideally provide the evidence measured through the sensor in the targeted location. This reflects the overall indication of air quality in the vicinity and how it can be related to the flow of traffic and socio-temporal activities such commuting activities and cultural activities. Therefore community-based assessment can be integrated as indicating the perception of air quality where users require to add feedbacks and comments on the quality of air and well-being based on the arrived location and arrival time. The overall results derived from the community engagement highlight the above statements.

The **hedonic measures** can be undertaken to make critical decisions throughout the policymaking process which can be interpreted on the digital platform hosting the spatial-temporal model. This is **a linkage** between the application of spatial-temporal model and community-based assessment which will accelerate the policy making process.

A digital platform such as IQAir is resourceful to observe and assess the air quality of the nearby surrounding. Using this platform as a reference, **the opinion of the communities** has been examined through the inquiries including (1) how the people react when seeing the air quality in their location and (2) the reaction if the locals experience air pollution frequently.

How would people likely respond when seeing the air quality in their location

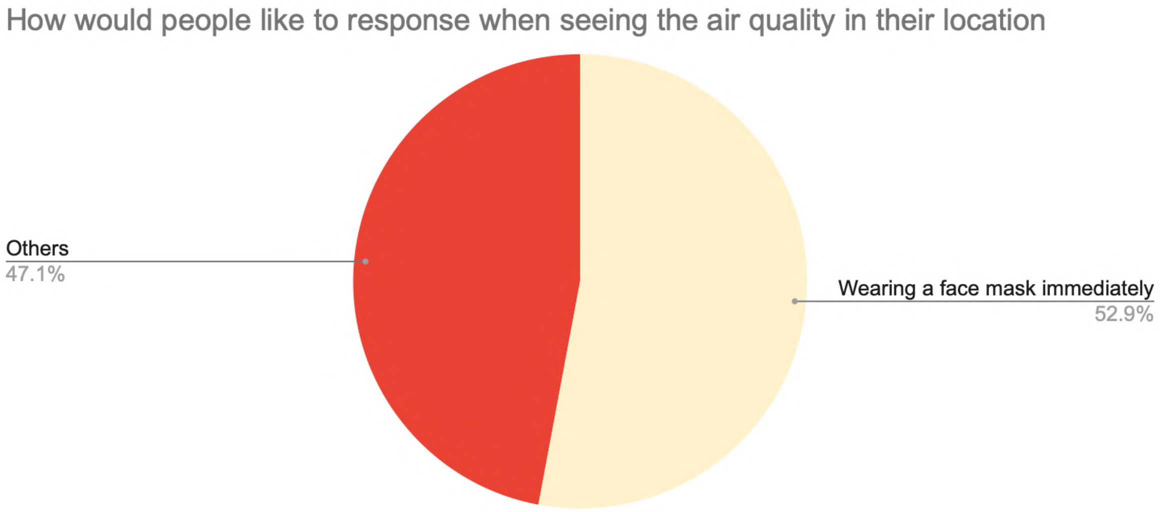


Figure 71: The action willing to take by the respondents when observing the air quality in their location

Among 17 responses (Figure.71), 52.9% of the participants respond by wearing face masks immediately after observing the evidence from the spatial model, in this case, IQAir whereas 47.1% of the responses are formed as **"others" category**. This unfolds various reactions towards the evidence from the model in which the respondents explicitly mentioned like

"I will not only wear a face mask but also change clothes to prevent from exposing the dust (Pollution)"

"I would like to raise awareness in that particular area where people are exposing too much pollutants"

In terms of **awareness raising**, it refers to change their lifestyle and raise preventive measures to improve indoor and outdoor air quality. The most common responses are altering the mode of transportation and in turn, empowering to use public transportation. Furthermore, the respondents prefer to inform to take precaution individually and collectively for reducing the use of fossil fuel consumption.

To analyse the reactions when the locals experience air pollution frequently, various responses were identified. The respondents stated the long-term inclusive plan to mitigate air pollution and find mitigation measures together with the locals. The visualization derived from spatial model can help observe the most polluted area in Yangon and include those affected community when creating the long-term strategy. A respondent stated the collective action that

"The exposed community should protect oneself by using marks, try to participate in the advocacy group to raise awareness about AQI in Yangon as it's a collective action,"

Another respondent stated that this will need to be taken as an action with the respective organizations such as governmental organizations and NGO. The effective control measures by the government are obliged to handle to reduce air pollution induced by transportation as a mandate.

Some respondents believe that this mitigation measures can be initiated individually. Those actions entail considering to use clean energy at home, to drive less and walk more to reduce individual carbon footprint. A respondent think that mitigating air pollution is out of their control. This reflects the scepticism towards individual actions on mitigating air pollution and motive regarding the action of reducing air pollution.
Respondents believe that green infrastructure and public spaces play a significant role in mitigating the air pollution in the neighbourhood level. They suggested that the polluted area is able to be improved air quality through creating green spaces in the surrounding.

Thus, local community in Yangon are able to share their thoughts and opinions upon air quality in the vicinity. The spatial model is informative for them to understand the air quality and improve the awareness of air pollution which can generate more willingness to change their behaviours intended to mitigate air pollution. In this context, the linkage between community-based assessment and the model can be identified which can lead to implement an effective policy.

Discussion

Current measures and improvements

To respond and adapt to the current situations, targeted communities expressed their suggestions and improvement that they can undertake. Individually, 43.9% of respondents are comfortably wearing masks to counter the polluted air among seven activities proposed in the questionnaires (Fig. 72). 17.7% of respondents can avoid the busy road and followed by that, 15.7% of respondents are able to reduce outdoor activity.

