“Digital Twins Enabled Indoor Air Quality Management for Healthy Living”

TwinAIR: Leveraging Digital Twins to Digitise and Optimise Indoor Air Quality for Occupant Health and Wellbeing

Sustainable Places

16th June 2023

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IES R&D IRELAND

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TwinAIR has received funding from the European Union’s Horizon Europe programme under grant agreement No101057779. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Health and Digital Executive Agency (HADEA). Neither the European Union nor the granting authority can be held responsible for them.

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Environment and health (2021) (HORIZON-HLTH-2021-ENVHLTH-02)

Living and working in a health-promoting environment'

Meeting Agenda

- Problem Statement & Ambition
- Consortium
- Methodological Approach
- Technological Interventions
- Questions

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Problem Statement

- Human exposure to poor air quality is a leading risk factor Global Burden of Disease (GBD) study[1]
- Ambient air pollution causing almost 4.1 million premature deaths globally
- Exposure to the microbiology of the built environment may cause or contribute to significant negative far-reaching effects on human health, including infectious and respiratory diseases, allergies, and even cancer.
- Household air pollution from solid fuels causes 2.3 million deaths each year and combined over 200 million disability-adjusted life-years (DALYs) globally each year[1].
- The main indoor air pollutants include PM, NOx, O3, CO, SO2, volatile and semi-volatile organic compounds (VOCs), radon, toxic metals, and micro-organisms[3].
- A study published in Environmental Health Perspectives found that improving IAQ could lead to an 8-11% increase in productivity[4].
- 2.2 million DALYs are lost each year in EU and 110 million citizens live in buildings with high concentrations of hazardous pollutants, because of inadequate levels of ventilation[2].
- Ambient Air Quality Directives in the EU in 2021 to include new indicators in air quality indices

1. http://ghdx.healthdata.org/gbd-results-tool 2. Joint Research Centre. 2016. Promoting healthy and energy efficient buildings in the European Union. European Commission, Italy. 3. Tran VV, et. al. Indoor Air Pollution, Related Human Diseases, and Recent Trends in the Control and Improvement of Indoor Air Quality. Int J Environ Res Public Health. 2020;17(8):2927. Published 2020 Apr 23. doi:10.3390/ijerph17082927 4. https://www.linkedin.com/pulse/price-slow-adoption-combating-sick-building-syndrome-post-covid-19/

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Problem Statement

*In response to the aforementioned challenges and needs, **TwinAIR** introduces a first of a kind technological solutions system to improve air quality in a wide spectrum of indoor living activities (residents, workplaces, transportation, hospitals etc.) while investigating how air pollutants in indoor spaces can adversely affect the health of the people inhabiting them, to support public health through community awareness and policy making.*

1. http://ghdx.healthdata.org/gbd-results-tool 2. Joint Research Centre. 2016. Promoting healthy and energy efficient buildings in the European Union. European Commission, Italy. 3. Tran VV, et. al. Indoor Air Pollution, Related Human Diseases, and Recent Trends in the Control and Improvement of Indoor Air Quality. Int J Environ Res Public Health. 2020;17(8):2927. Published 2020 Apr 23. doi:10.3390/ijerph17082927 4. https://www.linkedin.com/pulse/price-slow-adoption-combating-sick-building-syndrome-post-covid-19/

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Ambition

*"The key challenge & ambition of **TwinAIR** is to achieve high human engagement & high spatial convergence, enabling positive health outcomes through technology oriented research & solutions.*

***TwinAIR** will gain insights into exposure-response relationships, acute symptoms & health status linked to continuously monitored Indoor Air Quality (IAQ), under different intervention scenarios enabled by advanced technologies and tools."*

