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SubAir/AirCleaner

Seoul Metro Integrated Management System for Intelligent & Energy-efficient Indoor Air Quality Monitoring & Control

Karpjoo Jeong (jeongk@konkuk.ac.kr)

Department of Advanced Technology Fusion
(<http://atf.konkuk.ac.kr>)

Konkuk University





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Life in Future





Urban Life

- The **world's population** will rise from **6.5 billion to 9.1 billion by 2050**, according to a United Nations survey.
- By the year 2050, nearly **80% of the earth's population will reside in urban centers**.





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Skycraper





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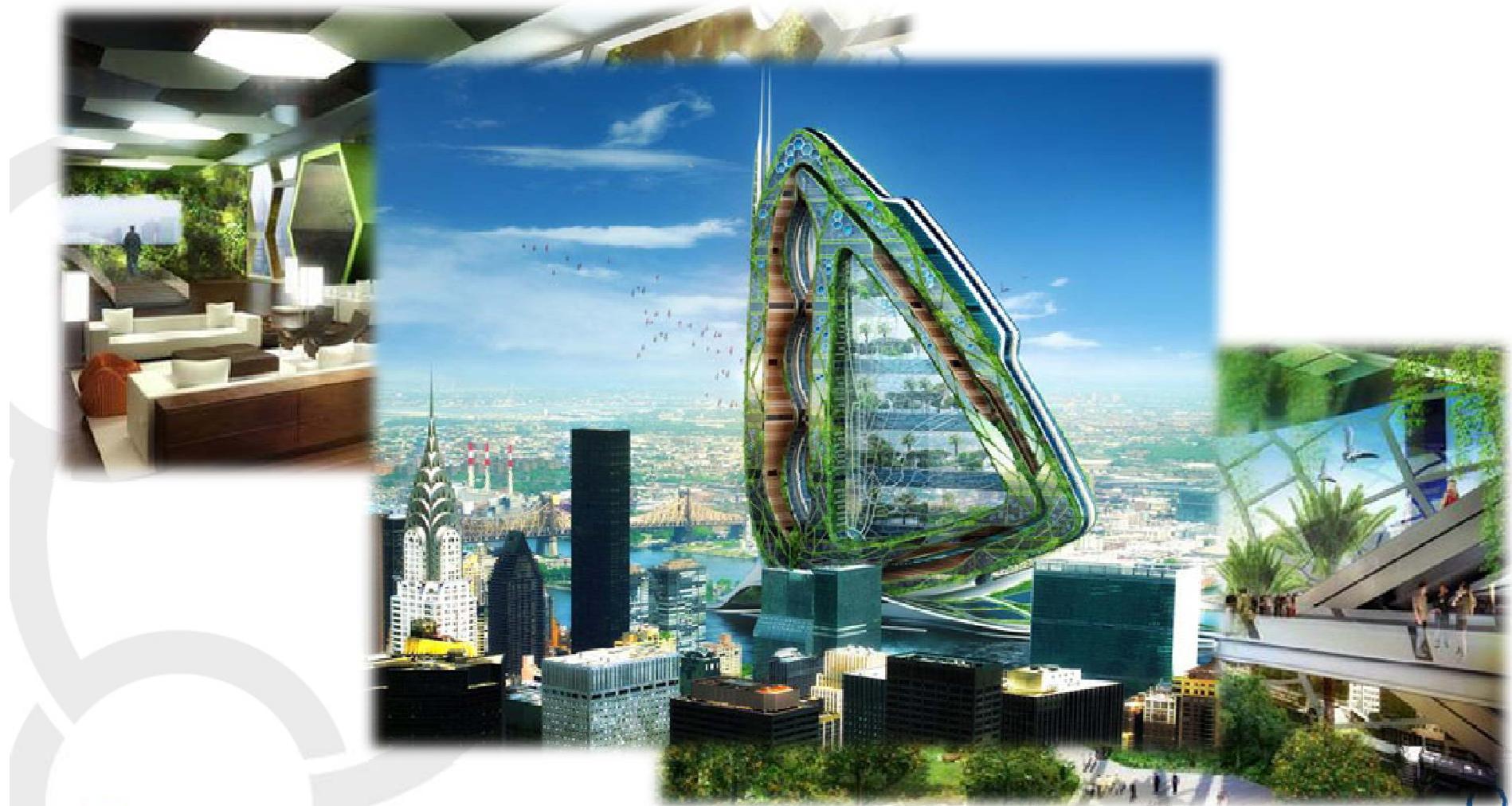
Futuristic Floating Ecopolis





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'Dragonfly' Vertical Farm





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Underground City: Montereal



Seoul Underground City

Yonhap News – September 16, 2009

- Seoul City mayor Se-Hoon Oh announced that Seoul would consider the construction of Underground city like Montereal's underground city





Seoul Underground Road Networks

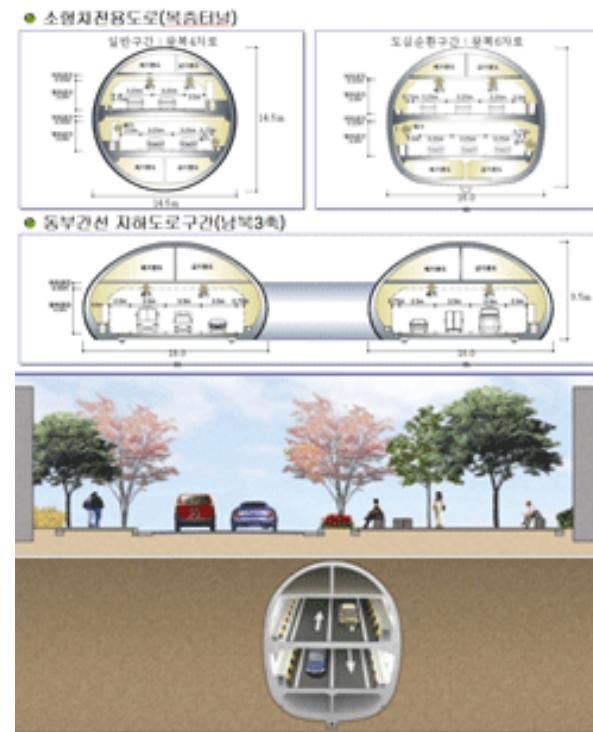
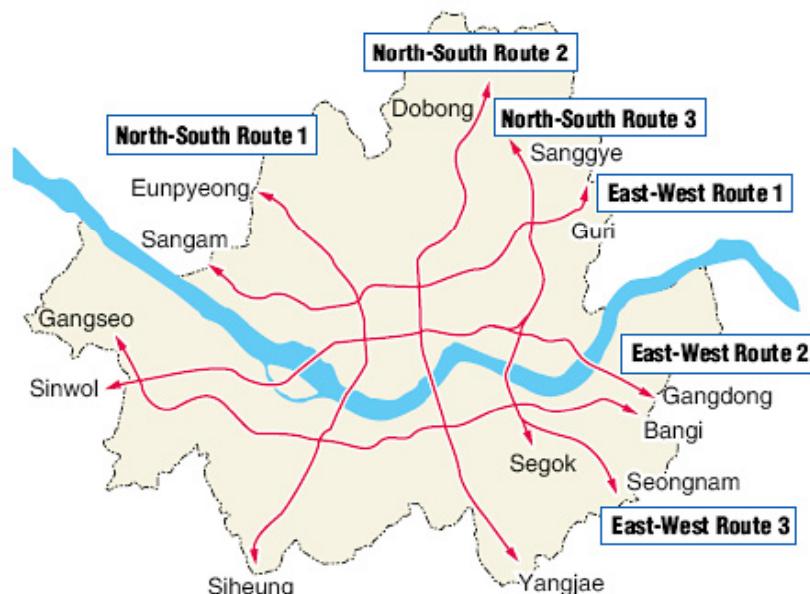
Korea Times –September 10, 2009

- **Seoul Plans Underground Road Networks**
- From 2017, Seoullites will be able to drive on underground roads free of traffic jams.
- The Seoul Metropolitan Government has now earmarked three quarters of million US dollars of the city's budget for a two-year research project into strategic planning for the construction of underground roads



Seoul Underground Road Plan

Seoul's Underground Road Plan





Well-being Life in Future

Require

Indoor Air Quality and Safety

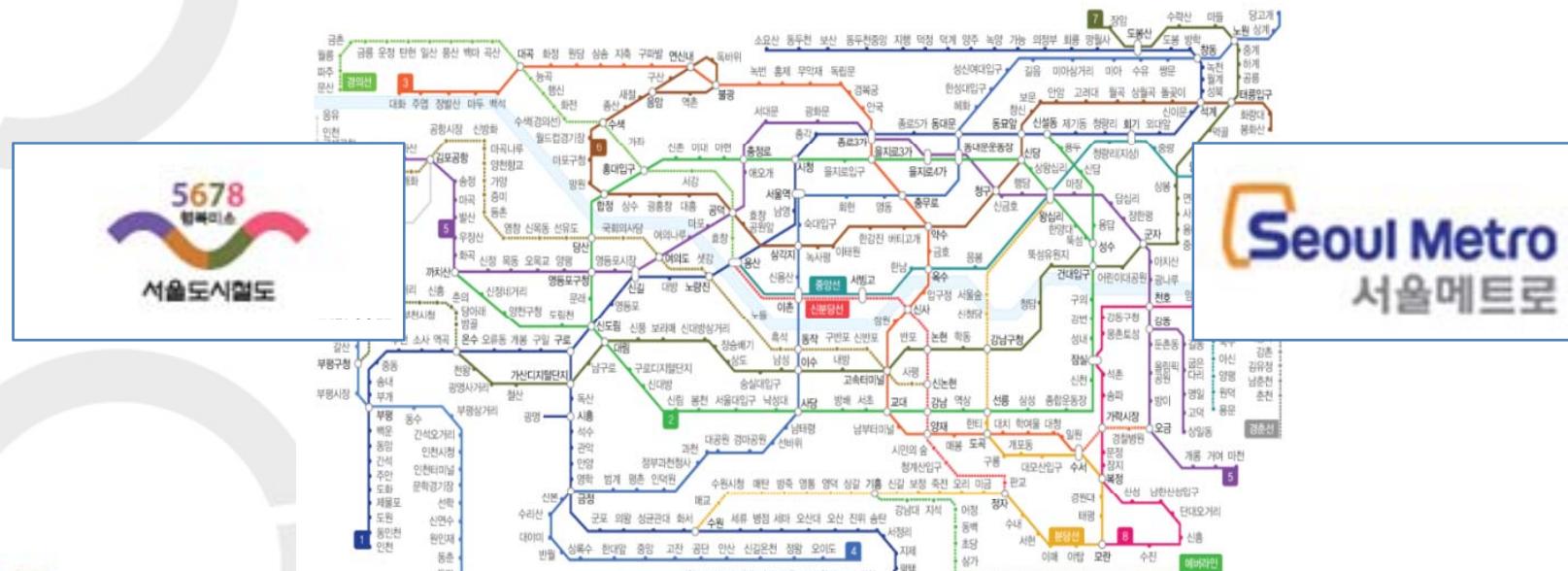




Seoul Metro

IAQ Improvement Efforts for Subway Stations and Tunnels

200 Million US dollars per year





Subways in Korea

- 6.5 million citizens use subways daily in Korea
- There are 508 stations (470 underground stations) in Korea. 265 stations in Seoul
- Increasing concerns about **health and safety** in subways
- **Indoor Air Quality (IAQ)** of underground subway stations & tunnels





