Computer simulation – Theory and Application

SB10 SEA – 5th May 2010

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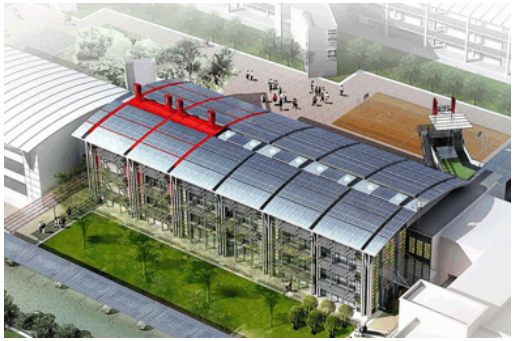
High Performance Building

What do we need to do building simulation?

- Low-energy and sustainable
- Challenges of low-energy design
- How do you know what is being designed will work?
- Quantify, Optimise and Verify
  - You need to quantify how the building will perform
  - How can you optimise building performance



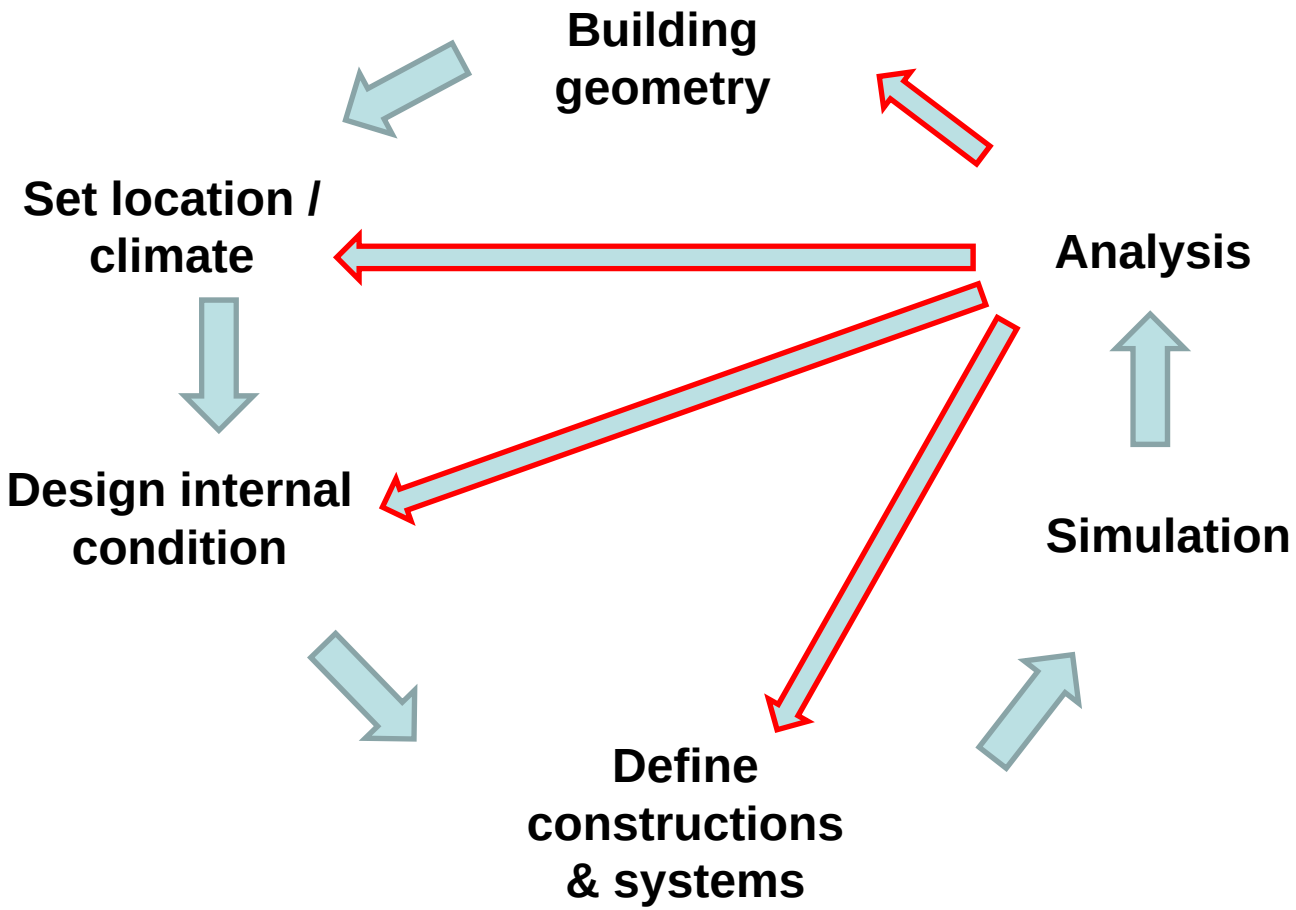
"If you cannot measure it, you cannot improve it." — Lord Kelvin