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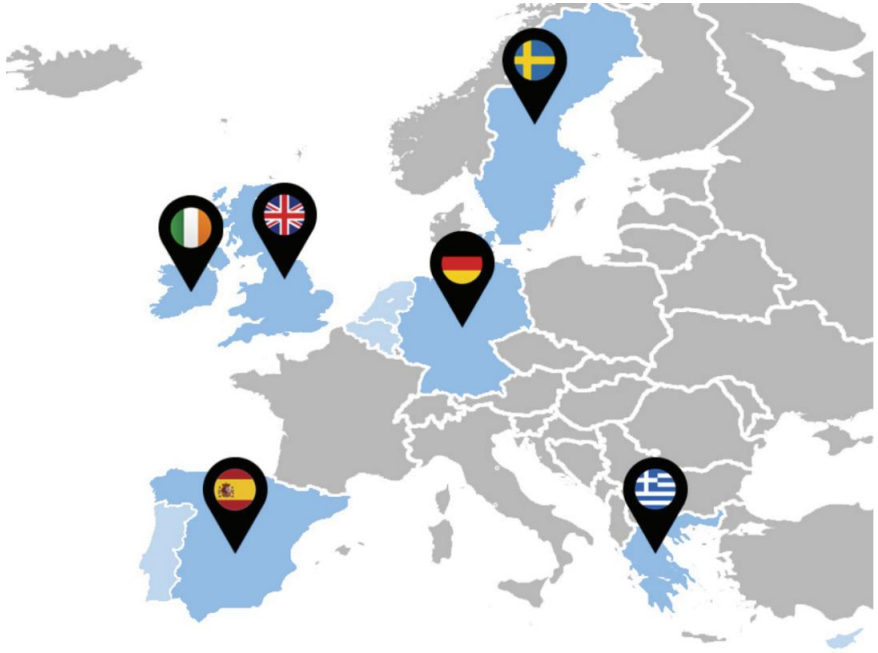
Consortium Members

- 48 Month Project (currently in M9)
- €7.99m total budget (RIA)
- 23 Partners across 9 Countries
- 6 Pilot Sites across 6 Countries
- 4000 users involved



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Consortium Members - Pilots

1. Vehicles

https://liu.se/en/article/campus-bus

Linkoping Intercity Bus

https://nordicroads.com/future-concepts-sustainable-urban-mobility-demonstrated-new-eu-project/

Linkoping Autonomous Campus Bus

https://www.elconfidencial.com/empresas/2016-12-08/avanza-autobuses-perdidas_1300595/

Avanza Intercity Bus (Valencia – Madrid)

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Consortium Members - Pilots

2. Buildings

University of Bristol Campus
& Hospital Buildings (UK)

ETRA Office
Valencia (ES)

Linkoping StudentsHus
Linkoping (SE)

Thriasio General Hospital
Elefsina (GR)

Primary Schools
Dublin (IE)

CIIT Office Building
Lemgo (DE)

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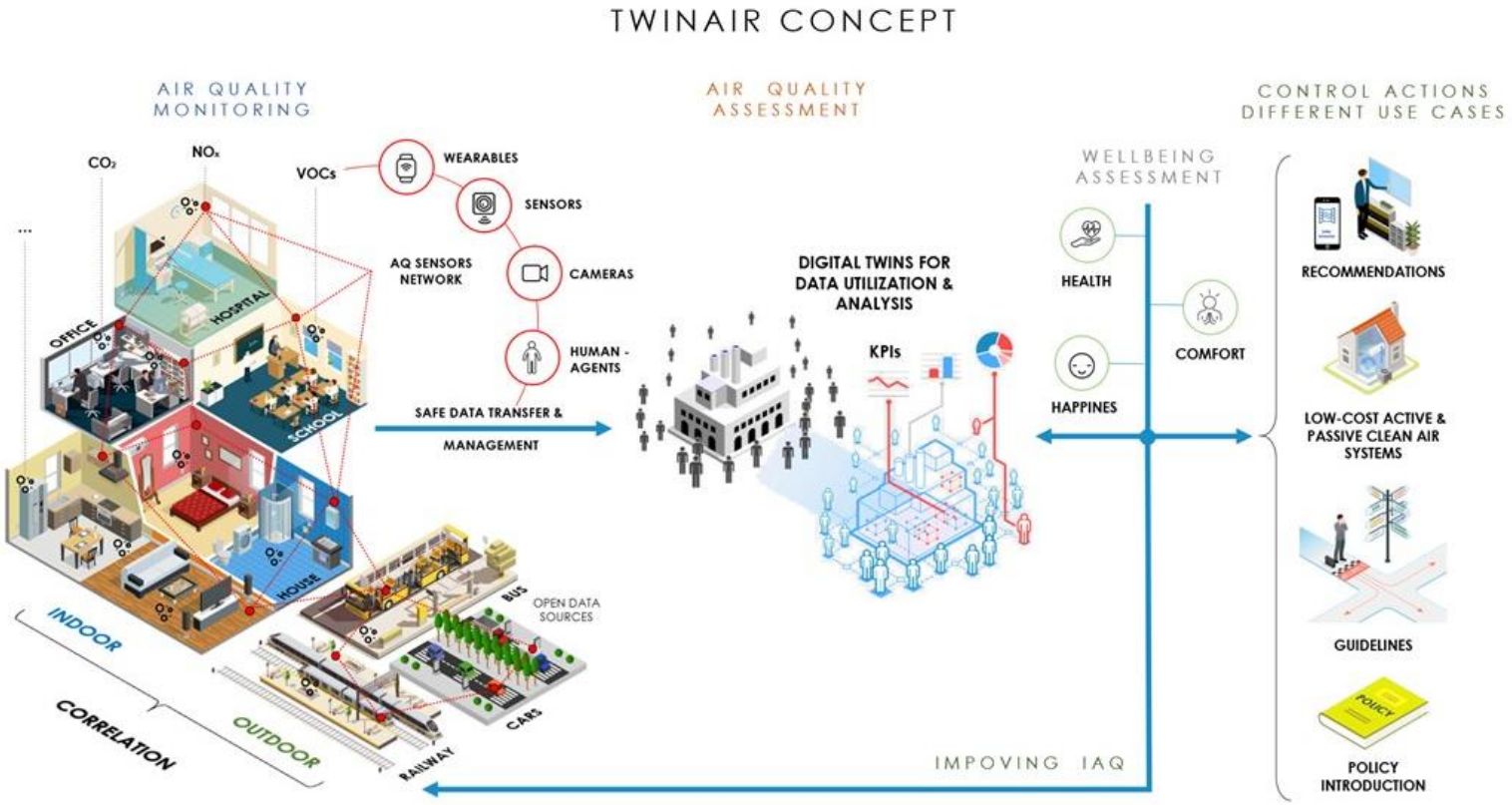
TwinAIR Approach