Subways in Seoul

Two public corporations for subways

- **Seoul Metro Corporation**

- Lines: 1 ~ 4.
- 117 stations and 143.9 km rails (mostly inside tunnels)



- **Seoul Rapid Transit Corporation**

- Lines: 5 ~ 8
- 148 stations and 152 km rails (tunnels)



- **Screen Doors**
 - Currently, 49 stations done and continuing
- **New ventilation systems**
 - Currently, 58 stations done and continuing



Seoul Metro

IAQ Improvement Efforts (2/3)

- **Rail track Improvement**

- From ballasted to slab. 45.9km completed out of total length 226.7km



Seoul Metro

IAQ Improvement Efforts (3/3)

- **Cleaning**
 - Vacuum cleaning car, High pressure water cleaning car. Plan to purchase large-sized water tank car (50tons, 2 cars)





IAQ Monitoring

- Periodic IAQ measurements by human experts
 - Measuring IAQ is time-consuming and error-prone
 - Only a few experiments conducted per year
- Experimental operation of online IAQ sensors at four stations as a testbed
 - Expensive (100,000 US\$ for one instrument)
 - Difficult to maintain
- Not much detailed info about IAQ in subways





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The SubAir Project

Prof. Jo Chun Kim(jckim@konkuk.ac.kr)
Department of Advanced Technology Fusion
Department of Environmental Engineering
Konkuk University





SubAir Vision



Better Indoor Air Quality
Maximize Ventilation, Outdoor Air, Filters

Intelligent & Energy-efficient Indoor Air Quality Monitoring & Control

Reduced Energy Consumption & Noises
Maximize Ventilation, Outdoor Air, Filters





SubAir Goals

- **Intelligent Wireless Sensors-based Monitoring** System for Real Time Air Quality Measuring
- **Intelligent, Online Remote Control** System for Facilities (ventilation, Filters)
- **Intelligent Prediction and Control Decision** System (Expert Systems)
- **Reliable and Flexible Integrated Management**



System Structure

Intelligent Prediction and Control Decision System

Reliable and Flexible Integrated Management

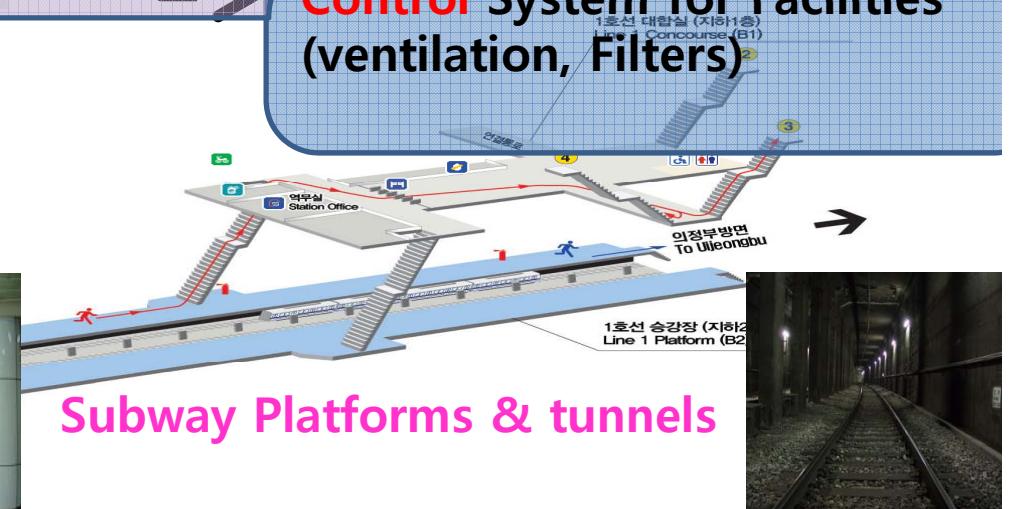
Intelligent Wireless Sensors-based Monitoring System for Real Time Air Quality Measuring



BK2

Subway Platforms & tunnels

Intelligent, Online Remote Control System for Facilities (ventilation, Filters)





SubAir Collaboration (1/2)



PI: Prof. Jo Chun Kim

Dept. Advanced Tech. Fusion
Dept. Environmental Eng.
Konkuk Univ.



Intelligent Error Detection, Prediction and Control Decision

Co-PI: Prof. In-Won Kim

Dept. Chemical Eng.
Konkuk Univ.

Prof. Chang-Kyu Ryu

Dept. Environmental Eng.
Kyunhee Univ.



Ventilation and Filters

Prof. Jai Hyo Lee

Dept. Mechanical Eng.
Konkuk Univ.

Prof. Young Min Cho

Dept. Environmental Eng.
Kyunhee Univ.



SubAir Collaboration (2/2)



Wireless Communication & Control System

Prof. Kyu Shik Kim
Dept. Electronics Eng.
Univ. of Seoul

Prof. Hee Shik Kim
Dept. Electronics Eng.
Univ. of Seoul



Integrated Management

Prof. Karpjoo Jeong
Dept. Advanced Tech. Fusion
Dept. Internet & Multimedia Eng.
Konkuk Univ.

Prof. Sang Boem Lim
Dept. Advanced Tech. Fusion
Konkuk Univ.



SubAir Project Budget and Years

- Project Years ('08 ~ '12). Five Years.
 - Phase I ('08 ~ '09). Field Surveys and Technology Development
 - Phase II ('10 ~ '12). Products and Testbeds
- Project Budget
 - One million US dollars per year
- Sponsors
 - Seoul City: Financial support
 - Seoul Metro: Target Domain





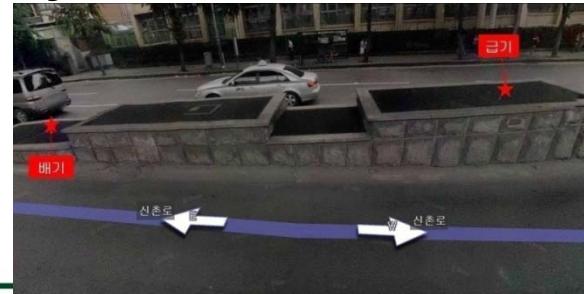
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Indoor Air Quality in Subways

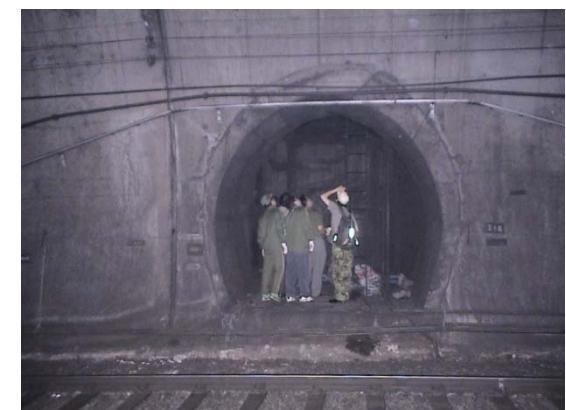
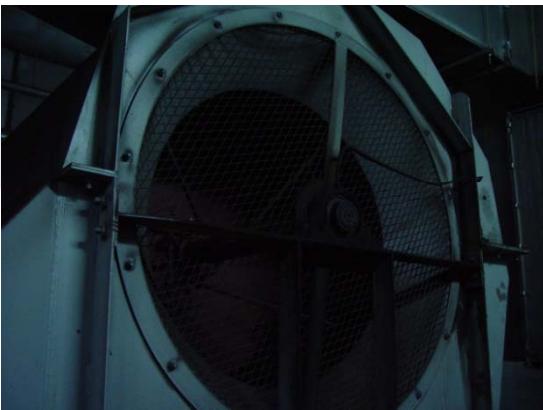


Air Spaces in Subways

- **Platforms**
 - Closed spaces after screen doors
- **Tunnels**
 - Almost open spaces
- **Trains**
 - Share air with tunnels
- **Outdoor spaces** eventually share air with these indoor spaces



Platforms and Tunnels



Trains

Train with automatic ventilation control



Roof Ventilation



Train with semi-automatic ventilation control



Floor Ventilation





Screen Doors

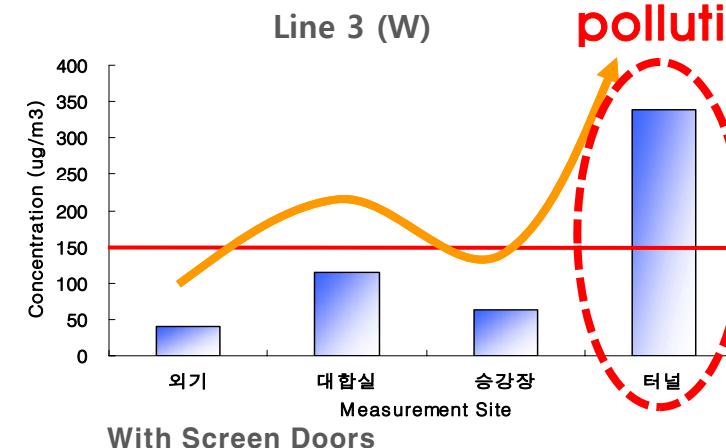
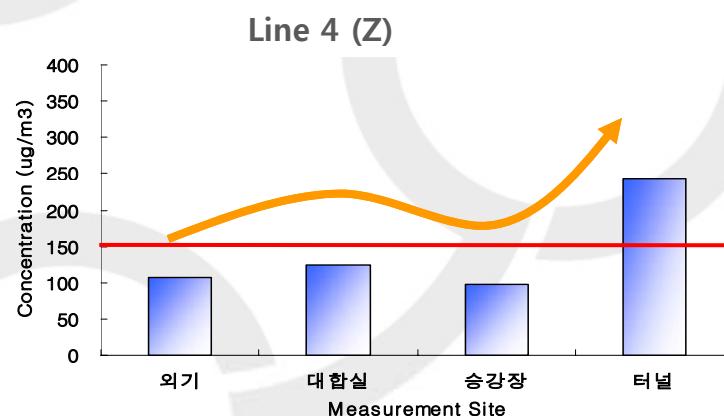
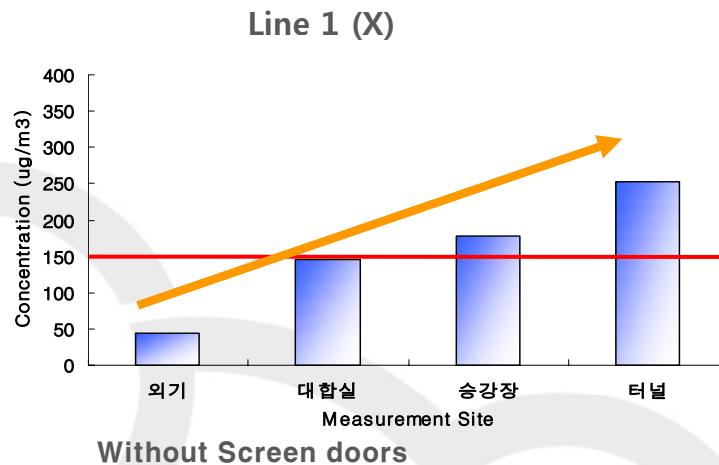
- Isolate Platforms and Tunnels
- Improve platforms significantly; worsen tunnels
- Trains constantly share air with tunnels and platforms do so intermittently