From the focus group discussions, some of the participants stated they cannot avoid the busy roads for their living although they exposed air pollution every day. Those people include taxi drivers, trishaw drivers and bus drivers who are actively using the transport system for their living. One of the participants stated that

"Even though we know that there is traffic congestion on the way, we cannot avoid it just because of air pollution. We need to bring our passengers to the destination,"

The priority can be a key role to understand the situation and why they cannot perform this action. Furthermore, trishaws and sidecars drivers are spending around 12 hours on the streets and are likely to expose polluted air. During the interview session with the expert, he mentioned that

"Due to the air pollution, drivers (trishaw) come to his clinic and receive the treatment frequently. Most of them were having sore throat which is one of the impacts of frequent air pollution exposure,"

Street vendors are able to wear the masks to protect the air pollution while some refuse to perform this action since it makes hard to breathe and uncomfortable to wear it all the time.

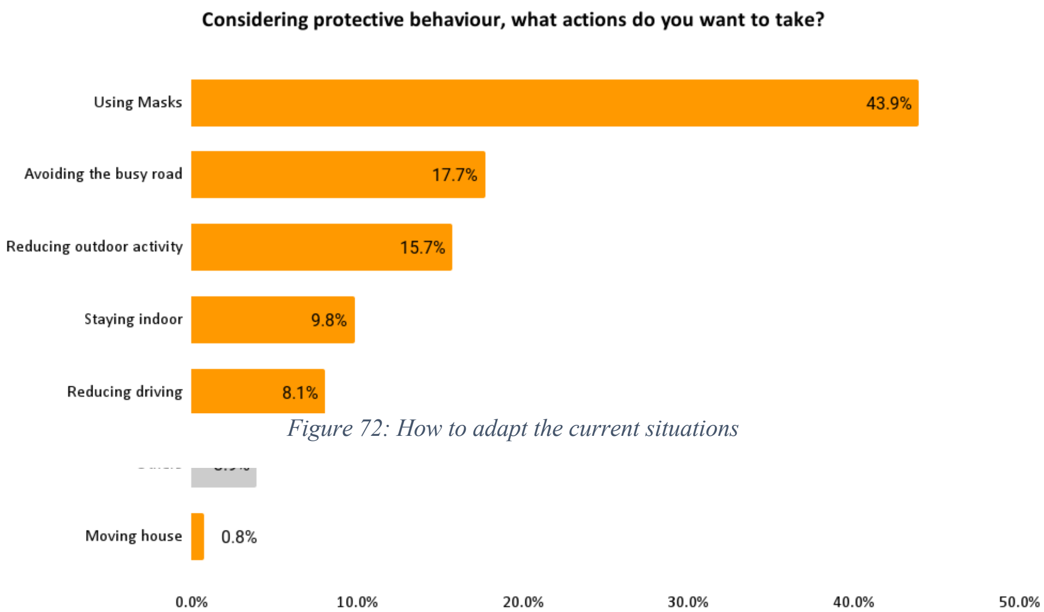


Figure 72: How to adapt the current situations

To understand willingness to change regarding options for **mode of transportation**, walking and biking emerge as top priorities, especially as **first or second choices (125 and 124 counts)** as shown in Fig 73, indicating a preference for active and sustainable modes of transport. Public transportation follows closely, with 140 counts as the third priority. Additionally, 169 counts indicate a preference for driving their car less, both in terms of kilometers and hours. This also implies that respondents prefer to create bike and pedestrian infrastructure and expand public transport networks as a localized action plan.

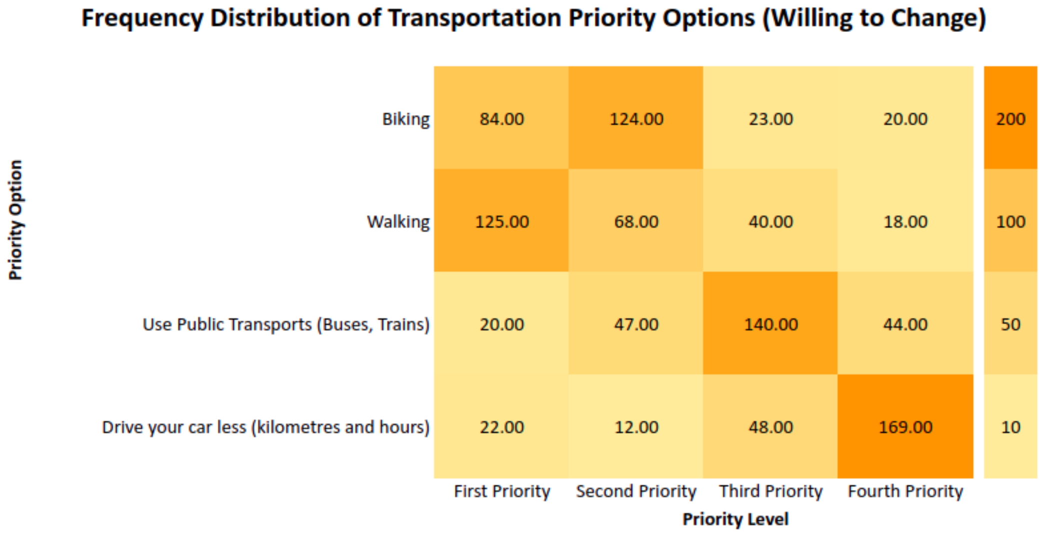


Figure 73: Transportation Priority Distributed by Frequency

Action plan

Suggested by the experts, the **awareness campaign of air pollution** are recommended to initiate in the city level focusing on elaborating the short-term and long-term impacts of air pollution towards urban health across various demographics. One expert suggested that
"Knowledge sharing (about air pollution) should be provided to the children which is important to build up the good habits since childhood. The children will realize the effects of air pollution and it is a national level task……."