Three Pronged Methodology

- Environmental Approach
- Health Approach
- Technical Approach



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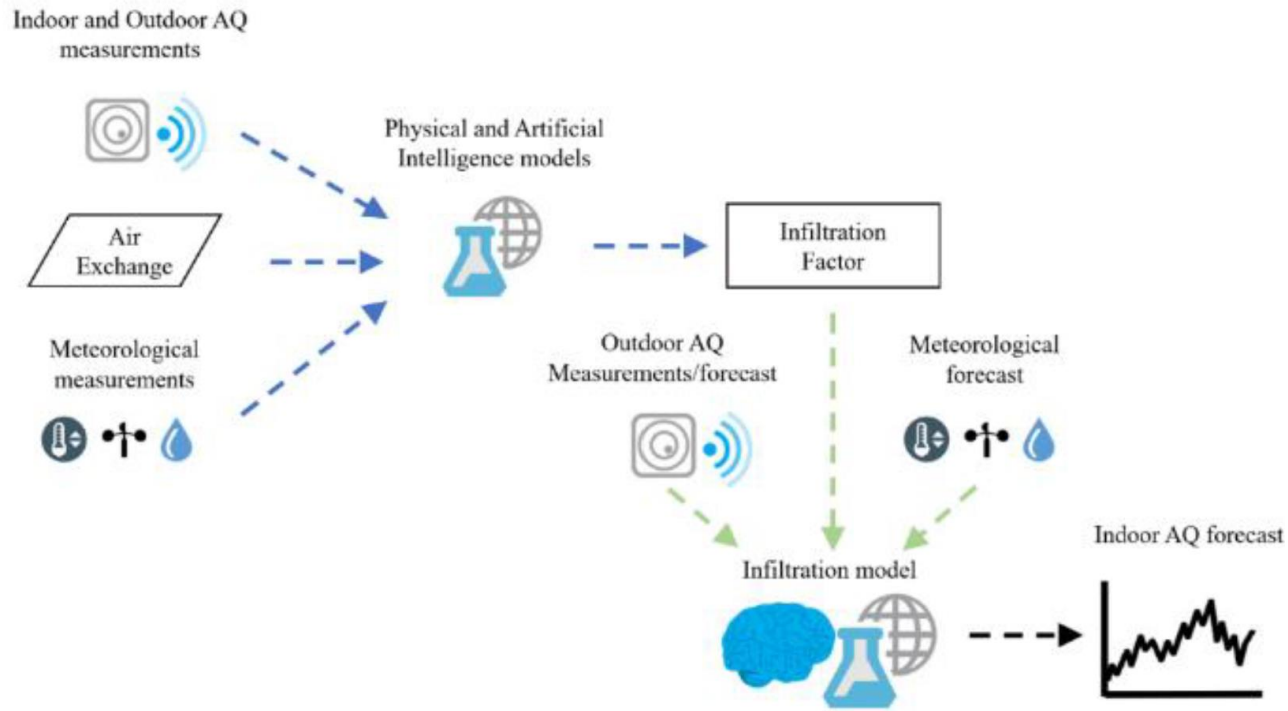
TwinAIR Approach