Tunnels: main target



Screen Door Impacts on IAQ





Ventilation: Ultimate Method

- **Natural Ventilation**

- All tunnels of Line 1; Some tunnels of Line 2;
Some trains
- **Free**, but ineffective

**Require Mechanical Methods
to create more ventilation**

- **Mechanical Ventilation**

- All platforms; All tunnels of Line 3 & 4;
Some trains
- **Effective** for IAQ improvement, but require
energy consumption

**Require Intelligent
Methods for Tradeoffs**





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Cost-effectively Improving Natural Ventilation in Tunnels

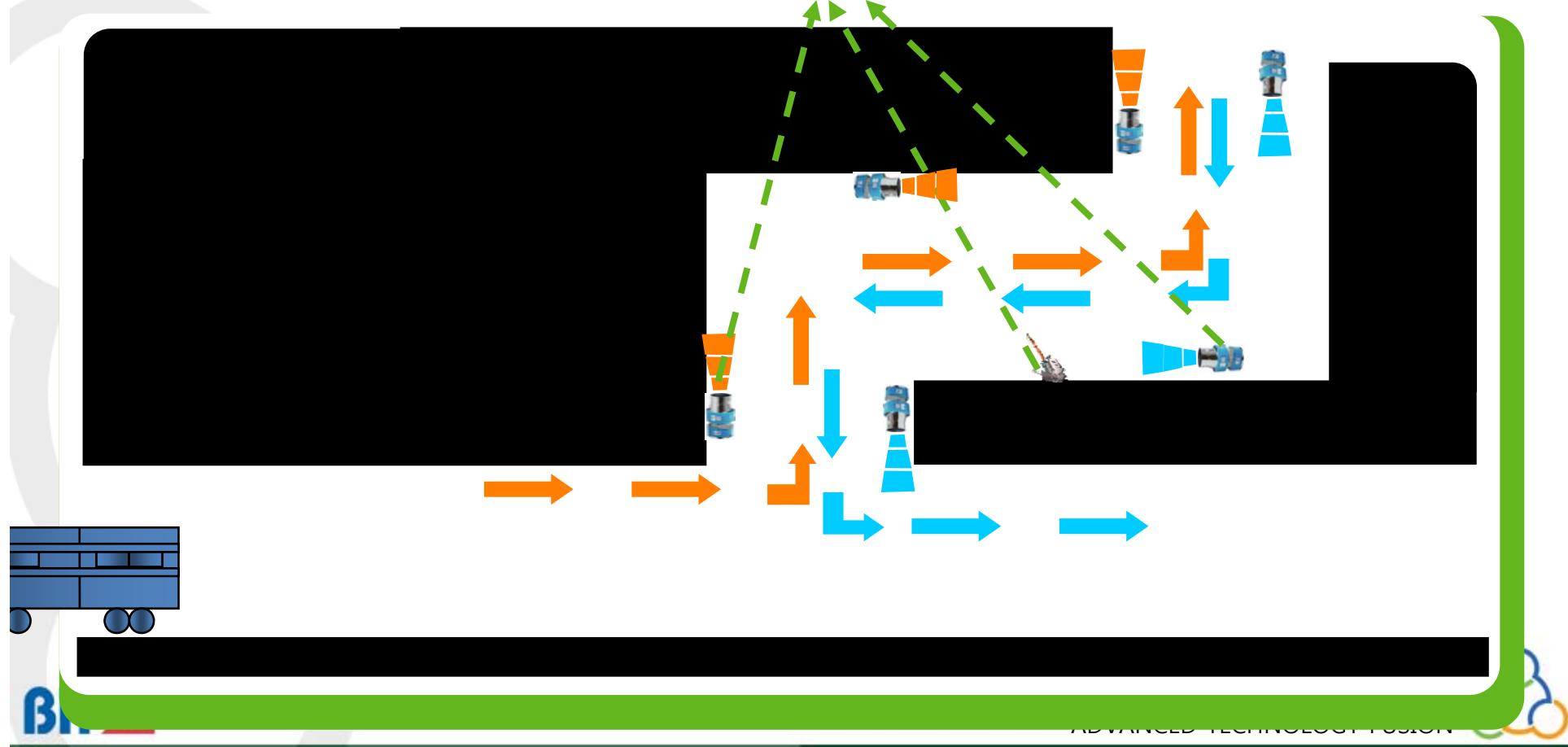
Using Train Wind and Small Jet Fans



Idea



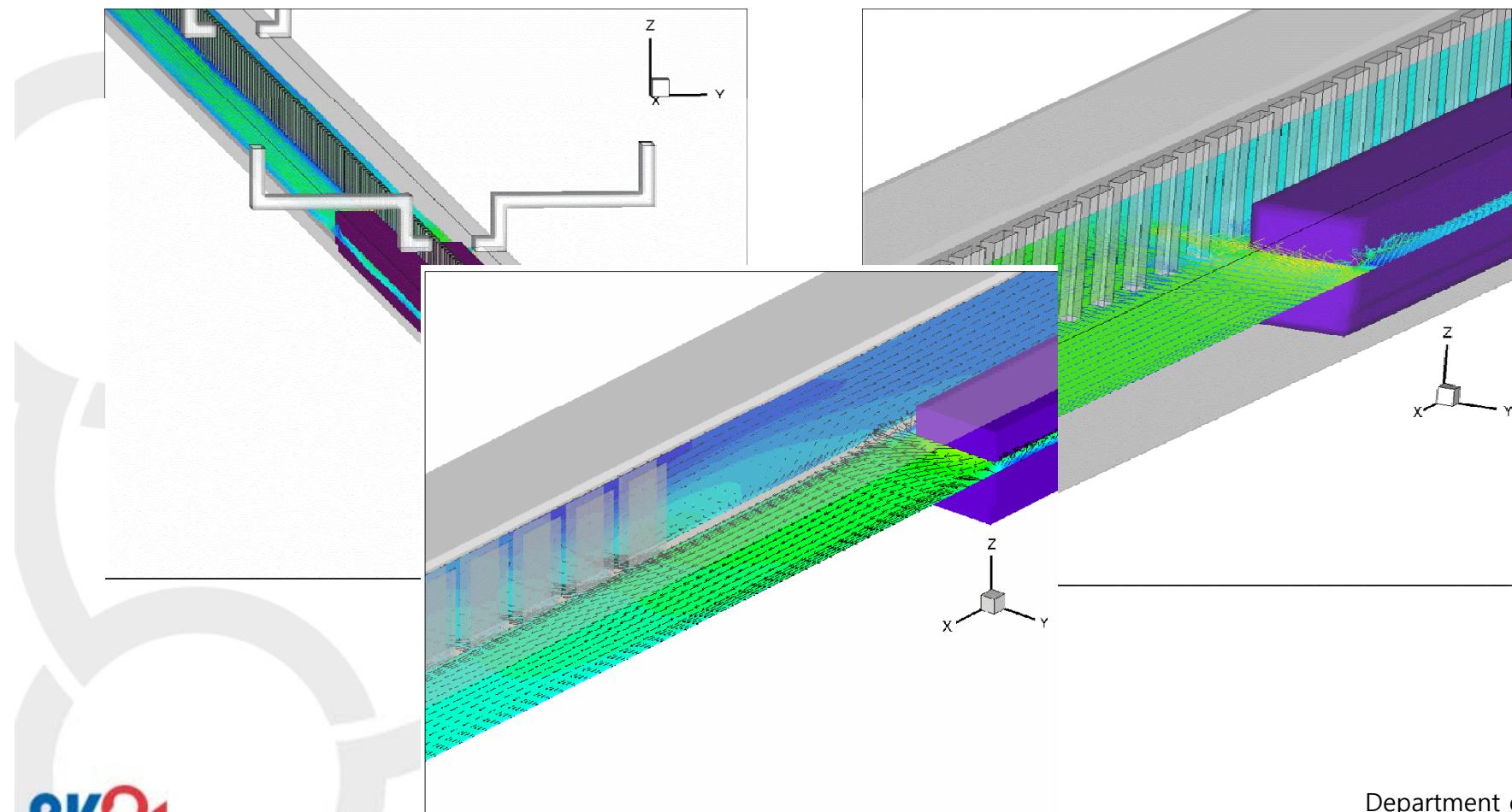
Patent No. : 2003-0000195
China 153335





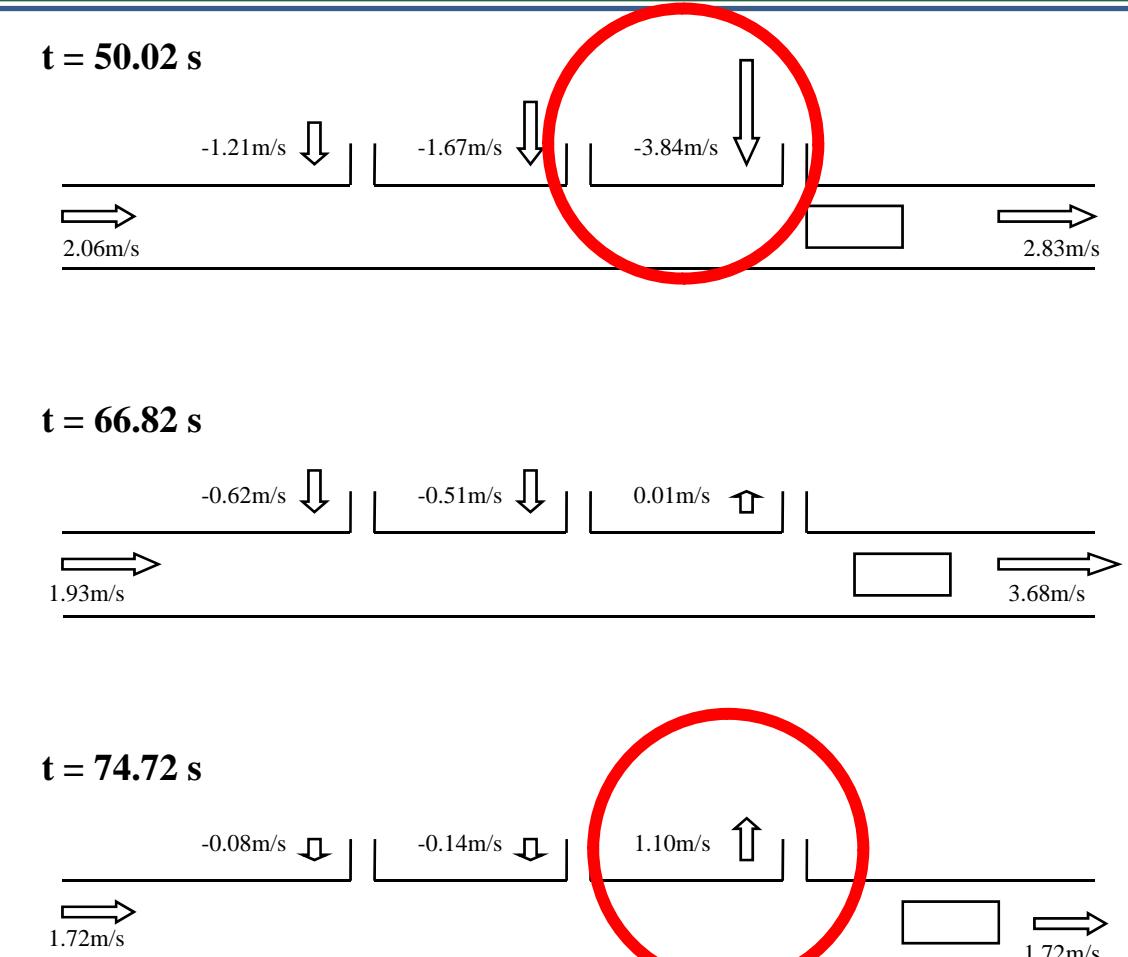
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CFD Analyses of Train Winds