"At the community level, community-based organizations which are usually active in providing awareness and capacity building with community play an important role to perform continuous engagement and open up the eyes of the community,"

As the expert stated, if the great engagement and successful campaign have been accomplished, the individual will follow to adhere the practices of the mitigation of air pollution. This reflects the cruciality of community engagement and capacity building about the practices of air pollution and mitigation the current measures in the neighbourhood level. This practices also remove the barrier of scepticism of air pollution in the city level.

During the focus group discussions, ten activities were proposed to adapt and mitigate the air pollution. Based on these activities, participants were answered about their capabilities in terms of economic and social aspects. Furthermore, they unfold **three additional suggestions** that they usually perform to reduce the impact of air pollution. This particular activity in the focus group discussions lead to assess the current measures and form a local partnership and coordination to address the issues of air pollution in their vicinity. Local participation is crucial in this stage as both individual and collective action plans have been established based on their perception and exposure upon air pollution which have been identified in our preceding activities. The action plan demonstrated in the **Table 6** composed by focus group discussions retaining **60 participants** in total.

Table 6: Action Plan

Actions	Possibilities	Challenges
(1) Use Face Masks	Most of the participants stated it is possible since it is readily available, affordable, suitable for use. Since COVID started, naturally participants are likely to wear masks whenever they go outside.	Few street vendors are unable to wear masks all the time as they need to communicate with their buyers. And it enables them to be uncomfortable to breathe.
(2) Do physical exercises	Few residents who live in the transport hub and informal settlements stated it is possible to perform this. Usually, they played Chinlone [Cane Ball – Myanmar Traditional Sport] and Football at public spaces.	Most of the participants are challenging to do so. They have no extra time for this or never do exercise. Some are having chronic diseases and thus, cannot do physical activities.
(3) Stay outdoor	Participants from location 1 and 2 are able to go outside, especially, since there is a park nearby. They also go near the bridge where fresh air can be retained which crosses through the river and stream.	Participants from location 3 are inaccessible to the public park as there is none. Thus, they usually have to travel downtown or outside the city to get fresh air.
(4) Stay indoor	Some participants spend most of their time at home as they live as housewives, or open the grocery stores at home, not because of reducing the exposure of air pollution.	Participants are struggling to stay at home to avoid the air pollution as their livelihood depends on outdoor activities. Some stated that their indoor air quality worsened due to their neighbourhood activities such as burning waste or indoor cooking.
(5) Use Active transport such as bicycle, walking.	Some participants who live in transport hubs and informal settlements are able to perform as the distance to their workplace or home is accessible to travel. They have physical capabilities to ride bicycles.	Street vendors in particular are unable to use bicycles to travel to different townships far away. They have limited time to use this active transport.
(6) Ventilate home	Few participants who live in informal settlements can implement it since they usually ventilate their home during daytimes. They have more windows and are likely to retain fresh air due to the presence of open space.	Participants in the transport hub are unlikely to perform. Most of the time, they close their windows and doors to prevent polluted air coming inside. They don't have enough windows to ventilate their home.
(7) Use Public Transport	Most of the participants are able to use public transport since it is affordable although not accessible to reach every corner of the city.	Some who live in informal settlements are inaccessible to public transport to reach their workplace.
(8) Reduce driving time	Electric and hydrogen-fuelled vehicles are described by some participants.	Taxi drivers are reluctant to perform this since their livelihoods depend on this. As most of the participants have no cars, this action is denied. Few people inquire about the impacts of mitigation by reducing their driving time.
(9) Avoid the polluted location	Taxi drivers, trishaw drivers can avoid the polluted location if the destination is accessible through narrow streets.	Street vendors and residents living in the transport hub cannot avoid it.

(10) Buy domestic air purifers	Few of the participants can purchase air purifiers depending on the prices and availability to improve indoor air quality, especially by the residents who live in the transport hub.	Most of the participants are unable to buy air purifiers as it depends on monthly income which they spend on basic needs such as food and water.

Furthermore, urban green infrastructure is imperative to mitigate air pollution among preference of local communities. As stated in Figure-74, 36.5% of the respondents are eager to **increase urban green infrastructure** including the number of green spaces and revitalization of public spaces. **Creating micro mobility infrastructures** and **expanding pedestrian infrastructure** follow intently with 22.1% and 20.4% respectively.