Environmental Approach

- Identification and characterization of pollutants
- Indoor and outdoor correlation



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TwinAIR Approach

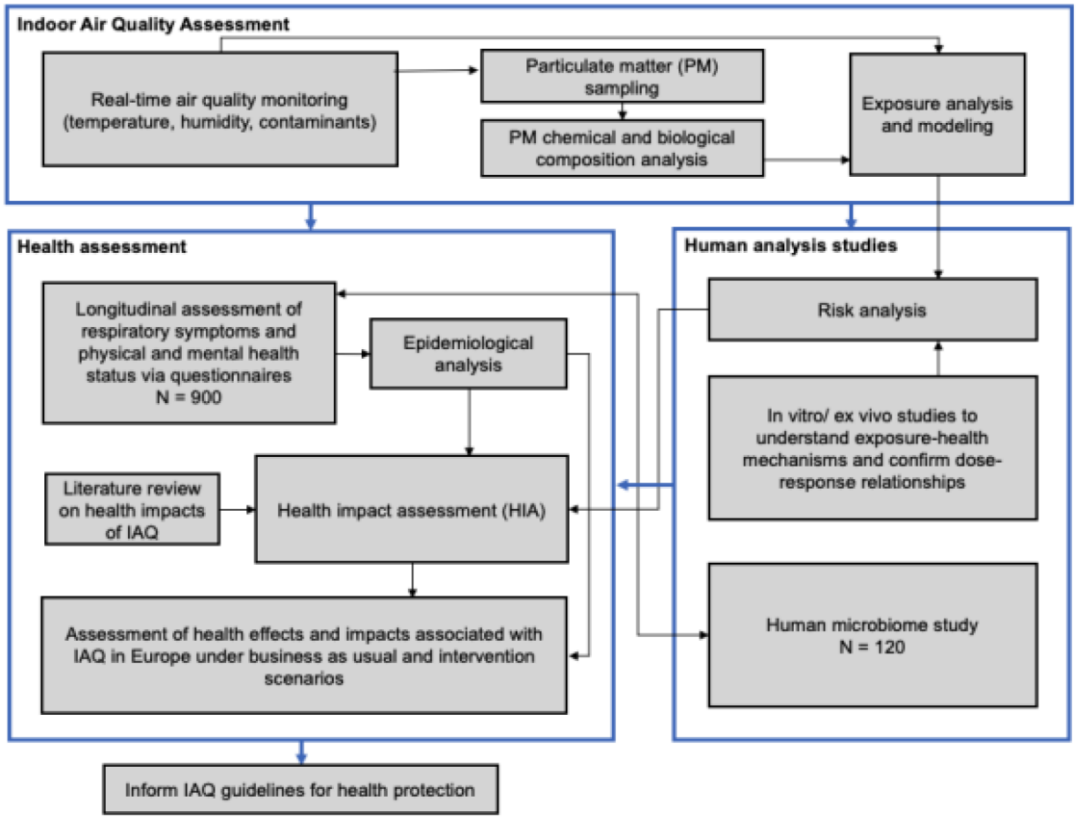
Health Approach

Innovative air monitoring methods evaluating the particles affecting health;

Continuous health measurements and questionnaires track self-reported well-being and respiratory symptoms.

