Design of Environment Control and Ventilation Systems for Metro Projects in Middle East Region

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Health and Safety moment

Safe by Design

Safe by Design plays an important role in Life
Agenda

- Atkins rail capabilities at a glance
- How metro projects are different from regular building projects?
- What is the environment control & ventilation systems design philosophy?
- How the Environment control & ventilation Systems design is impacted by shift of World focus to sustainability and resource optimization?
- What are the challenges to the design engineers and the solutions?
- Conclusions.
- Q&A
Atkins rail capabilities at a glance

- Largest rail consultancy in Middle East
- Involved in almost every metro project in the region
- Vast UK rail infrastructure experience
- 3500 staff worldwide experienced in planning, designing, delivering, commissioning and operating railways
How metro projects are different from regular building projects?
How metro projects are different from regular building projects?

**Metro Projects**

**Regular Building Projects**

TYPICAL 3rd TO 23rd FLOOR AREA PLAN

TYPICAL BUILDINGS IN A TOWNSHIP
Metro Vs regular building projects

Metro projects
- Extensive initial requirements
- The design aspiration ‘lead’ the project
- The engineering component is accentuated and defines limitations
- The preliminary/detail design stages are essential and extended in time
- The functionality is more important

Design

Regular Building projects
- Minimal initial requirements
- The system requirements ‘lead’ the project
- The engineering component is designed to solve the proposed solution
- The concept design/ideation stages are essential and extended in time
- The form and functionality have similar importance
How metro projects are different from regular building projects?

- Infrastructure project.
- Function of Buildings (Stations, Depots, Tunnels, Egress Points, etc.) are based on dynamics.
- Compliance of additional international standards.
- Special systems.
- Reliability, Availability, Maintainability and Safety (RAMS) Requirements.
- Design Phase difference among different stakeholders.
- Interface with many stakeholders and integration of large number of services.
Infrastructure Projects

• Depends on Government’s future planning / vision & mission statement.

• Planned based on future requirement and not just current requirements.

• Proposed to resolve the traffic congestion, reduce vehicular pollution and improve mass transport services in the area / city.

• Becomes backbone of further development of area it passes and reduce travel time.

• Public transport system.
Functions of the building

- Train movement and design headway.
- Multiple, dependant but unique and atypical buildings.
- Location and space challenges.
- Variable passenger flows.
- Architectural aspiration.
- Physical challenges: Bulky structural members, future expansion considerations.
Train speed and headway (time interval between arrival or departure of succeeding and following train in one direction)- 2 minutes or 3 minutes.

Lesser Headway

Higher Train Speed

More Passenger flow

Higher capacity of Environment Control and TVS Systems
Multiple, dependant but unique & atypical buildings

- Above ground / At Grade / Underground Stations
- Normal or Transfer / Interchange Station
- Island platform type and Side platform type
- Tunnel: Single / Dual tunnel type. Bored or Cut & Cover type
- Viaduct
- Operation Control Centre (OCC)
- Depots
Location and space challenges/variable passenger flow

- Location in city’s congested areas / busy areas / underground or over the roads.
- Space constraints for intake and exhaust air louvres.
- Vicinity of adjacent buildings / infrastructures.
- Heritage buildings / monuments in the area.
- Smoke management and noise control.
- Possible diversions of existing utilities.
Bulky Structure Design

Structure members are designed for the dynamic load of multiple train movement and vibrations resulting from repeated acceleration and braking.

Lesser Headway

Bulkier the structure members
Compliance of additional international standards

• Design compliance to NFPA130 standard.
• Battery room ventilation in compliance to NFPA 1 standard.
• IEC62485-2 standard
• RAMS requirements as per EN 50126, EN 50127 & EN 50129 standards
Special systems

- Rail system (Traction power supply, signalling and communication systems, etc.)
- Platform screen door operation system.
- Automatic fare collection system.
- Tunnel ventilation and tunnel cooling systems.
- PLC / SCADA system.
Reliability, Availability, Maintainability and Safety (RAMS) requirement

• Safety is paramount in metro design.
• Need to have redundancy of the HVAC equipment for the increased % of availability for the critical operation systems.
• HVAC system should be simple and easy to be repair in less time.
• Equipment to comply with the local and international codes and standards.
• Local maintenance and services availability.
Design Phase difference among different stakeholder’s SOW

- The information and requirement of different stakeholders are key inputs for the ECS & TVS system design.
- Due to the phase difference of different stakeholders design processes, the availability of all input data and correctness of the same data is a big challenge. Therefore lots of assumptions are to be made at initial design stage of ECS & TVS system design.
- Nos. of design iterations increases if the major change is informed by the stakeholder.
Interface with many stakeholders and integration of large number of services

- Architectural & Interior Design teams
- Landscape Design team
- Structural team
- Civil Engineering team
- Utility Design team
- Rail System Design team
- PSD and AFC Systems Design teams
- Tunnel / Trainway Alignment Design teams.