Theory

- **Quite literally buildings are a balancing act of:**

    - Heat
    - Moisture
    - Air flow and pressure
    - Daylight and solar

Process of building simulation



Type of simulation

Energy/Carbon

Thermal/Energy/Solar simulation

- BEIT (Building Energy Intensity Tool)
- IES VE
- Energy 10
- Design Builder/Energy Plus
- TAS
- Equest
- Trnsys
- BSim
- many more……

Comfort/Indoor Environment

Lighting simulation

- Radiance
- Dialux
- Rayfront
- Ecotect
- many more….

Air Flow simulation

- Zonal Model
    - MacroFlo
    - Airnet (EnergyPlus)
- CFD
    - Fluent
    - CFX
    - StarCD
    - MicroFlo
    - many more….

Acoutics simulation

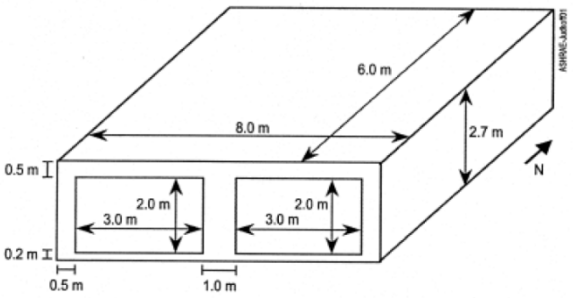
Validation of energy simulation software