Human microbiome studies to examine the effects of the air composition on the human body

Health impact assessment (HIA) to inform the EU IAQ guidelines



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TwinAIR Approach

Technical Approach

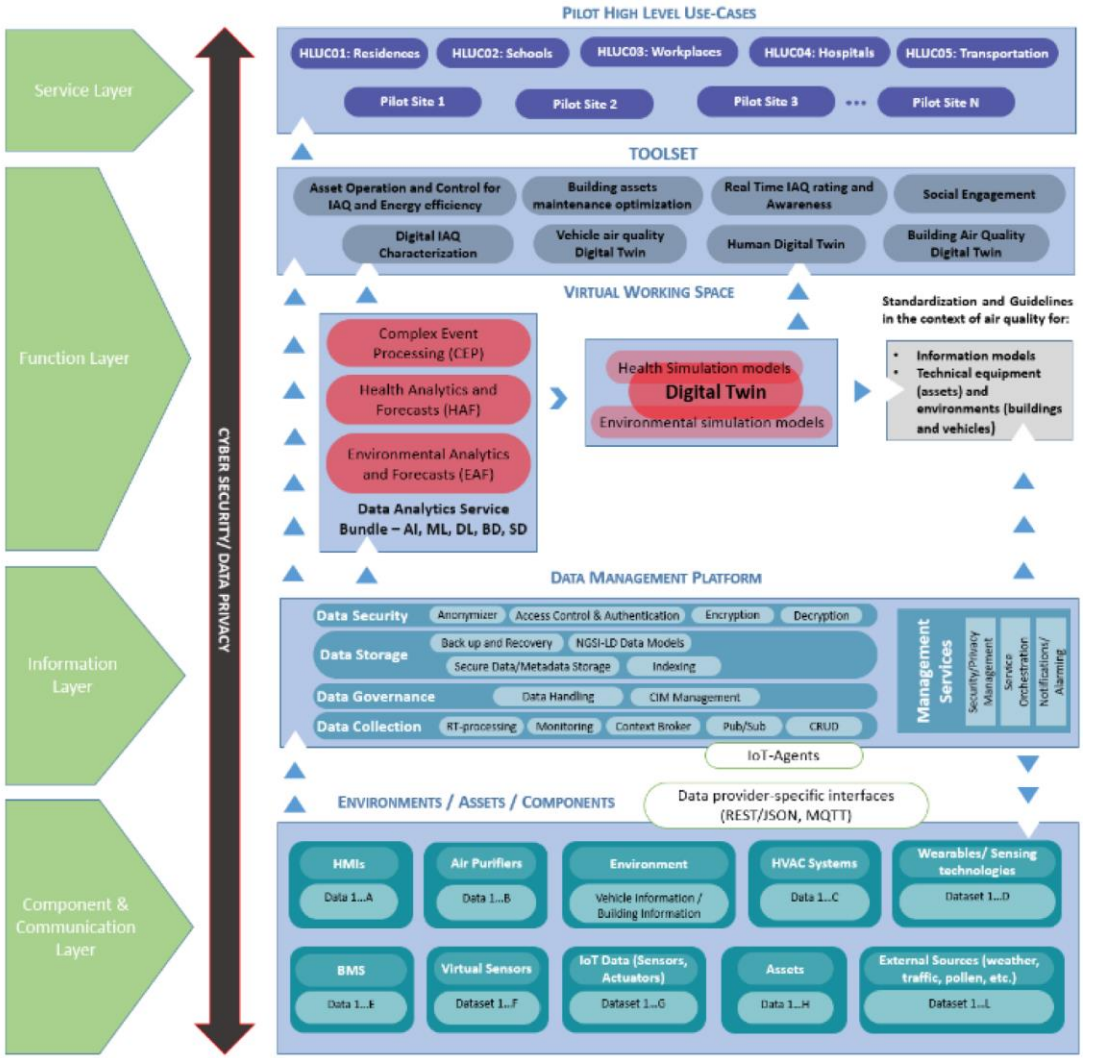
A multi-level Digital Twin (DT) that represents indoor air quality in the built environment and transport

for real time air quality data utilization and response enhancement to ensure optimal air conditions comfort and wellbeing.