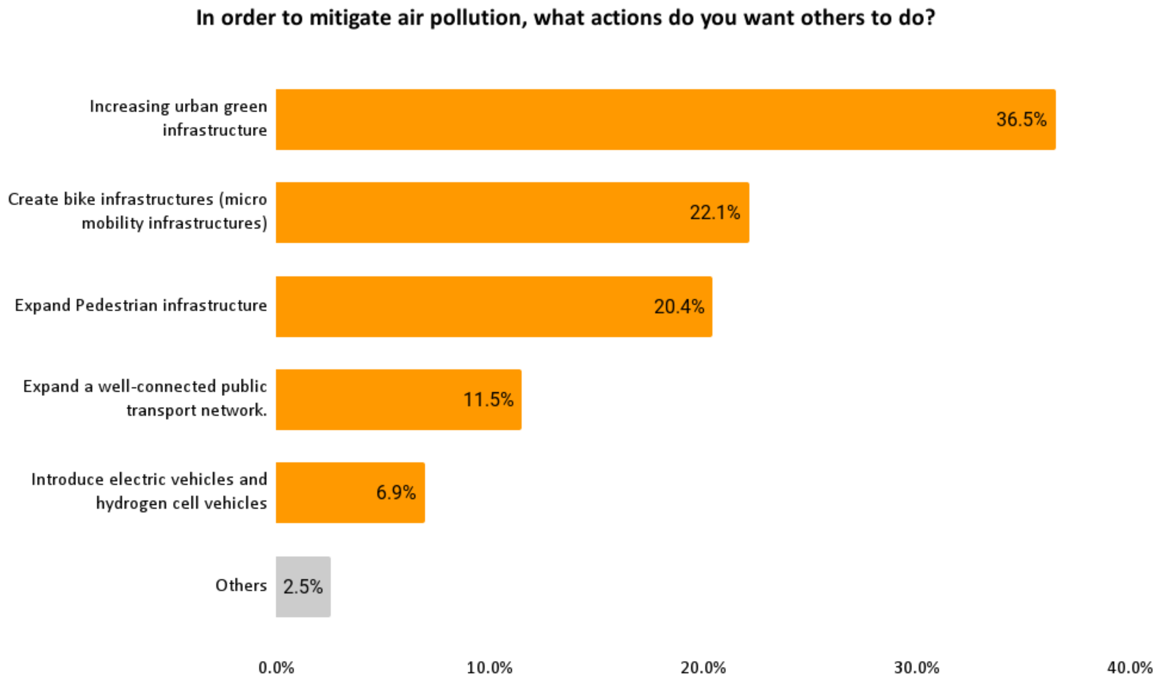


Figure 74: Preferred actions to take collectively by the local community

Improvement suggested and adopted by the locals

Based on the survey, focus group discussions and interviews, three additional preventions can be found. Those are (1) throwing water on the dusty streets, (2) hanging out vinyl, cloth, or green sheets in front of the apartments or shops, and (3) visiting public spaces such as monasteries and near rivers and parks. This enables community participation to shape the impact action plan. The context is solely based on community level, the suggestions and opinions stated by the vulnerable communities manifest in the plan.

To unfold these, **throwing water on the dusty streets** are usually implemented in the morning (around 5 to 7 am) and evening (around 4 to 6 pm). This leads to preventing the incoming dust generated by the by-products of the active transport on the street. As stated by most of the participants, it is a common solution which they usually apply. Residents who live in the transport hub are able to do this whereas those living in informal settlements are incapable due to the limited amount of water they can use. An economic challenge between these targeted communities can be found in this statement.

Another prevention is called **hanging out vinyl, cloth, or green sheets** (Fig. 75). The street vendors and residents who live in the transport hub commonly install these accessible and easy items in front of their households or shops. They stated that the sheet can prevent incoming dust or even blackish gases emitted by the transports. This tends to protect from the sunlight and intense heat which can disturb the thermal comfort in their indoor activity. It is affordable and available to purchase for everybody.

Final prevention is called **visiting public spaces**. All the participants stated the significance of having public spaces, especially parks full of shady trees and lakes. Physical exercise can be achieved with fresh air and pleasant environments. Since most of the parks in Yangon are economically accessible to everyone as there is no charge whereas only few public spaces are available in Yangon. Participants mostly mention Maha Bandula Park in Downtown, Hlawga park, Kandawgyi park and so on. Those are the most prominent parks among people and even most of the participants visit these from a greater distance. Local small parks are listed during the session as they usually visit once or twice in a week. Additionally, participants frequently mention the space near the rivers and streams as air passing across the water enables them to experience a fresh and humid environment.

According to the responses from the local community, these current measures and improvements can be considered to obtain effective and efficient tools and policies and relevant support from the international actors. Associated with adopting an impactful climate action plan, the local knowledge has to be included to match with their needs and opportunities to participate in decision making.

Figure 75: Community mitigation efforts in Yangon

Significance of the result to targeted beneficiaries in the study sites

The initial findings from the project underscore the critical link between urban transport systems and air pollution level, providing data-driven foundation for targeted interventions to improve air quality. This comprehensive approach, utilizing state-of-the-art sensor technologies and data collection methodologies, offers actionable insights that directly inform urban planning and policy-making efforts in Manchester, Bangkok, and Yangon. These insights underpin the development of evidence-based policy recommendations aimed at reducing pollution levels and minimizing public health risks associated with air pollution. By suggesting mobility planning that considers local morphology and advocating for the redesign of Transit-Oriented Developments (ToDs) in high-density Asian cities, the project emphasizes the need for a comprehensive approach that acknowledges the complex interplay between urban design, transport infrastructure, and air quality.

The projects' alignment with **SDG 3 (Good Health and Well-being), SDG 11 (Sustainable Cities** and **Communities),** and **SDG 13 (Climate Action)** offers a model of how technological innovation, when coupled with participatory approaches and policy foresight, can lead to sustainable urban development that prioritizes public health and environmental integrity. The project's comprehensive approach to addressing transport-induced pollution serves as a proof of concept for other urban areas grappling with similar challenges, providing a blueprint for creating more sustainable, healthy, and resilient urban environments across Southeast Asia and beyond.

Proof of Concept: The sensor-based analysis and the spatiotemporal modelling serve as tangible proofs of concept, validating the feasibility and scalability of technological innovations in addressing transport-induced pollution.