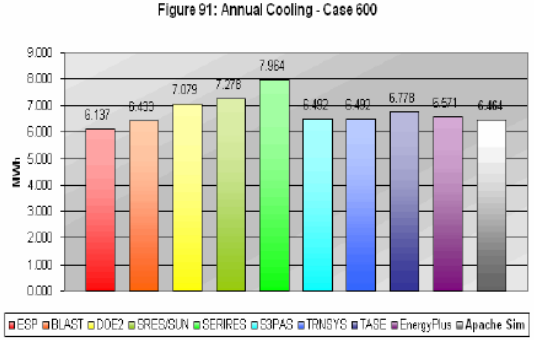
ASHRAE 140.1 Bestest

CIBSE TM33

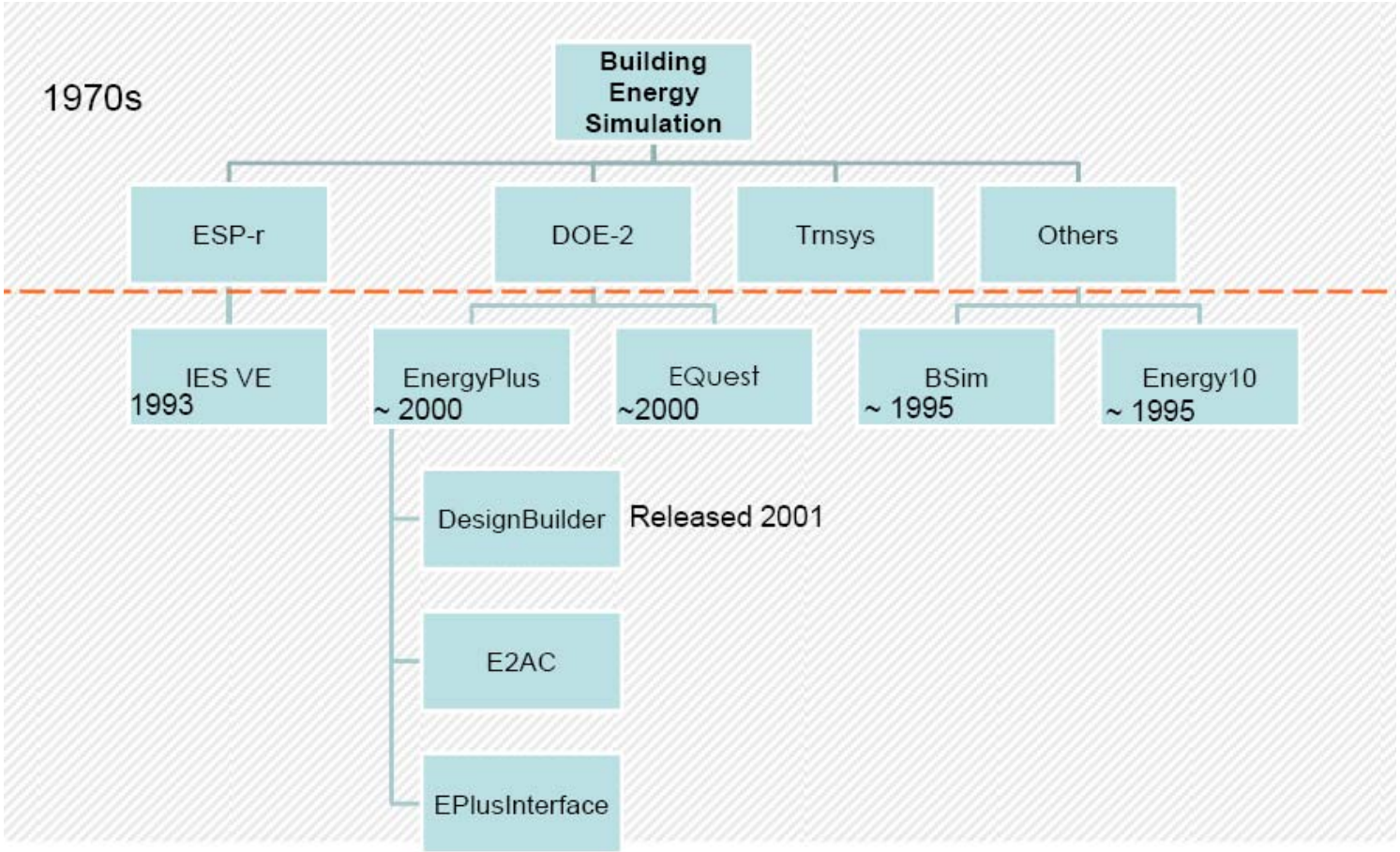
Tested on:
- Orientation
- Glazing properties
- Fabric (low/high mass)
- Emissivity
- Solar absorptance
- Internal gains
- Infiltration
- Heating and cooling
- Night ventilation
- Sunspace

Measured on:
- Heating load
- Cooling load
- Air temperature
- Incident solar radiation
- Direct transmitted solar gain