Open-source, interoperable and secure big data management

Data analytics services include physics-based and AI based simulations

IoT, virtual sensors, HVAC systems, wearables, external sources



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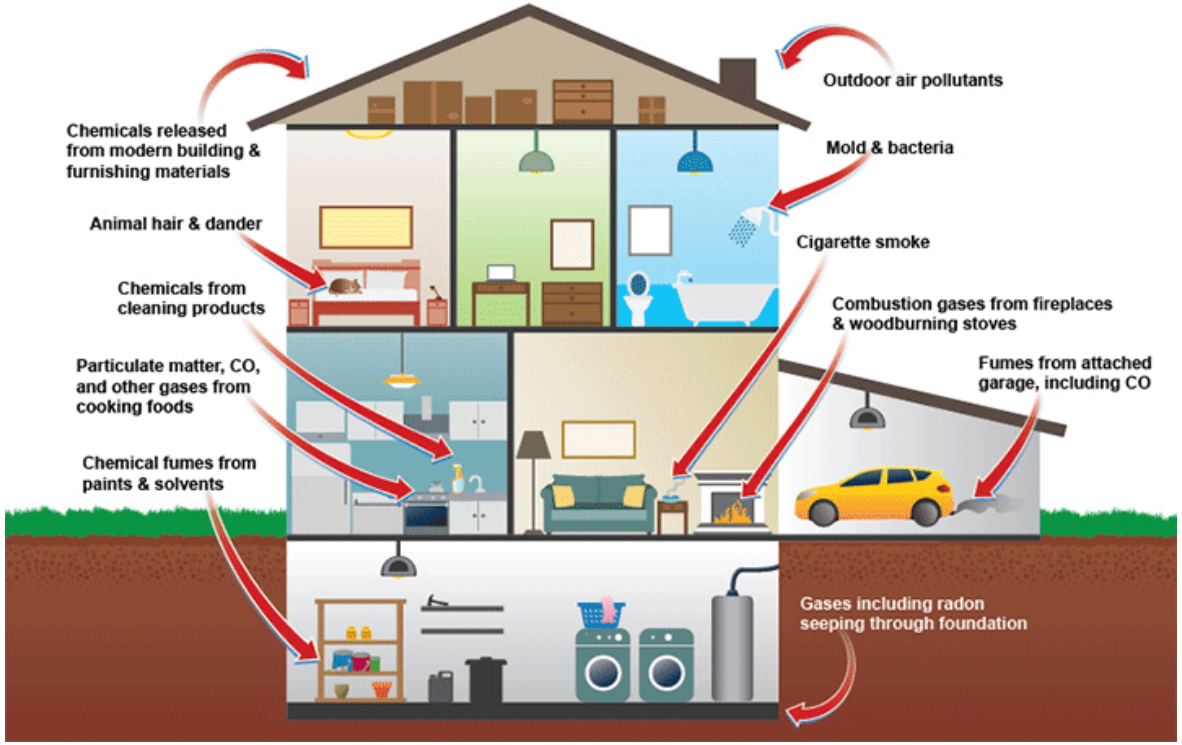
Interventions

1. Digital IAQ Characterizations

- Digital Library of IAQ contaminants & their sources including:
  - Construction Materials & Furnishings
  - Processes & Tasks (e.g. Cooking, cleaning, industrial, etc.)

- Digitalization of the particle pathways & transfer mechanisms driving contaminant spread in buildings

- Will form the foundation for the expansion of the DT physics engine to model IAQ & drive other services (e.g. Virtual / Proxy Sensors)



https://ehs.georgetown.edu/environmental-affair/indoor-air-quality/

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Interventions

2. Vehicle Digital Twin

- Performance based digital twin of various bus types in SE & ES
- Will analyse the interactions of the bus cabin with the surrounding environment
- Will predict passenger comfort & potential exposure to pollutants, particularly the indoor/outdoor environment
- Practically involves significant manipulation of weather files to account for micro-climates as well as reflect conditions when the bus is moving.