CFD Analyses Results

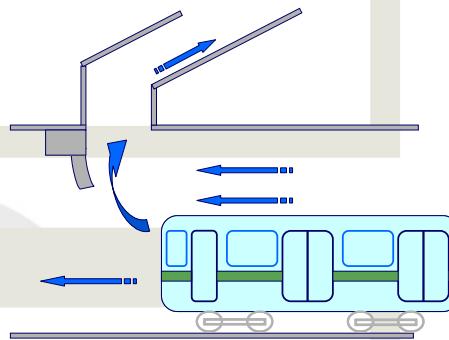
- Utilize air flow when trains come to platforms
- Need to **boost air flow by using small jet fans**



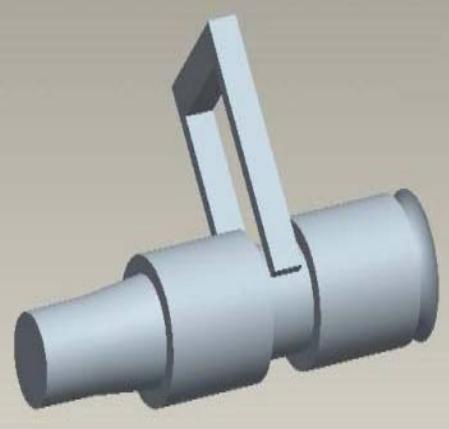
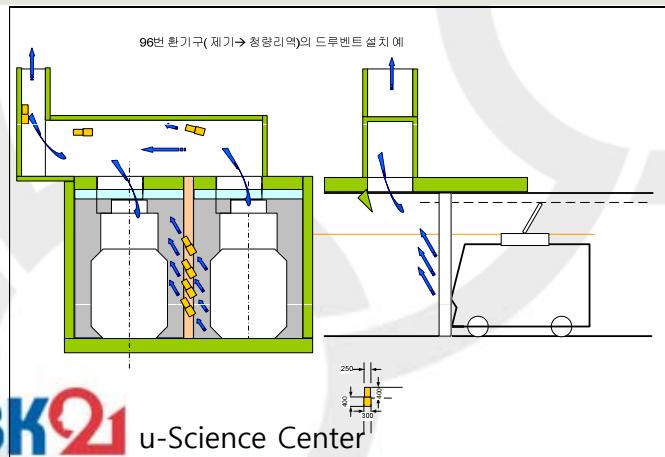
Tunnel Prototype

Objectives

- (A) Physically experiment ventilation effects
- (B) Evaluate design variables



B. Tunnel Design with Small Jet Fans

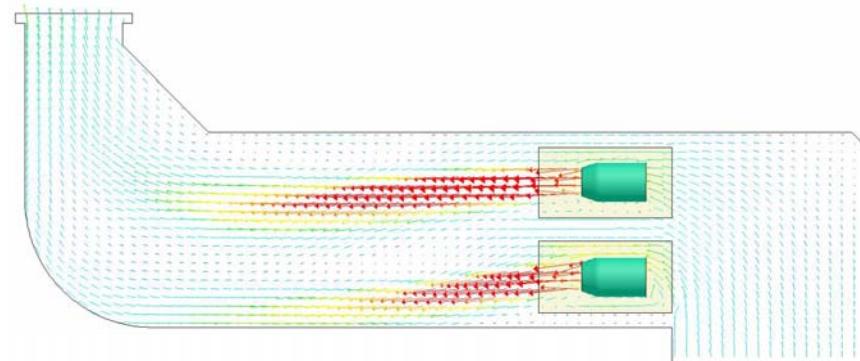
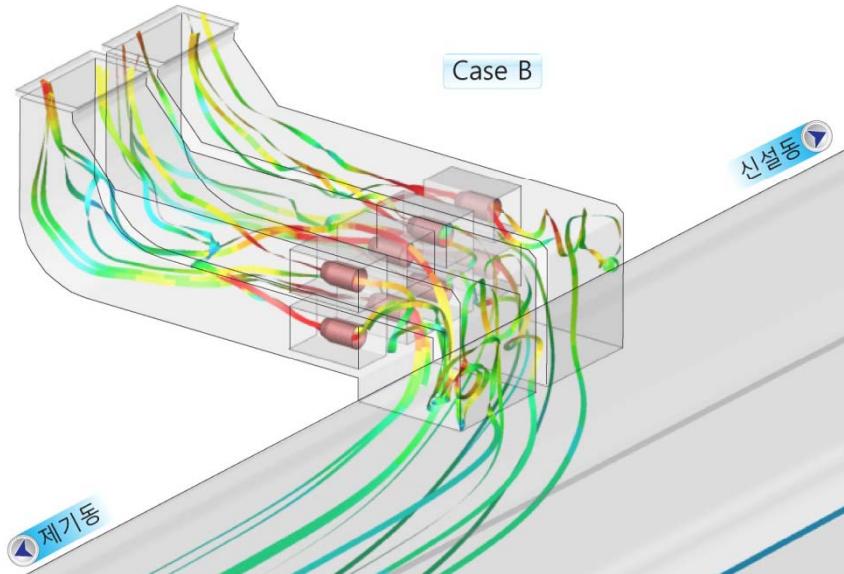


ADVANCED TECHNOLOGY FUSION



CFD Analysis on Fan Location

- Have computed air flow about five design plans about jet fan locations



On-Field Prototype on tunnels

Measuring effects on air flow





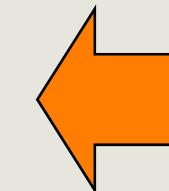
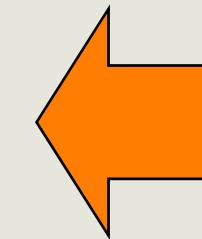
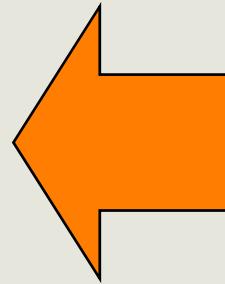
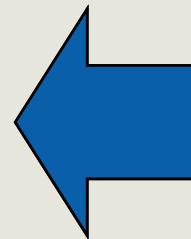
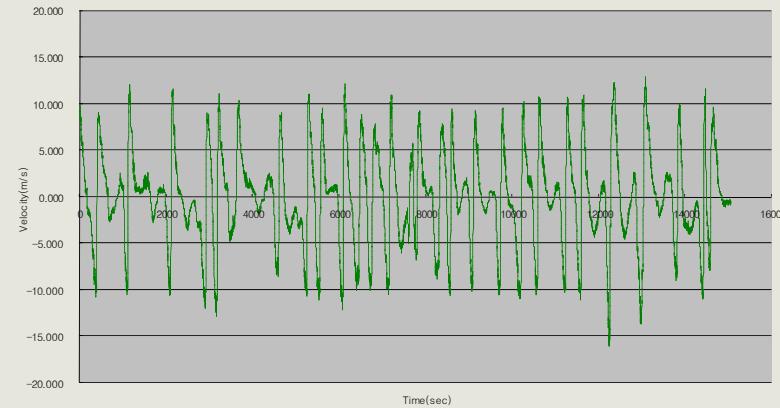
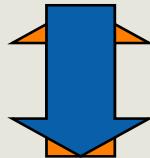
Air Flow without Jet Fans

30,500 CMH

Natural Ventilation

OUT: 34,000 CMH

IN: 30,500 CMH





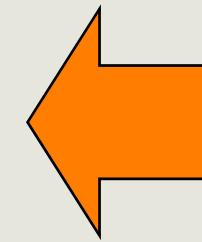
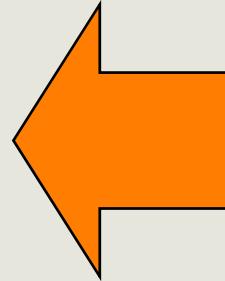
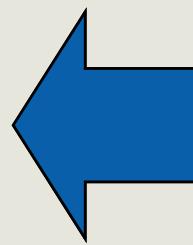
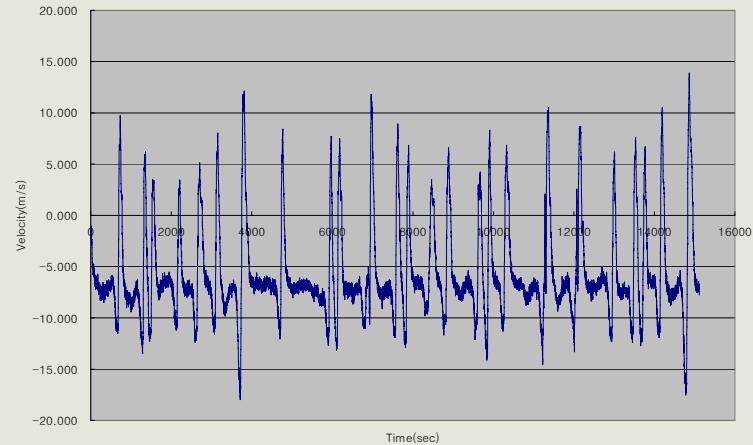
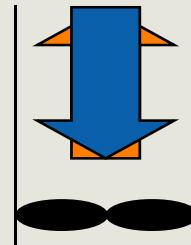
Air Flow with Jet Fans