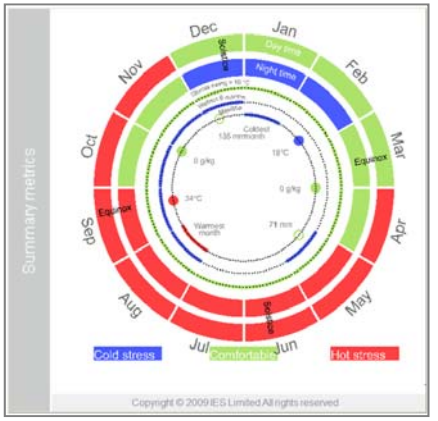


Brief history of building energy simulation



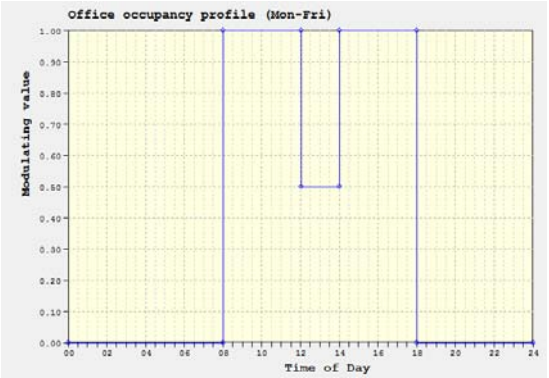
Thermal/Energy simulation

- **Climate**
  - Historic hourly weather data



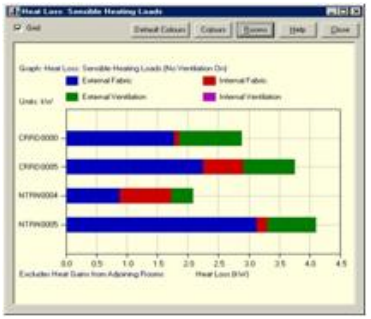
- **Heat transfer**
  - conduction
  - convection
  - radiation
  - heat transfer through air movement in systems (i.e. HVAC)
  - causal gains

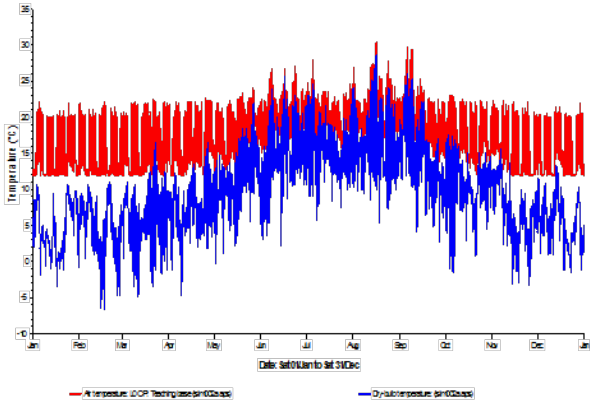
- **Schedule/Profile/Control**

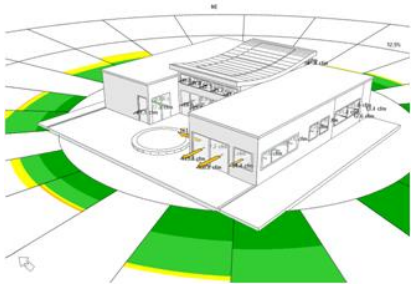


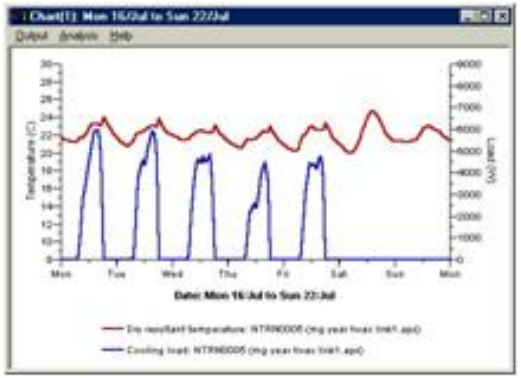
Thermal/Energy simulation

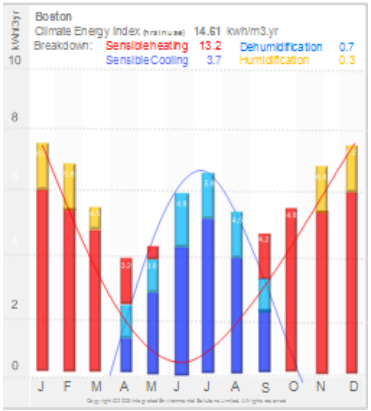
- Thermal performance analysis
- Building fabric design
- Occupant comfort analysis
- Natural ventilation studies
- Facade analysis
- Energy consumption prediction
- Plant design and sizing
- Detail HVAC system analysis
- Mixed mode design
- Carbon emissions