https://liu.se/en/news-item/har-rullar-forskningen-fram

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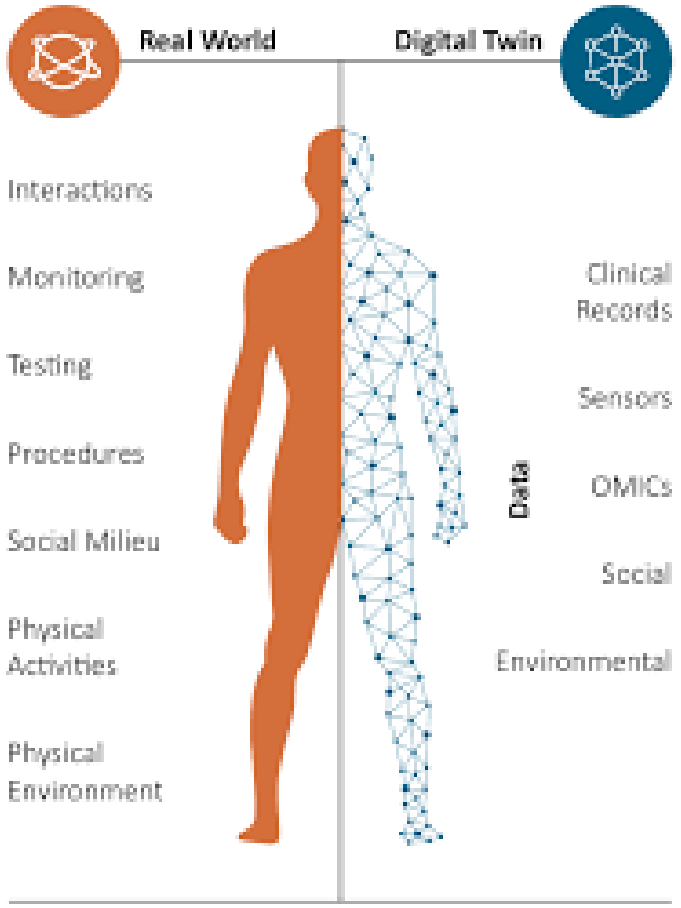
Interventions

3. Human Digital Twin

- Linked to a wearable sensor that will capture the air quality in the immediate vicinity of the stakeholder
- Will facilitate dose response experiments that provide data & insights for the Health Approach of the methodology
- Aggregator for a wide range of data sources and profiles



https://arxiv.org/ftp/arxiv/papers/1910/1910.13520.pdf

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Interventions

4. Building Asset Operation & Control for Improved IAQ & Energy Efficiency

- An intelligent building controller will leverage the analytical & physics engine of the Building Air Quality Digital Twin
- Will dynamically adjust ventilation rates and control sequences to optimize IAQ while ensuring energy efficient operations
- Implemented through an API connection to the BMS system
- Considers both filtration and ventilation systems

https://www.pictureperfectcleaning.ca/having-good-indoor-office-air-quality/

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Interventions

5. Building Asset Maintenance Optimization

- Risk based maintenance optimization approach to predict failures of the HVAC system & the associated health risks
- Proactive approach to filter replacement to ensure high IAQ is maintained at all times
- Maintenance prioritization algorithms will be incorporated within existing predictive maintenance strategies

https://plantscapes.ae/green-wall-dubai/

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Interventions

6. TwinAIR Real Time IAQ Rating & Awareness

- Real-time qualitative Air Quality Index Calculator based on European Environmental Agency Air Quality Index (AQI)

- Considers 5 key pollutants:
  - Particulate Matter (PM10)
  - Fine Particulate Matter (PM2.5)
  - Ozone (O)
  - Nitrogen Dioxide (NO_2)
  - Sulphur Dioxide (SO_2)

  - Will investigate whether modifications to the existing AQI model is required

https://www.nytimes.com/wirecutter/reviews/best-home-air-quality-monitor/

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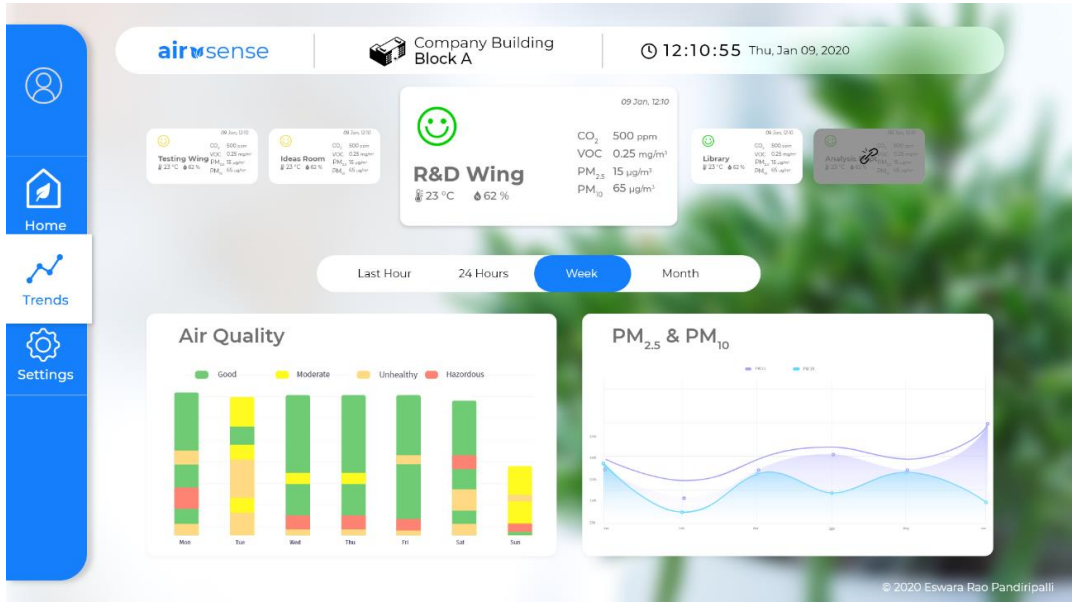
Interventions