SGD relevance: The initiatives aimed at reducing air pollution and its consequential health impacts are crucial steps towards achieving good health and well-being for all (WHO, 2022). The emphasis of mitigating health impacts for sustainable urban environments and transport models is directly aligned with fostering sustainable cities and communities, especially in the context of rapidly urbanizing cities in Southeast Asia.

The specific key findings and recommendations from the project resonate with the needs and realities of the local communities in the targeted study sites. By identifying pollution hotspots and understanding the nuances of urban transport's impact on air quality, the project outlines tailored interventions that can significantly enhance the living conditions in these areas. These recommendations advocate for the integration of air pollution control measures with urban heat island mitigation strategies, localized air quality studies, improved public communication on air quality, and urban design considerations that prioritize health and sustainability.

Beneficiary Impact: The specific findings and recommendations have significant implications for the targeted beneficiaries in Manchester, Bangkok, and Yangon. By providing a framework for reducing pollution levels through strategic urban planning and transport management, the project directly contributes to alleviating the public health risks associated with air pollution. This is particularly crucial for local communities in Southeast Asia, where the rapid pace of urbanization and industrialization exacerbates the challenge of maintaining air quality. The emphasis on community engagement and stakeholder collaboration ensures that these interventions are not only grounded in scientific research but also reflective of community needs and preferences, enhancing their sustainability and impact. The focus on low-income and vulnerable communities in Southeast Asia, being the primary recipients, ensures that the project will bring substantial benefits to these groups, enhancing their quality of life, reduced health adversities, and providing them with cleaner and more sustainable urban environments.

The project's methodologies and findings offer clear pathways to impact, informing policy recommendations that aim to reduce exposure to harmful pollutants, thus aligning with several **Sustainable Development Goals**. Specifically, the project contributes **to SDG 3 (Good Health and Well-being) by addressing the health impacts of air pollution, SDG 11 (Sustainable Cities and Communities**) **by promoting sustainable urban environments, and SDG 13** (Climate Action) by highlighting the relationship between pollution control and climate mitigation efforts. Through its innovative approach, the project exemplifies how technological advancements and community engagement can coalesce to address complex environmental health challenges, setting a precedent for future research and policy-making in the realm of sustainable urban development.

The BREATHE-Cities project's innovative approach and actionable outcomes provide a blueprint for addressing urban air quality issues in a manner that is both scientifically rigorous and deeply connected to local contexts. As such, it represents a significant step forward in the pursuit of sustainable urban environments that prioritize public health, resilience, and inclusivity, offering valuable lessons and strategies for other Southeast Asian countries facing similar challenges. As the project progresses, its findings will continue to inform strategies that not only mitigate the immediate effects of air pollution but also contribute to the long-term sustainability of urban centres globally, echoing the core principles of the Sustainable Development Goals.

Implications and reflections of the result to the wider, sector-relevant innovation and development in Southeast Asia region

The BREATHE-Cities project's insights into the critical role of urban transport in contributing to air pollution levels and the deployment of sensor technologies for precise monitoring provide a compelling model for broader application across Southeast Asia. As part of the project's broader objectives, plans for ASEAN-wide engagement are underway to share findings, methodologies, and policy recommendations with a broader audience. This engagement aims to foster regional dialogue on sustainable urban transport solutions, leveraging the project's insights to inform policy-making at the ASEAN level. Through the planned workshops, policy briefs, and collaborative research initiatives as described in WP3, *CAPACITY BUILDING AND KNOWLEDGE SHARING SESSIONS*, specifically tasks 5.1, 5.1.1. and 5.2 the project seeks to contribute to the ASEAN Plan of Action for Energy Cooperation and the ASEAN Smart Cities Network discussion, reinforcing the role of innovation and technology in achieving sustainable development goals. The project's specific findings and recommendations resonate with the region's urgent need for innovative solutions to the pervasive problem of urban air pollution, driven by rapid urbanization, dense transportation networks, and unique socio-political landscapes.

The implications of these outcomes extend to a wider spectrum of sector-relevant innovation and development across Southeast Asian countries, promising transformative changes in how urban environments are managed. For instance, the project's recommendations for **integrating** air quality indices with microclimate temperatures and designing mobility with local morphology in mind offer **actionable strategies** that can be **adapted by cities** like Jakarta, Indonesia, and Hanoi, Vietnam. These cities, which face severe traffic congestion and air pollution, can leverage the project's methodologies to develop more effective urban planning and transport policies that mitigate pollution and enhance public well-being.

Moreover, the project’s emphasis on **community engagement** and **stakeholder collaboration** provides a blueprint for enhancing the sustainability and acceptability of urban planning initiatives. Cities such as Penang, Malaysia, and Da Nang, Vietnam, which boast strong community ties, can derive substantial benefits from adopting participatory design approaches in environmental governance. This method ensures that solutions are not only scientifically sound but also culturally and socially resonant, thereby increasing the likelihood of successful implementation and long-term sustainability.

The **scalability of the sensor technology** used in the project for air quality monitoring highlights the potential for broad adoption across the ASEAN region, from technologically advanced cities like Singapore to those with more limited resources like Phnom Penh, Cambodia. Singapore's Smart Nation initiative, for example, could incorporate these advanced sensor technologies to achieve a more nuanced environmental monitoring system, while Phnom Penh could initiate cost-effective air quality monitoring efforts, laying the groundwork for comprehensive environmental governance.