10,400 CMH

With small jet fans

OUT: 77,000 CMH

IN : 10,400 CMH



Small-Jet Fan based Fire Smoke Control

- Line 1 & 2 all stations with natural ventilation



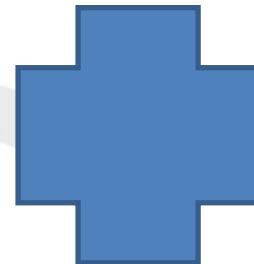


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Intelligent Error Detection, Quality Prediction, and Ventilation Control Decision



Heterogeneous Sensors



Current Sensors

- Big and Expensive; more accurate
- only a few installed
- Expensive maintenance

New Sensors

- Small/inexpensive; less accurate
- Many installable
- Low maintenance overhead





Evaluating Sensors

- B-ray Sensors (expensive) & Light Scattering Method (LSM) Sensors (less expensive)
- Explore how to use LSM sensors together with B-ray sensors so that we can have more sensors



Two Commercial Products

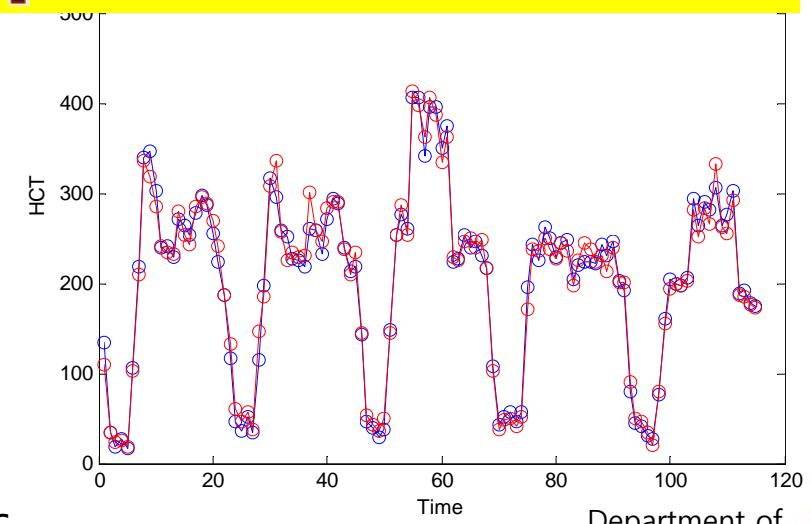
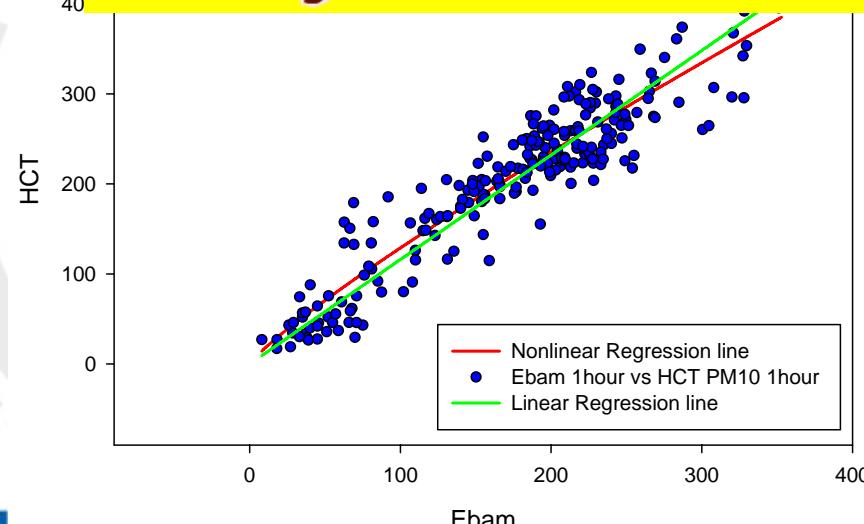
Ebam



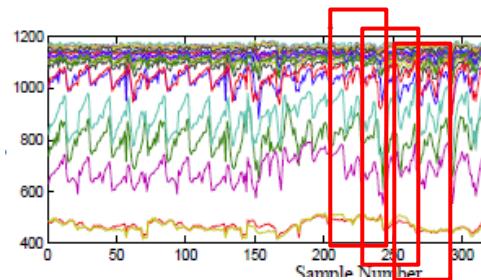
HCT



They show comparable results



IAQ Prediction

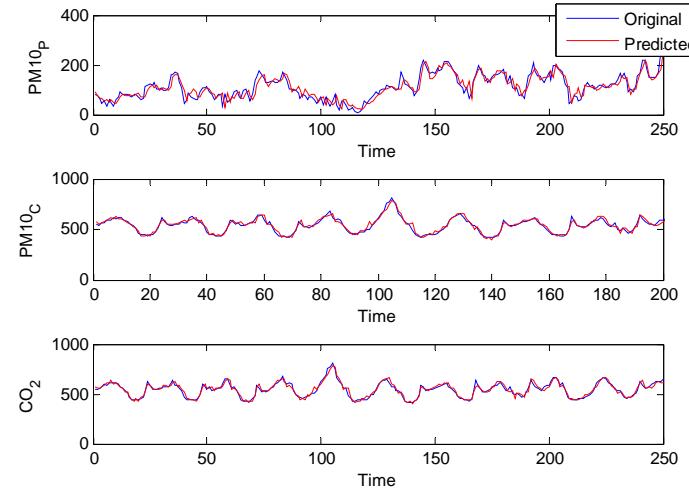


Neural Network based Analysis

Predict future quality based on past trends

10 day prediction

승강장
미세먼지



대합실
미세먼지

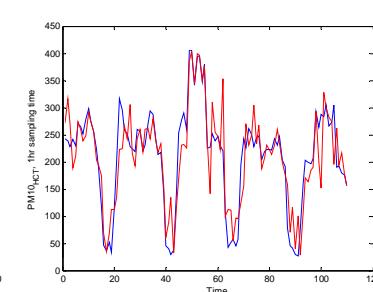
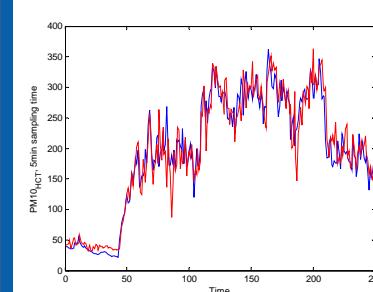
승강장
이산화탄소



u-Science Center

PM10 after 5min

PM10 after 1 hour

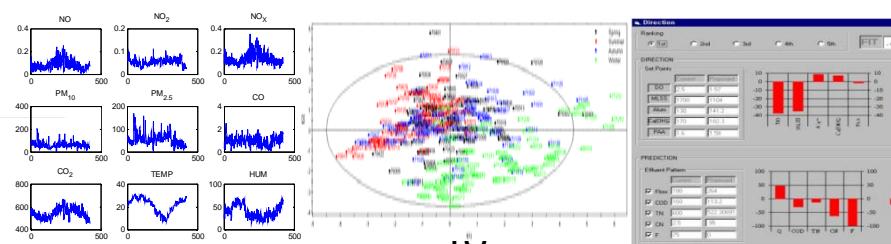
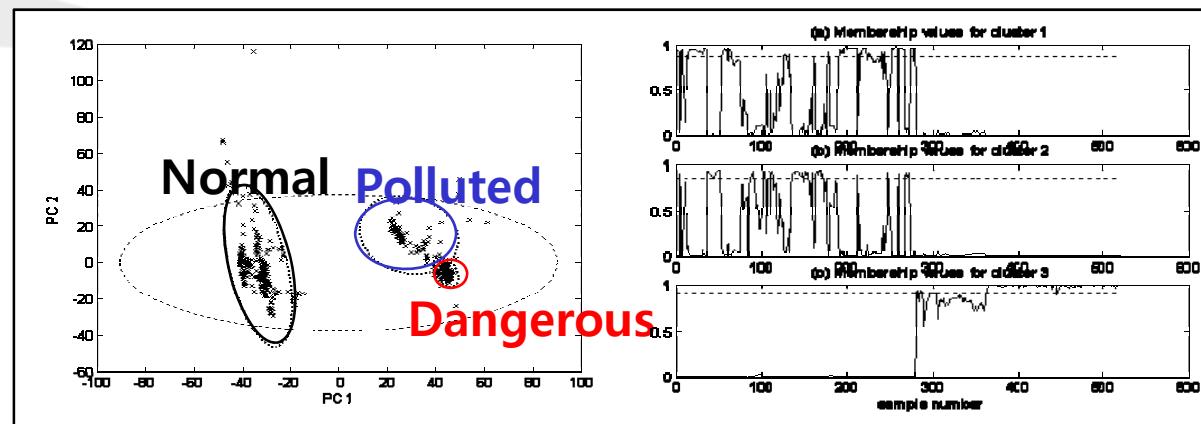


Station X PM10
Prediction



Multivariate Analysis

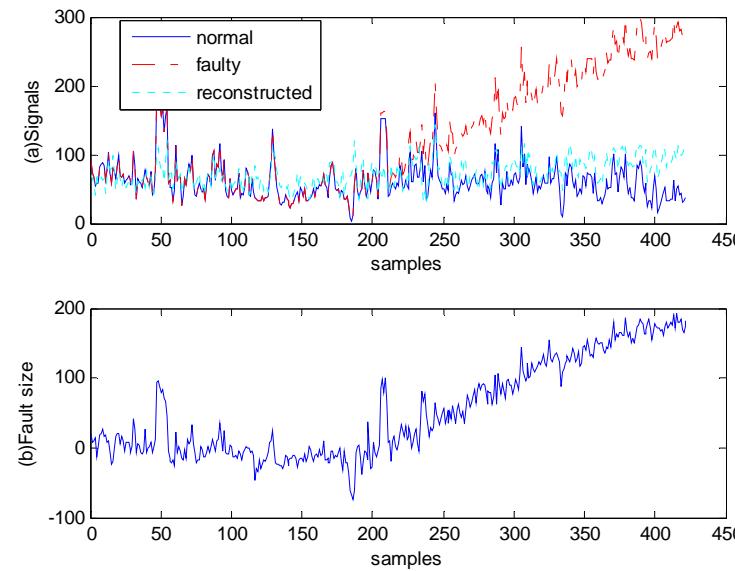
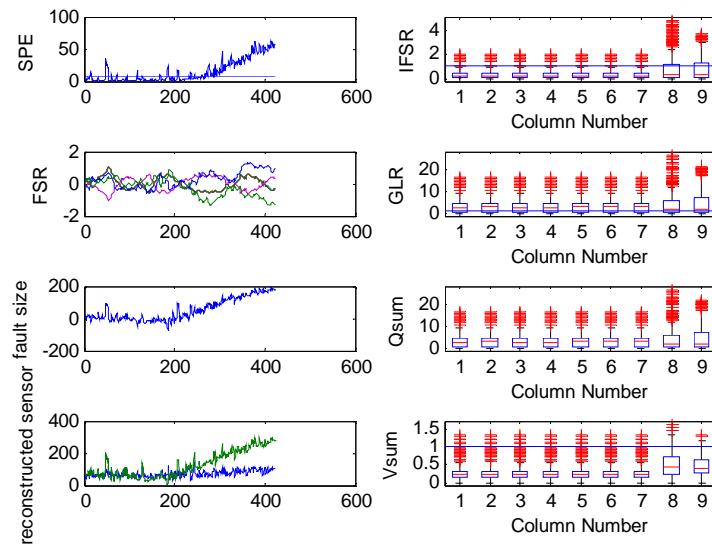
- Predict IAQ collectively by multivariate analysis
 - Consider 4~5 variables