7. Social Engagement

- User Engagement Tool to facilitate:
  - Stakeholder Engagement with Relevant Data
  - Analysis & Visualization
  - Integration with Community Engagement Features
  - Inter/Intra Community Knowledge Sharing



http://www.eswar.design/portfolio/intelligent-indoor-air-quality-monitoring-system/

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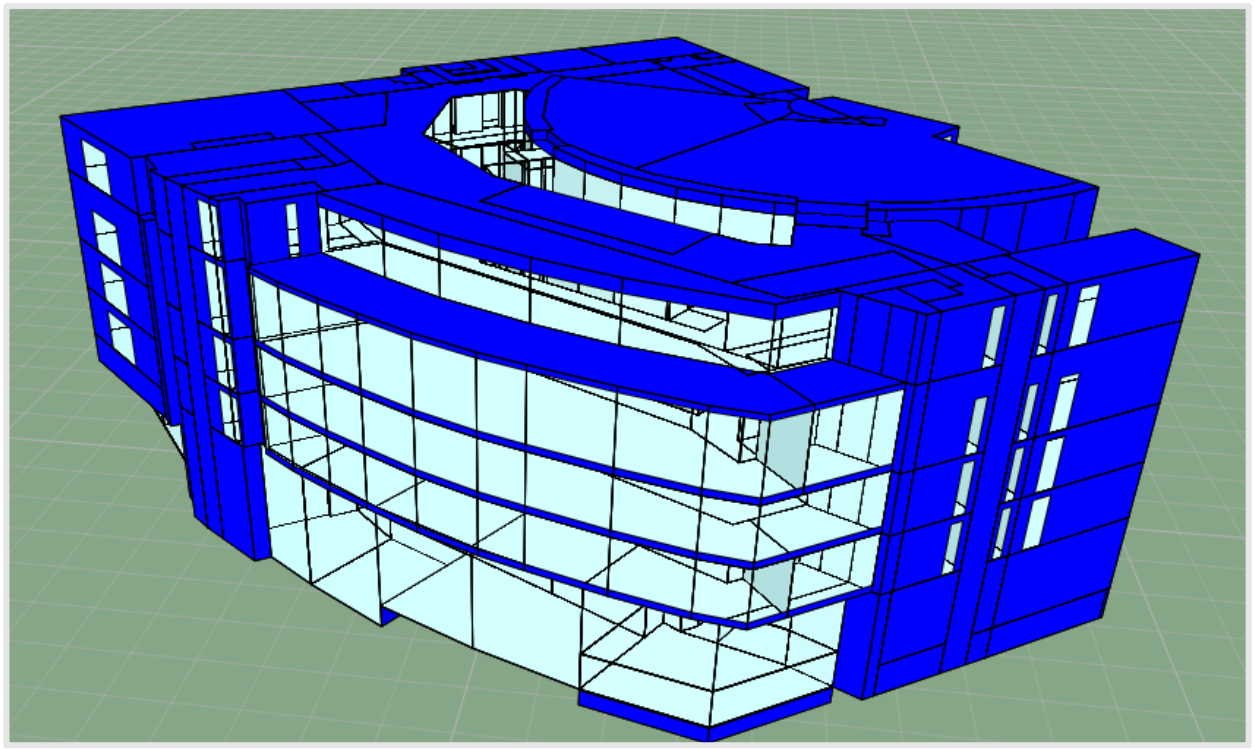
Interventions

8. Building Air Quality Digital Twin

- Decision Making Application leveraging Physics-based performance Digital Twins
- Enables user to test various operational and renovation scenarios to ensure optimum IAQ & energy efficiency
- Facilitator for other interventions and services



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Thank you!

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TwinAIR

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Visit the website

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