Additionally, the project's approach to **cross-city** and **international knowledge exchange** addresses the challenge of **transboundary haze pollution**—a pressing issue for Southeast Asia. By fostering regional cooperation mechanisms and sharing data-driven insights, the project contributes to strengthening initiatives like the ASEAN Agreement on Transboundary Haze Pollution, enhancing regional capacities to tackle air pollution on a larger scale.

Reflecting on examples from across Southeast Asian countries:

- **Singapore:** Can utilize the project's outcomes to refine its environmental monitoring and incorporate advanced technologies and community feedback into sustainable urban development strategies.
- **Vietnam:** Hanoi can apply the project’s sustainable urban transport strategies to reduce motorbike emissions and promote cleaner transportation options, aligning with national green growth objectives.
- **Indonesia**: Jakarta can benefit from the project’s insights into the nexus between transport policies and air quality, leveraging data-driven strategies to combat its air pollution challenges.
- **Philippines:** Metro Manila can draw on the project’s methodologies to tailor air quality improvement plans that reflect its diverse urban demographics and socio-economic conditions.

The BREATHE-Cities project not only offers a pathway to cleaner air and healthier communities in Southeast Asia but also serves as evidence of the relevance of integrated, technology-driven approaches to urban environmental challenges. By embracing these innovative solutions and fostering collaboration within and between nations, Southeast Asia can make significant strides towards achieving sustainable urban development and meeting the Sustainable Development Goals.

Scalability of innovation at ASEAN level

The BREATHE-Cities project's innovative approach to urban air quality management, encompassing advanced sensor technologies, participatory community engagement, and integrative policy frameworks, offers a scalable and adaptable model for the ASEAN region. The key findings and recommendations from the project provide a robust foundation for scaling innovations across diverse urban environments within ASEAN, enhancing the collective capacity to tackle the pressing challenge of air pollution.

Scalability of Innovation at ASEAN Level:
The project's deployment of **real-time air quality monitoring using advanced sensors** can be tailored to the varying capacities and urban infrastructures of ASEAN cities. This scalable solution facilitates accurate pollution tracking and hotspot identification, critical for informed urban planning and policy-making across the region.
The emphasis on **participatory design** and **stakeholder involvement** ensures that air quality management strategies are deeply **rooted in local contexts**, enhancing their relevance and effectiveness. This model encourages ASEAN cities to foster community ownership of air quality initiatives, ensuring sustainable and culturally sensitive implementation.

The project underscores the value of **cross-city learning and collaboration** encouraging **ASEAN-wide** dialogue and **knowledge sharing**, the project highlights the benefits of collaborative approaches to environmental challenges. The digital platform which is underway will display the emissions of different pollution in the selected areas as indicators of the difference to the larger available air quality data. Establishing a regional platform for data and **strategy exchange** can accelerate the adoption of successful interventions, leveraging collective experiences for mutual benefit. This approach fosters local ownership and ensures that interventions are tailored to the unique socio-cultural and economic contexts of each city, enhancing their effectiveness and sustainability. Initial literature review shows a dramatic increase in Urban Heat Stress in a number of cities in SEA region. Studies show, for example, doubling of Urban heat stress area in Bangkok in the last 10 years. This study would help unpacking the variables, and their extent, that contribute to such phenomena, including the role of urban configuration, NDVI, and others.

The insights into the impact of transport policies on air quality offer valuable lessons for ASEAN countries looking to develop or refine their urban transport and environmental policies. The project's findings can inform the development of **integrated policy frameworks** that consider air quality alongside other urban development goals, such as mobility, economic growth, and public health.

Results of ASEAN-wide Engagement / Activities:
While the BREATHE-Cities project primarily focuses on Manchester, Bangkok, and Yangon, its methodologies and findings have significant relevance for the wider ASEAN region. Specific activities or engagement at the ASEAN-wide level could include:
Workshops and Conferences: By organizing ASEAN-focused events, the project can facilitate the dissemination of its innovative methodologies and findings, sparking regional discussions on best practices in air quality management and fostering collaborations among member states.
Policy Recommendations and Guidelines: Tailoring the project's recommendations to the ASEAN context can provide member states with actionable guidelines for enhancing urban air quality, supporting the development of comprehensive and integrated environmental policies.
ASEAN Urban Air Quality Network: The formation of a dedicated network based on the project's collaborative and data-driven approach can serve as a cornerstone for regional efforts to improve air quality, promoting ongoing research, policy development, and public engagement.
Pilot Projects and Scale-Up Initiatives: Implementing pilot projects in selected ASEAN cities can demonstrate the adaptability and effectiveness of the project's interventions. Successful pilots can pave the way for broader scale-up initiatives, encouraging widespread adoption of proven air quality management practices across the region.

The BREATHE-Cities project, through its key findings and strategic recommendations, demonstrates the critical importance of integrated, technology-driven strategies in addressing urban air pollution. Its model of sensor-based monitoring, community-centric engagement, and policy innovation offers a path forward for ASEAN cities seeking to improve air quality and public health. By leveraging the project's insights and adopting its scalable innovations, the ASEAN region can make significant strides towards sustainable urban development and enhanced well-being for its urban populations.