- Acoustic consultants
- Fire and Life Safety Engineer
- Electrical Services Design team
- Public Health Engineering design team
- Fire Protection system design team.
- Manufactures’ recommended solutions
- RAMS Requirement
- Construction team
What is the environment control & ventilation systems design philosophy
What is the environment control & ventilation systems design philosophy?

• Simple, safe, available, reliable, maintainable and code compliant.

• Repairable / replaceable in less time.

• Design considers the equipment delivery route for construction and future maintenance phases (especially for underground stations).

• Save energy by using free cooling when the environment enthalpy is lower than the inside design parameters.

• Design system with equipment having modular construction to reduce installation & replacement time and increase reliability.

• Customised design solutions in place of available standard design solutions.
What is the environment control & ventilation systems design philosophy?

Design considers the equipment delivery route for construction and future maintenance phases.
How the environment control and ventilation system design is impacted by shift of world focus to sustainability and resources optimisation?
How the ECS and TVS systems design are impacted by shift of world focus to sustainability and resources optimisation

- Choosing more metro projects for ease of mass transportation.
- Design based on Life Cycle Cost rather than only installation cost.
- Energy conservation.
- Use of innovative system design to reduce energy consumption, construction time, increase quality & reliability.
- Use of non-CFC based materials / systems
- Reduce rework (both in design and construction)
How the ECS and TVS systems design are impacted by shift of world focus to sustainability and resources optimisation

- Use of automation in design, construction and operation.
- Efficient and demand based operation of the system
- Focus on health and comfort (improved IAQ and temperature control)
- Use of new design tools
- Use of new construction tools and methodologies (Adopt multi-services Prefab / modular construction process to reduce the construction time on site and improve quality)
What are the challenges to the design engineers and the solutions?
What are the challenges to the design engineers and the solutions?

- Extreme weather conditions (hot, humid and dusty environment) in the Middle East region.
- Variable passenger flow during the day.
- Wastage of coolth energy with air leakages through PSDs and Station entrances.
- High density of heat inside the station and tunnel.
- Design energy efficient environment and tunnel ventilation system design.
- Safe Fire evacuation system.
- Multidisciplinary services coordination.
What are the challenges to the design engineers and the solutions?

**Challenge:** The extreme weather conditions result in large cooling requirements (so the large air-conditioning systems including chillers, air handling units, ducts, pumps), more numbers of (rows) AHU cooling coils for dehumidify the air and large filtration systems.

**Solution:** All the possibilities to be explored to reduce the ambient heat flow from outside to indoor the space in coordination with Architectural design teams.

- Reduce the Overall heat transfer co-efficient (U-value) of exposed wall / roof / glass façade without sacrificing Architectural branding.
What are the challenges to the design engineers and the solutions?

- Proper shading to be provided to all exposed sides of the glass façade.
- If possible, provide the heat recovery system from the exhaust air and precool the fresh air.
- Use the U-values based on ASHRAE 90.1 standard.
- Use the Ventilation based on ASHRAE 62.1 standard.
- Provide the high efficiency sand trap louvres.
- Use the filtration system based on ASHRAE 52.2 standard.
What are the challenges to the design engineers and the solutions?

**Challenge:** Variable passenger flow during the day which also varies station to station.

**Solution:** The average passenger flow to be determined for each station based on it’s location.

- Pedestrian modeling software to be used to determine the peak and average passenger flow and fluctuation in the passenger profile during the day for to use in heat gain calculation for Environment Control system sizing.

- Peak flow to be considered for Station space sizing while Average passenger flow to be considered for ECS system sizing.
**Challenge:** Wastage of coolth energy with air leakages through PSDs and Station entrances

**Solution:** Eliminate / reduce wastage of coolth energy with air leakages through PSDs and Station entrances by:

- Establish the maximum air leakage (infiltration / exfiltration) though the Platform Screen Doors based on dwell time and the train headway by Computation Fluid Dynamic (CFD) model.
- Air pressurise the Platforms / use the door brushes to avoid the hot air rushing in from tunnel / outside.
- Air curtains for the Station entrance doors.
What are the challenges to the design engineers and the solutions?

**Challenge:** High density of heat inside the station.

**Solution:** Coordinate with other teams and collect all correct inputs contributing to the heat dissipation inside the station / depot including:

- **Lighting:** Promote LED / Compact Fluorescent Lamp lighting and natural sky lighting.
- **The equipment heat dissipation should be based on inputs from Rail system and other stakeholder system inputs.**
- **Ensure to get the maximum allowed temperature for the equipment.**
- **Occupancy:** Correct passenger flow modeling based on reasonable & realistic assumption.
What are the challenges to the design engineers and the solutions?