ADVANCED TECHNOLOGY FUSION

Sensor Data Error Detection & Recovery

- IAQ sensors are very sensitive and need error detection and calibration
- Test with NO and PM10 sensors





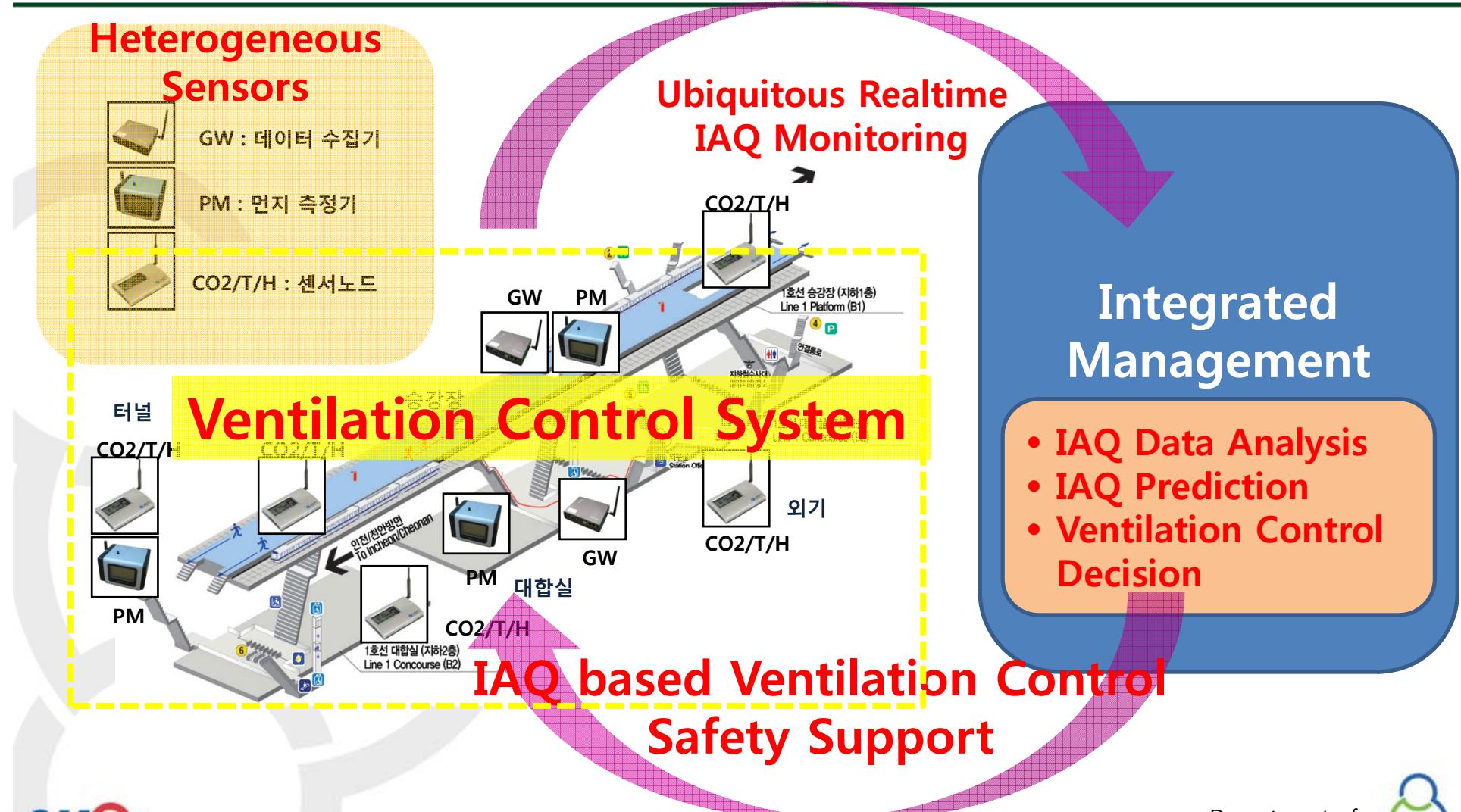
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Integrated Management

AirCleaner System



AirCleaner System



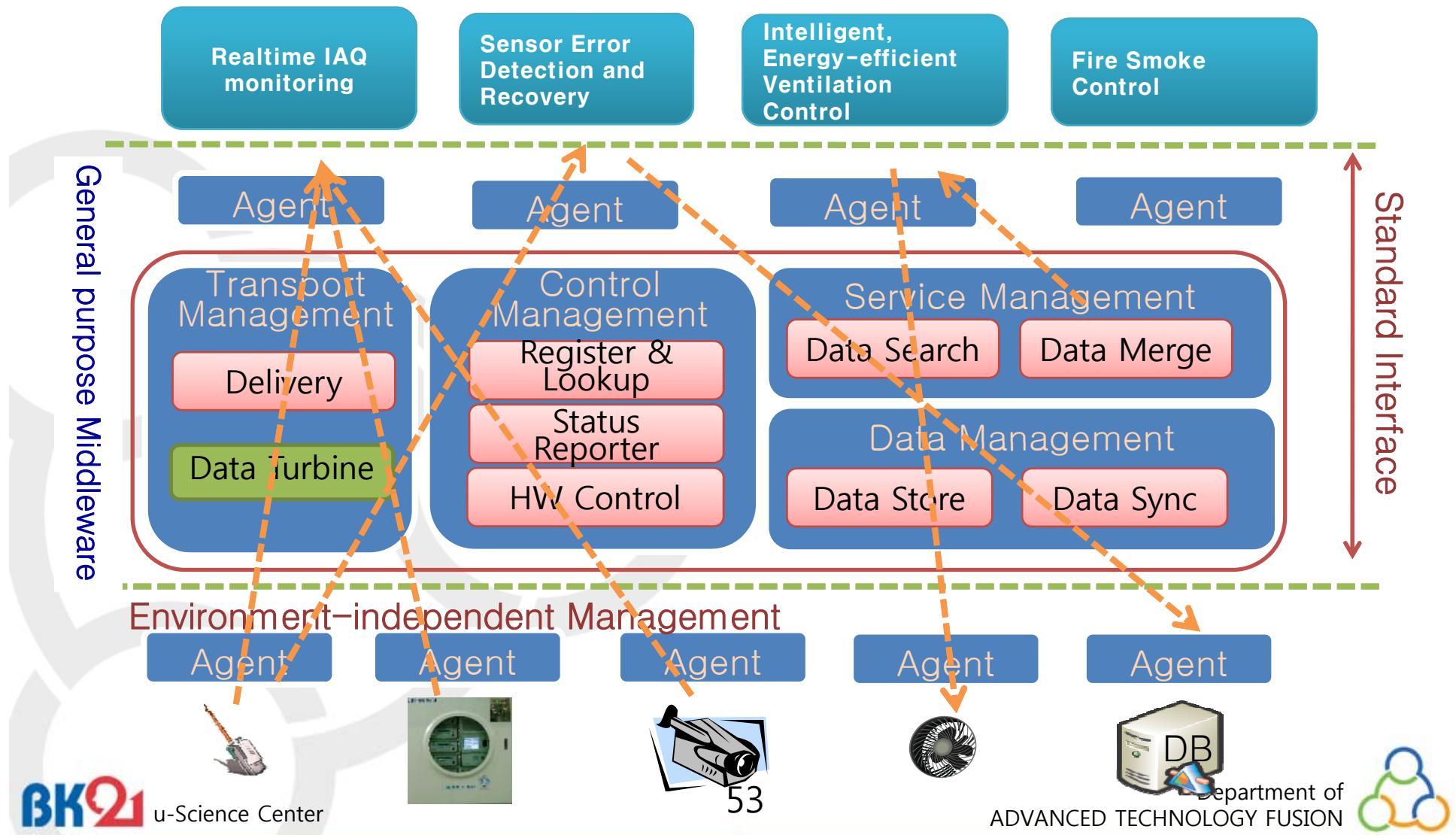


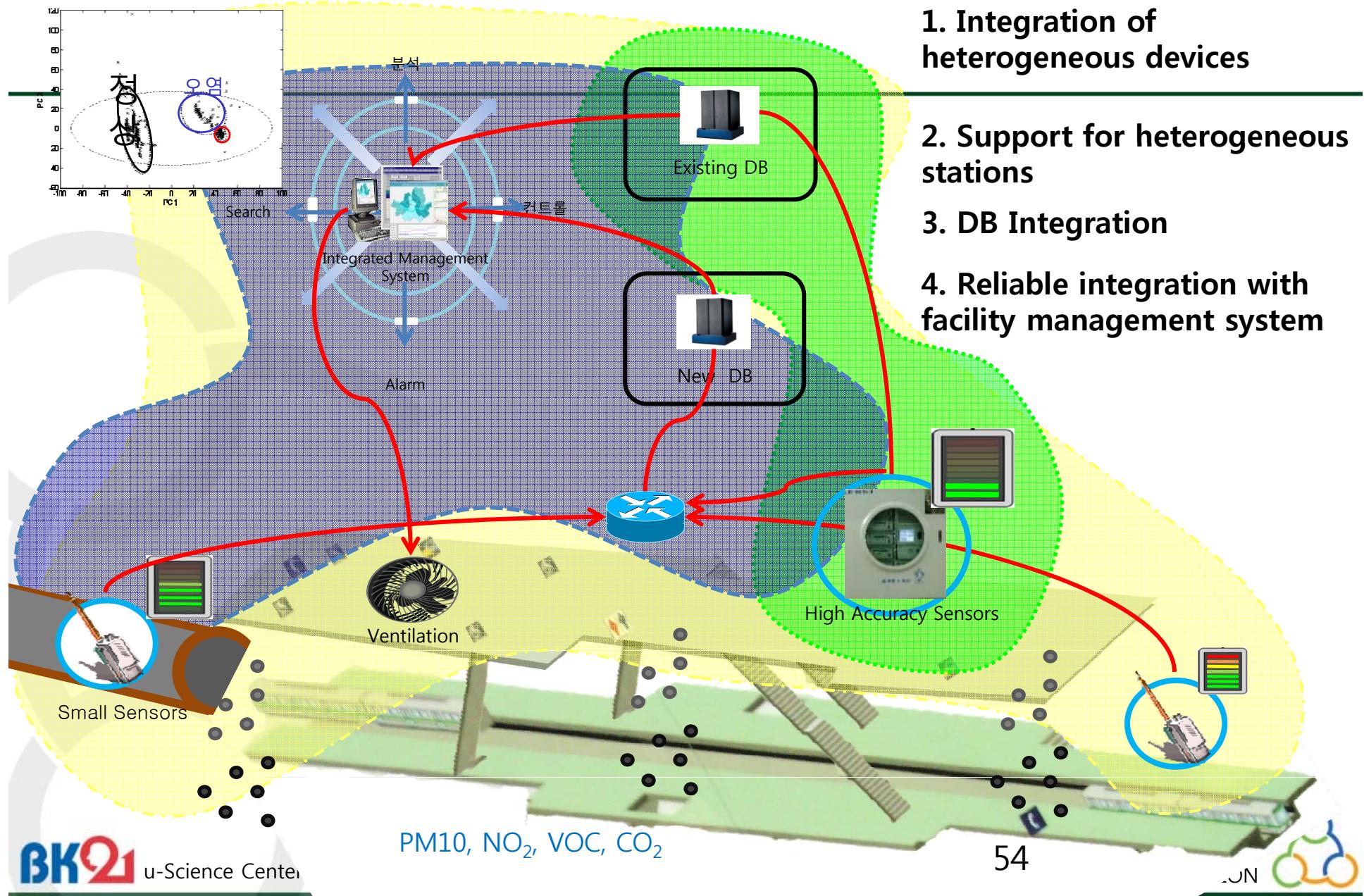
Goals

- Integration of heterogeneous devices
- Support for heterogeneous stations
- DB Integration
- Reliable integration with facility management system