Limitations of the project

The BREATHE-CITIES project, aimed at exploring resilient and sustainable urban transport strategies to mitigate transport-induced pollution, encountered several limitations during its implementation. These limitations not only highlight areas for methodological and strategic improvement but also emphasize the critical areas where future research and intervention efforts can be directed. Some of the key limitations identified from the project's final report include:

1. **Limited Duration for Comprehensive Impact Assessment**: The project's findings on the significant spatial variations in pollution levels across urban settings underscore the necessity for longitudinal studies. Such studies would enhance the understanding of how the dynamics of urban canyons, transport hubs, and the efficacy of technological interventions evolve over time, contributing to a deeper understanding of long-term impacts on air quality and public health.
2. **Dependence on Sensor Technology**: While the project innovatively utilized sensor technologies for real-time air quality monitoring, the limitations identified call for the development of more robust sensor networks. Integrating these technologies with broader environmental monitoring systems and enhancing data accuracy and coverage can mitigate the risks of data unreliability. This aligns with the recommendation to develop air quality indices that integrate pollution levels with microclimate temperatures, addressing potential gaps in sensor coverage and accuracy.
3. **Variability in Urban Contexts**: The project’s engagement across diverse urban environments like Manchester, Bangkok, and Yangon highlights the importance of contextualized solutions. Future initiatives can build on this by developing more adaptable and scalable interventions that consider the unique challenges of each urban setting. This approach resonates with the recommendation to reconsider the design of TODs in high-density cities, factoring in the unique urban configurations and their impact on pollution levels.
4. **Community Engagement Challenges**: The challenges in engaging communities, especially in politically unstable contexts, highlight the need for innovative and flexible engagement strategies. Building on the project’s participatory approaches in Myanmar, future efforts could explore more inclusive methodologies that ensure wider community involvement, thereby enhancing the development and acceptability of urban planning and transport policies.
5. **Data Collection Constraints**: The reliance on innovative community-based approaches due to constraints in traditional data collection, particularly in Yangon, underscores the need for diverse data collection methodologies. Future projects could incorporate a mix of quantitative and qualitative data collection methods to provide a comprehensive overview of pollution sources and health impacts, aligning with the call for localized air quality studies.
6. **Policy and Regulatory Frameworks**: The project’s encounters with rigid policy and regulatory frameworks emphasize the need for adaptive policy strategies that can accommodate rapid innovation. This is particularly relevant to the recommendations for mobility planning and clean air strategies for urban centers. Advocating for more flexible regulatory frameworks that support innovative urban planning and transport solutions can facilitate the implementation and scalability of effective air quality management interventions.

By addressing these limitations through targeted research and strategic interventions, future projects can build on the BREATHE-CITIES project’s foundational work. This entails advancing scalable, adaptable solutions that cater to the specific needs of diverse urban settings, fostering inclusive community engagement, and advocating for supportive policy frameworks. Such efforts would significantly contribute to mitigating urban air pollution and enhancing public health, aligning with the Sustainable Development Goals and advancing urban sustainability across ASEAN and beyond.

Potential next steps of the project, and their significance in correspondence to the current project results, beyond the current RIDA funding period

Building upon the BREATHE-Cities project's key findings and recommendations, the potential next steps outlined below are aimed at further advancing the project's impact on urban air quality management and public health, extending its influence beyond the current RIDA funding period. These steps are crucial for enhancing the project’s contributions to sustainable urban development and public health improvements across diverse urban landscapes.

- **Expansion and Integration of Sensor Networks**: Given the project’s innovative use of sensor technology for air quality monitoring, a natural next step is to expand these networks across additional urban areas. This expansion should focus on integrating a wider range of environmental parameters and pollutants to gain a more nuanced understanding of urban air pollution dynamics. The insights from the project highlight the importance of designing sensor networks that can capture the complexities of urban air quality, taking into account the interplay between air pollutants and urban heat islands.

- **Refinement of Predictive Models and Data Analytics**: Leveraging the extensive data collected, there's a significant opportunity to enhance predictive models and analytical tools. These advancements will enable urban planners and policymakers to simulate the impacts of different urban planning and transport scenarios on air pollution levels. This aligns with the recommendations for localized studies of air quality that investigate both macro and micro levels, aiming for models that can adapt to the specificities of diverse urban settings.
- **Scaling Technological Interventions Across Urban Contexts**: Building on the successful proof of concept for using sensor technologies and data analytics in air quality management, the project points to the necessity of scaling these solutions. Investigating the scalability of such technological interventions involves exploring the integration of advanced technologies like artificial intelligence and machine learning, which could offer real-time insights for decision-making in air quality management.
- **Deepening Community Engagement and Collaboration**: The project has underscored the value of community engagement and stakeholder collaboration in designing and implementing air quality initiatives. Future efforts should aim to deepen these partnerships, ensuring that interventions are not only tailored to the specific contexts of each community but also embraced and sustained by those communities. This approach is crucial for creating interventions that are culturally sensitive, context-specific, and widely accepted.
- **Policy Development and Advocacy at Multiple Levels:** Utilizing the project's findings to influence policy and advocacy at local, national, and ASEAN levels is a critical next step. The goal is to encourage the adoption of integrated policies that prioritize health and environmental sustainability in urban and transport planning. This effort should build on the project's insights into the effectiveness of urban planning and transport policies in reducing air pollution and its health impacts.
- **Facilitating Cross-City and International Exchanges**: The establishment of platforms for sharing experiences, strategies, and data can significantly enhance the collective ability to address urban air quality challenges. By fostering an environment of cross-city and international knowledge exchange, cities can learn from each other's successes and challenges, promoting a collaborative approach to sustainable urban development.
- **Conducting Longitudinal Health Impact Studies**: To comprehensively assess the effectiveness of air quality interventions, conducting longitudinal studies on their long-term health impacts is essential. These studies would provide deeper insights into the efficacy of interventions and their ability to improve public health outcomes in urban environments.
- **Disseminating Findings and Advocating for Best Practices**: Publishing the project's outcomes in scientific journals and at conferences will ensure that the academic and broader research communities benefit from the innovative methodologies and insights developed. Additionally, advocating for the adoption of best practices derived from the project can guide future urban air quality management efforts.