Challenge: Design energy efficient environment and tunnel ventilation system design.

Solution: To find out the solutions to the above challenge, the following points need to be understood:

• What is “energy efficiency”?
• How to measure it?
What are the challenges to the design engineers and the solutions?

What is energy efficiency?

“Using less energy to provide the same services / outputs”

(Source unknown)
What are the challenges to the design engineers and the solutions?

How to measure the energy efficiency?

Comparing the Services Design to the following standards:

- US Green Building Council’s LEED rating (Leadership in Energy & Environmental Design)
- Dubai Green Building Regulation
- Abu Dhabi’s “Estidama” Pearl rating
- Qatar’s Global Sustainability Assessment System (GSAS) rating.
- UK’s Building Research Establishment Environmental Assessment Method (BREEAM) rating
What are the challenges to the design engineers and the solutions?

**Challenge:** Design energy efficient environment system (ECS) and tunnel ventilation system (TVS) design.

**Solution:** The ECS and TVS system need to design considering the Project Life Cycle cost (Capex + Opex) and not only Capex.

- Use less energy
- Use efficiently
- Use renewable energy

- Use the free cooling when the ambient temperatures (enthalpy) is less than the indoor temperature (enthalpy).*
- Design and specify energy efficient equipment / system.
- Design the ECS and TVS system with all equipment and capable to operate on demand based requirements.
What are the challenges to the design engineers and the solutions?

- CO₂ sensors to control fresh air requirement.
- Occupancy sensors to automatically dimming / switch off lighting (Safety & security perception / concerns)
- Occupancy sensor to start / stop the travellators & escalators.

• Use of Green Energy.*
• BIM 3D coordinated design*
• Third party testing and commissioning and re-balancing of ECS & TVS after 3 years of installation.*
What are the challenges to the design engineers and the solutions?

Use of Free cooling during lower ambient temperature (Low enthalpy) than the indoor temperature (enthalpy)

- In normal operation mode: fresh air 2 to 10% depending upon occupancy.

- In open mode (when ambient temperature is lower than designed temperature): Fresh air 100%
What are the challenges to the design engineers and the solutions?

Use of Free cooling during lower ambient temperature (Low enthalpy) than the indoor temperature (enthalpy)

- Tunnel cooling AHU on / off and ventilation fan speed controlled by tunnel & ambient temperature to maximise the free cooling from ambient air by Train push-pull effect.
- TVS Fan speed modulation based on required ventilation air flow to maintain the tunnel temperature below the threshold limit.
What are the challenges to the design engineers and the solutions?

Use of Green Energy

• Integration of Solar PV cells in the Station and Depot roofs for Power generation and direct use in the buildings or power grid feeding (if allowed)

• Use of Solar powered emergency lighting for Viaduct

• Use of Solar powered LED lighting for the Station entrances, Depots and surrounding landscape areas
What are the challenges to the design engineers and the solutions?

Use of BIM 3D Coordinated Design

What is BIM?

BIM stands for Building Information Modeling:

- **Building**
- **Information**: a linked database of all the components within the model
- **Modeling**: a graphical representation of all the components in the model shown their correct location in space. Building information modeling extends this beyond 3D, augmenting the three primary spatial dimensions (width, height and depth) with time as the fourth dimension (4D) and cost as the fifth (5D)
What are the challenges to the design engineers and the solutions?

Use of BIM 3D Coordinated Design

Design Optimisation:

• Dynamic link between model and data/calculations enables a number of design options to be quickly compared

• Comparisons can include minimum energy usage, lowest first cost, lowest embodied carbon etc

• Depending on project priorities final design can incorporate a mix of optimised systems depending on project priorities
What are the challenges to the design engineers and the solutions?

Use of BIM 3D Coordinated Design
Better Coordinated Services Design
What are the challenges to the design engineers and the solutions?

Third party testing and commissioning and re-balancing of ECS and TVS after 3 years of installation and operation.

- MEP services to be tested and commissioned by Third Party within the tolerance limits specified in codes and standards.

- The ECS and TVS need to re-balanced after 3 years of operation by this time the Actual cooling requirement will be established and the Air-conditioning equipment could be set for the optimum energy efficiency
Conclusions
Conclusions

- Metro stations and depots are highly complex, energy intensive buildings.
- Energy reduction strategies are an essential component of meeting sustainability requirements.
- Use of Solar Energy could reduce the operational cost significantly.
- Middle East can play a key role in championing best practice.
Due to limited time allowed, complicated topics such as Tunnel Ventilation system design, ECS & TVS operation modes in different Fire scenarios, etc. are not covered in this presentation. In case anybody is interested in these topics, please contact me at Pramodkumar.jha@atkinsglobal.com
Q&A
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