AirCleaner Structure







Prototype at Jegi Station

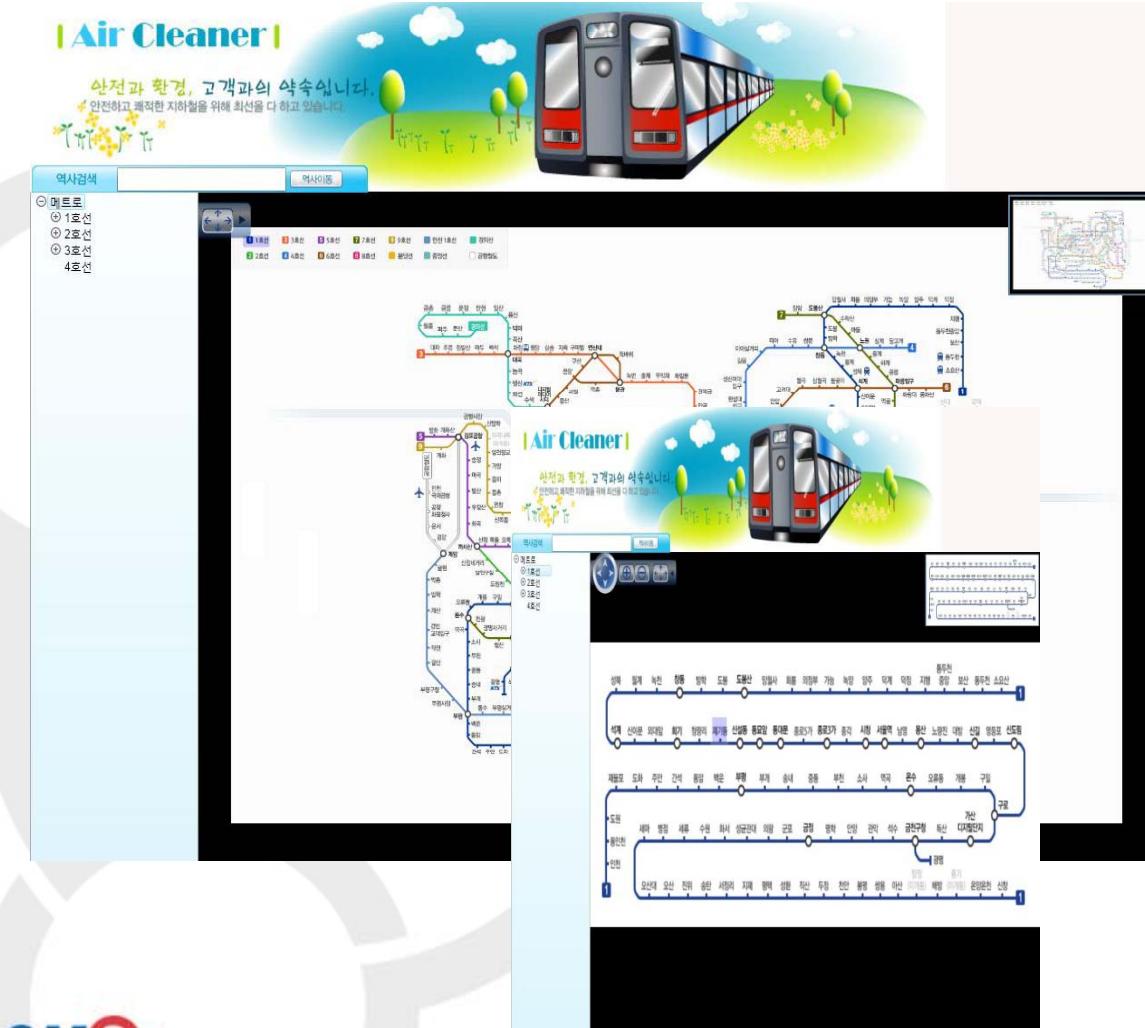
- Integrated developed technologies at the Jegi station
- Also combine industrial partner solutions into the prototype





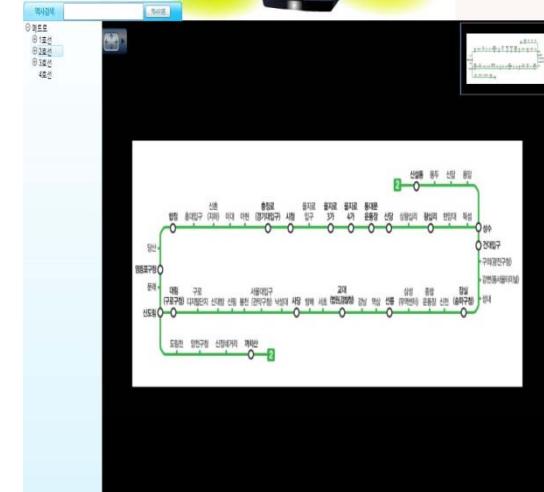
Air Cleaner!

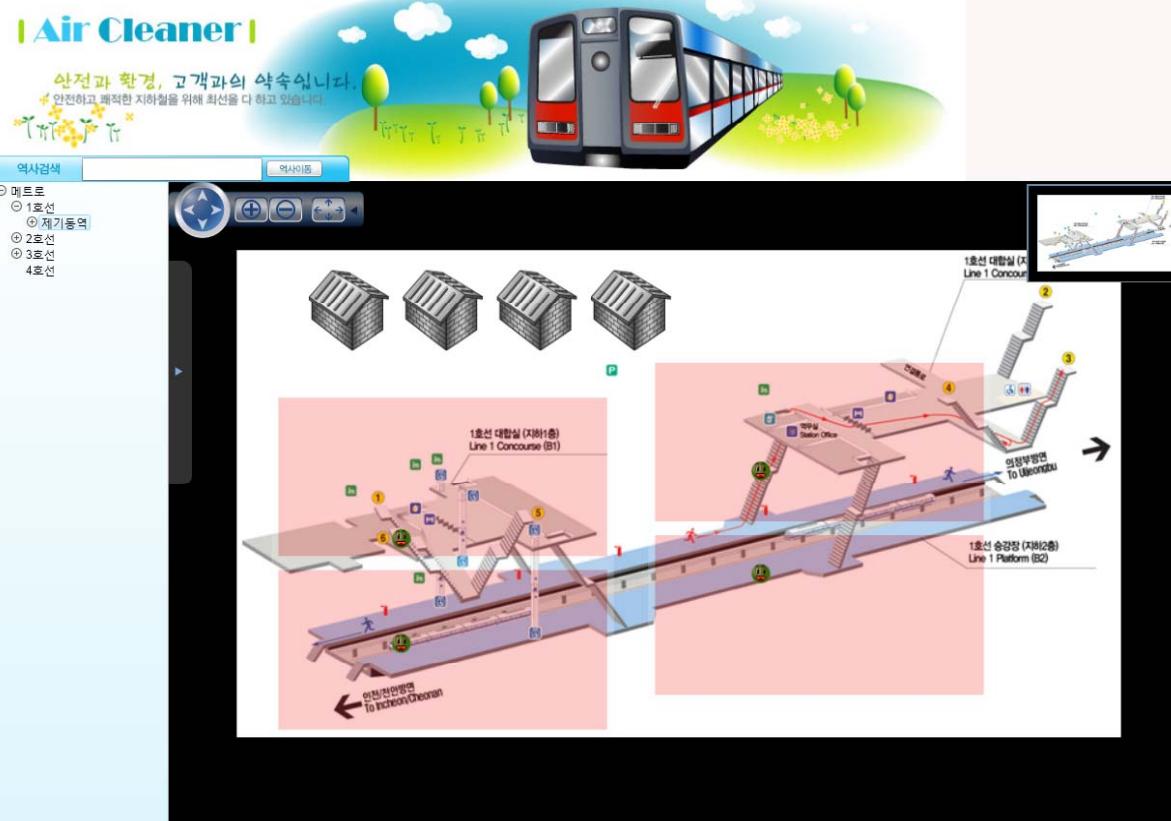
안전과 환경, 고객과의 약속입니다.
안전하고 편리한 지하철을 위해 최선을 다하고 있습니다.



Air Cleaner!