These steps represent a holistic and forward-looking approach to building on the BREATHE-Cities project's achievements. By emphasizing the integration of technology, community engagement, policy development, and scientific research, these next steps promise to significantly contribute to the advancement of urban air quality management practices, promoting healthier and more sustainable urban environments across the globe.

RECOMMENDATIONS

BREATHE-CITIES Project calls for committed system-wide actions

Building on the BREATHE-CITIES Project's comprehensive analysis and innovative methodologies, the recommendations are designed to instigate system-wide actions aimed at enhancing air quality and mitigating the health impacts of urban pollution. These recommendations are focal for policymakers, urban planners, and stakeholders across the Southeast Asia region and globally, encouraging a collaborative approach to creating sustainable and healthy urban environments.

Integrated Air Quality and Health Stress Index
Developing an integrated air quality index that incorporates both air pollution levels (PMx, NOx, COx, and Vox) and microclimate temperature data is essential. This combined index should reflect the compounded impacts of urban heat islands and air pollution, offering a more accurate representation of environmental health risks.

Urban Design and Planning
Urban design must prioritize the mitigation of urban heat islands through innovative planning that incorporates air movement modelling, the use of reflective surface materials, and the integration of green infrastructure. Such designs will not only reduce urban heat but also improve air quality by facilitating the dispersion of pollutants.

Localized and Tailored Mobility Planning
Mobility planning should be localized, considering the specific morphologies and socio-economic characteristics of urban areas. This includes redesigning Transit-Oriented Developments (TODs) in high-density settings to alleviate pollution and congestion and ensuring that mobility plans cater to the diverse needs of urban populations.

Enhancing Public Awareness and Communication
There is a crucial need for effective communication strategies that inform the public about air quality issues and health risks. Leveraging technology through apps and websites to provide real-time, integrated air quality information will empower citizens to make informed decisions about their daily activities and exposure.
Data-Driven Clean Air Strategies
Urban centers require clean air strategies that are informed by data analysis and community input. Such strategies should promote active transportation modes like walking and cycling, reduce congestion, and address non-emission sources of pollution, creating a holistic approach to improving urban air quality.

Community and Business Engagement
Engaging the public and local businesses in the development and implementation of clean air strategies is essential for ensuring their effectiveness and sustainability. Educational campaigns and initiatives that foster community involvement in environmental stewardship will be critical for long-term success.

These recommendations, grounded in the BREATHE-CITIES Project's findings, underscore the importance of a multi-faceted approach to addressing urban air pollution. By integrating advanced technologies, fostering community engagement, and implementing adaptive policy frameworks, cities can develop resilient, sustainable urban transport strategies that mitigate pollution and enhance public health. This holistic approach, informed by the project's innovative research, provides a roadmap for urban areas in Southeast Asia and beyond to tackle the complex challenges of air pollution and urban heat, contributing to the creation of healthier, more livable cities for future generations.

Reflection on the implications of the BREATHE-Cities Project Results for Transboundary Air Pollution

The BREATHE-Cities project developed sophisticated sensor technologies and data analytics models that can significantly aid in the monitoring and management of air pollution on a regional scale. These technologies could be adapted to monitor transboundary air pollution by providing real-time data on pollutant dispersion and concentration levels across borders. This would enable a proactive response to pollution incidents, facilitating timely interventions to mitigate their impact.

Extending the Model to Tackle Transboundary Issues

The sensor network and analytical models established by the project can serve as a foundational framework for a regional air quality monitoring system. By expanding this network across ASEAN countries, it would be possible to create a comprehensive, real-time visualization of air quality dynamics, including the movement of transboundary pollution plumes. Such a system could support the ASEAN Agreement on Transboundary Haze Pollution by providing empirical data to inform policy decisions and cooperative actions.

Collaborative Framework for ASEAN

To effectively tackle transboundary air pollution, a collaborative framework is essential. The BREATHE-Cities project's approach to community engagement and stakeholder collaboration could be leveraged to enhance regional dialogues and partnerships. Sharing best practices, methodologies, and data through ASEAN-wide workshops, policy briefs, and conferences can strengthen regional capabilities to address air pollution collectively. This can foster a unified approach to environmental governance, aligning national policies with regional strategies to combat air pollution.

Policy Recommendations for Regional Cooperation

Establish an ASEAN-wide air quality monitoring network using the BREATHE-Cities project's sensor technologies. This network would enhance the region's ability to monitor and respond to air pollution events that cross national boundaries.

Develop regional guidelines and standards for air quality that consider the unique challenges of transboundary pollution. These should be informed by the data and insights generated from the expanded monitoring network.

Facilitate data sharing and transparency among ASEAN countries to ensure that all members have access to timely and accurate information about air quality, particularly during pollution events caused by forest and peat fires.

Implement joint emergency response protocols for pollution events, enabling coordinated actions such as shared resources for firefighting, joint public health advisories, and cross-border environmental impact assessments.

Promote public awareness and education campaigns across the region to increase understanding of transboundary air pollution issues and encourage public support for regional policies and initiatives.

By integrating the BREATHE-Cities project's findings into a broader ASEAN context, the project can contribute significantly to the region's efforts to manage and mitigate the effects of transboundary air pollution. This not only aligns with the environmental goals of the ASEAN community but also enhances the health and well-being of its populations, fostering sustainable development across the region.

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