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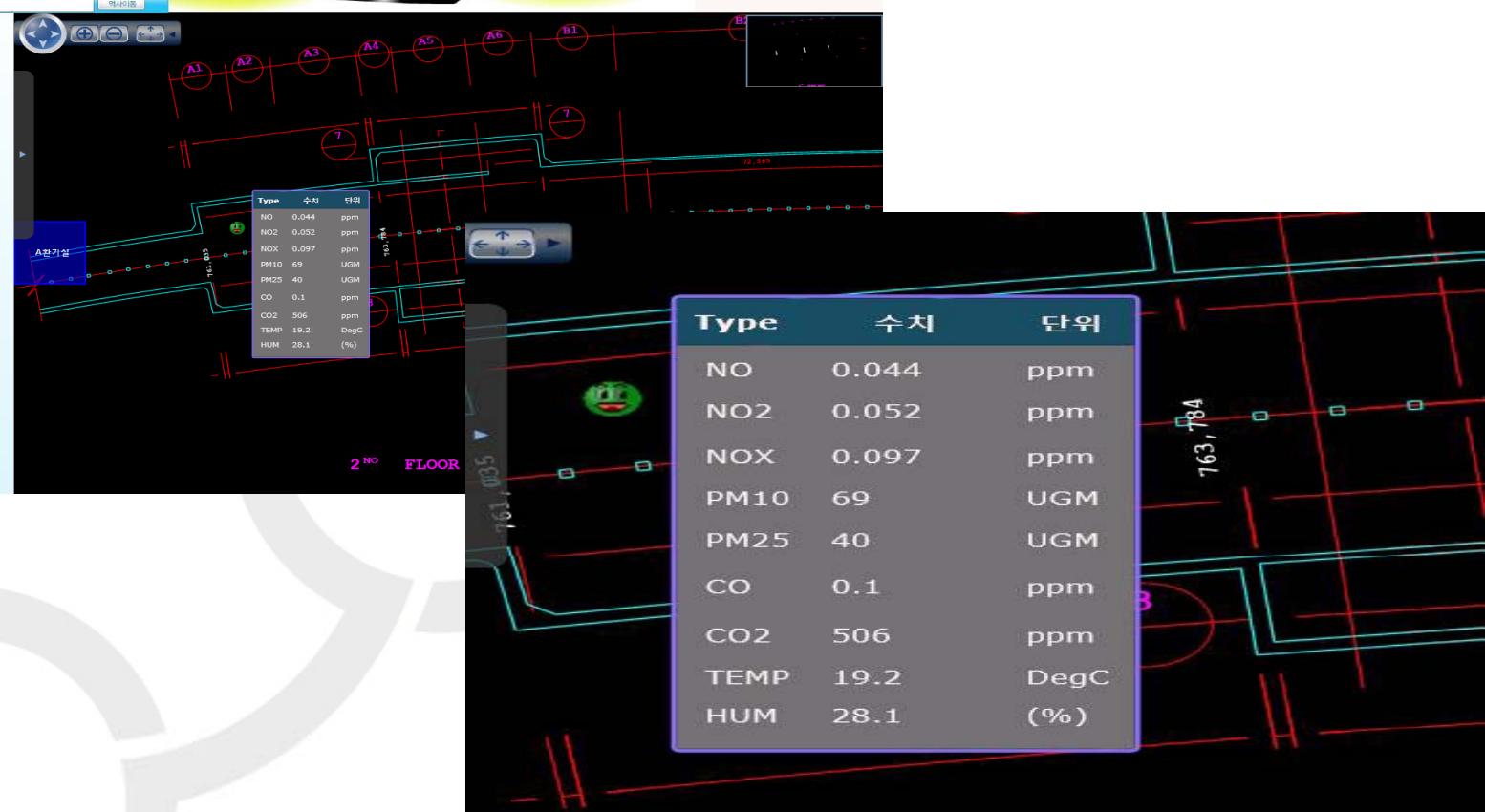


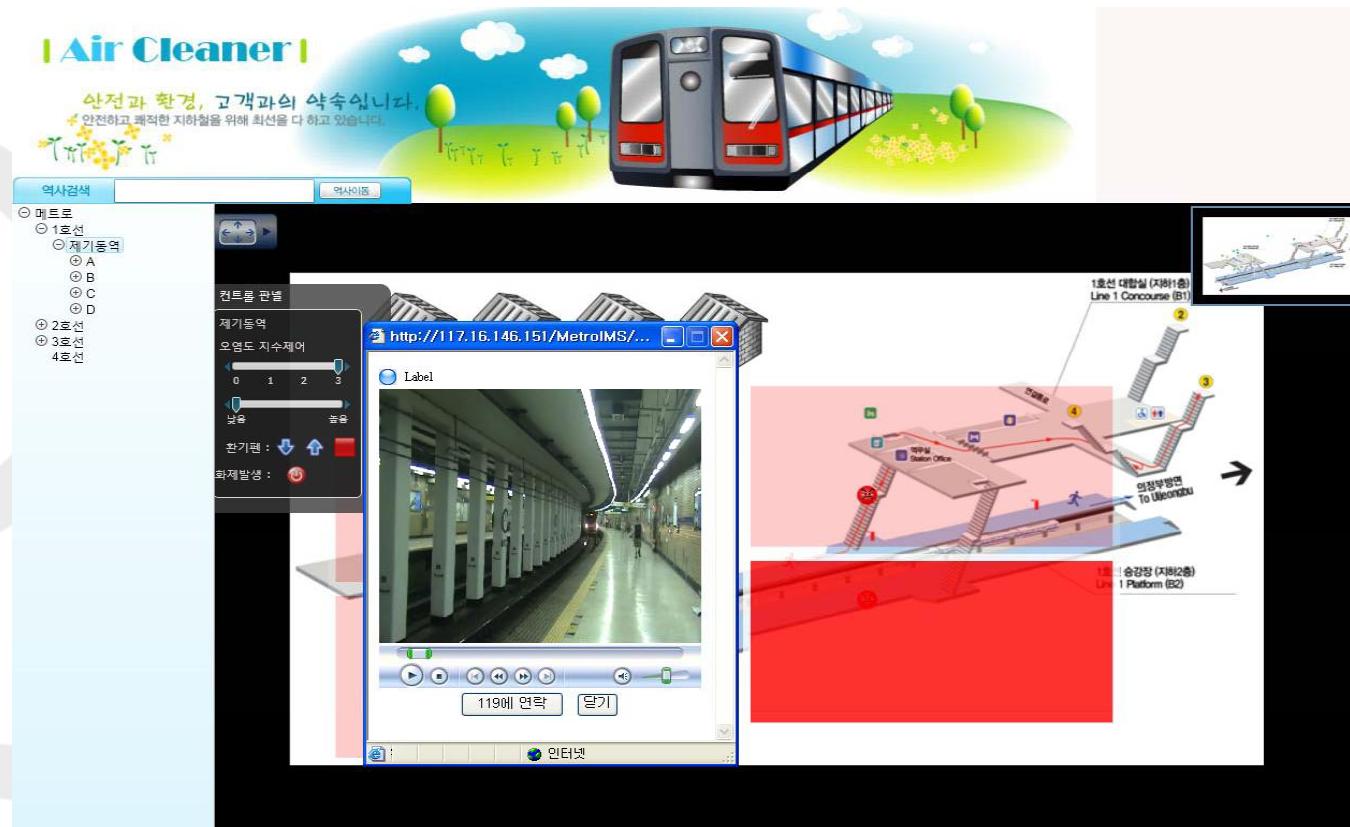


Air Cleaner

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안전하고 편리한 지하철을 위해 최선을 다하고 있습니다.

- 메트로
- 노선
- 계기동작
- A
- B
- C
- D
- 2호선
- 3호선
- 4호선



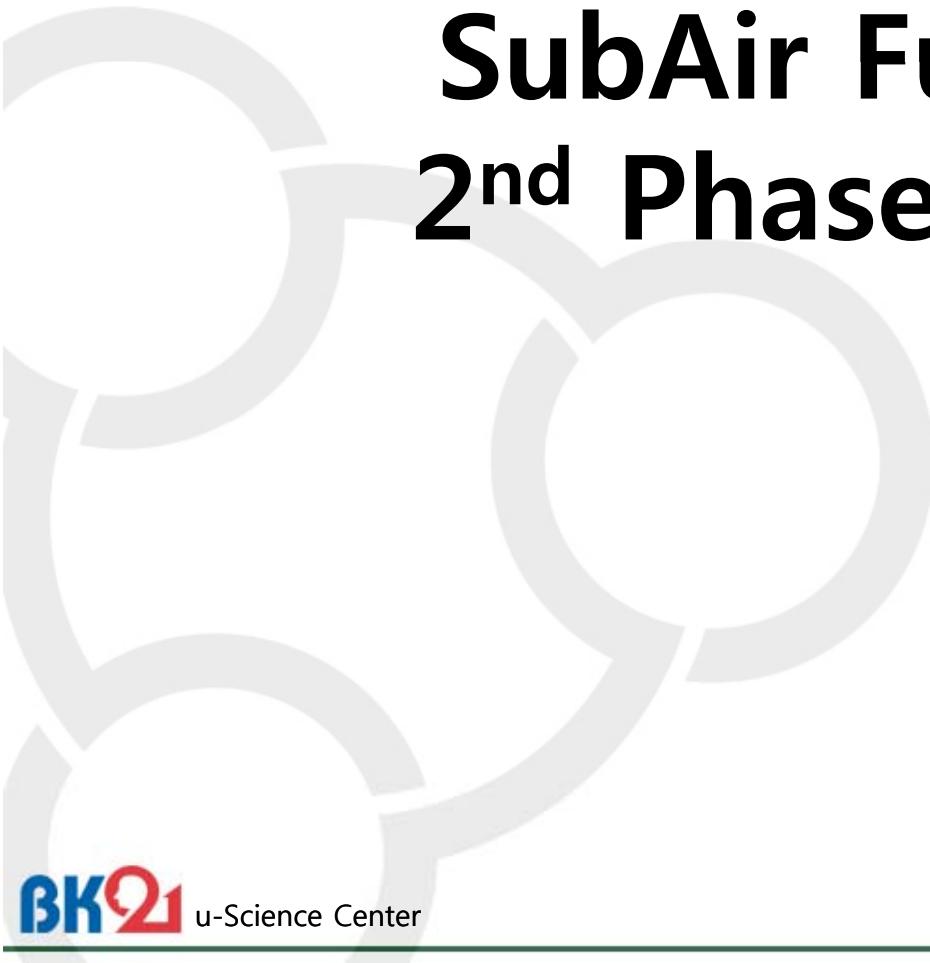




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SubAir Future Plan

2nd Phase: '10 ~ '12





Major Goals

- Develop **Theoretical Air Models** for Subways
 - Based on CFD. Tunnels are open spaces
- Develop **IAQ sensor networks**
- Develop **ventilation networks**
- Construct a **testbed site** at subway stations.
 - Three adjacent stations: Daechung, Hakyowool, Ilwon





Strategies

Industry-University
Collaboration

Green Subway

International
Collaboration

Technical R&D

Policies

Academic Societies

Korean Society of Environmental Health,
Korean Society for Atmospheric Environment,
The Korea Society for Environmental Analysis,
etc.

Government

Seoul Metro, Seoul City

Enterprise

Ventopia, Yesco, Nara Controls,
SafeTia, HCT, ECMiner etc.



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Research Center for
Indoor **Air Quality** and
Ubiquitous Safety





Motivations

- Increasing Concern for **Indoor Air Quality and Related Safety**, especially in **underground living spaces**
- **Few** Industrial and Research Technologies **Available**
- Requirements for **Grand Technology Fusion** among Environmental Technology, Automation & Control, Mechanical Engineering and Information Technology
- Requirements for **Collaboration** among Universities, Government Research Institutes and Industrial Solutions Providers **in a global scale**

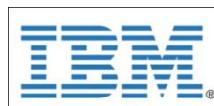




Collaborators

Foreign Companies & Research Institutes

SIEMENS



International University Partners



Government Research Institutes

KAIST



Government Research Institutes

국립환경과학원

보건환경연구원
Sihe.seoul.go.kr

Sensors



Facility Management System



(株) 雪華
ENGINEERING





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Seek for Collaboration !!!