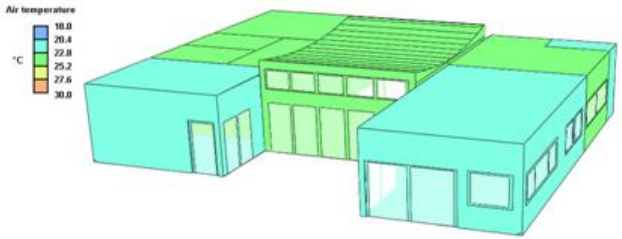








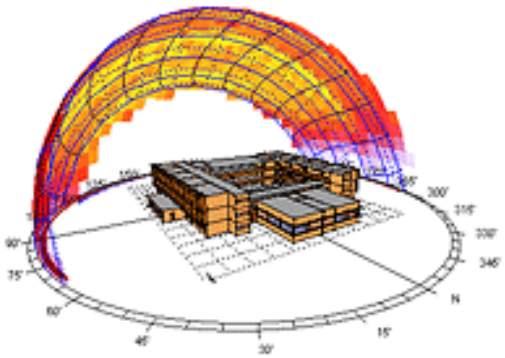


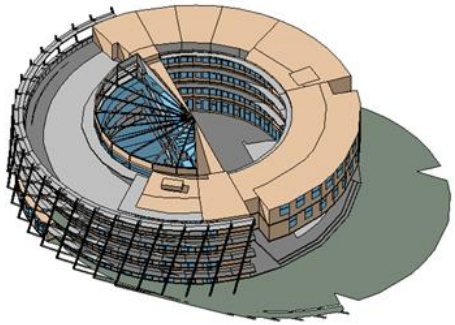


Solar simulation

Use solar tracing technique for isolation through multizones.

- **Solar shading analysis.**
- **Shading device optimisation.**
- **Urban development shading analysis.**
- **Work with dynamic thermal simulation for more accurate solar gain calculation.**





Lighting simulation

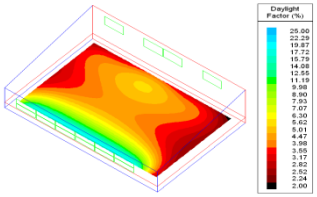
Two main common method for lighting simulation

- **Radiosity simulation**
- **Ray-tracing simulation**

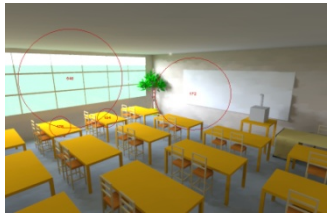
<u>Sky model commonly used:</u>
- CIE overcast sky/clear sky for daylight factor simulation.

- Sunny day for glare analysis.

<u>Radiosity simulation</u>
- Space is divided into mesh of pataches.
- Each patch is considered as a Lambertian reflector, i.e. constant luminance, independent of the viewing direction.



<u>Ray-tracing simulation</u>
-Tracing the direction of rays.
- Generate rendering image and view results at any point on the image.
- Generate snap-shot of lighting assessment based on time, date and sky condition.
- Can be time consuming!



Lighting simulation

Illuminance (Brightness)

Lux level

Daylight Factor (DF)

Daylight factor is a ratio of light quantity indoor to the available light outside.
Daylight factors are provided via overcast sky conditions.

$$DF = (E_{internal} / E_{external}) \times 100\%$$

Glare analysis

Guth Visual Comfort Probility (VCP) (developed for electrical lighting)

- **> 70% VCP is deem acceptable comfort**

Glare Indices (CIE, Unified, etc.) (developed for electrical lighting)

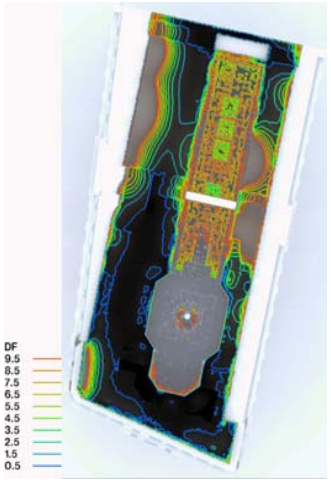
- **< 19 ~ 22 is deem acceptable comfort.**

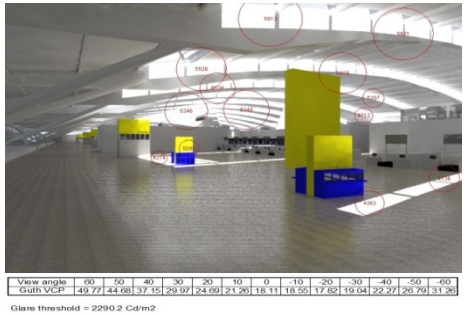
Lumens intensity (cd/m2)

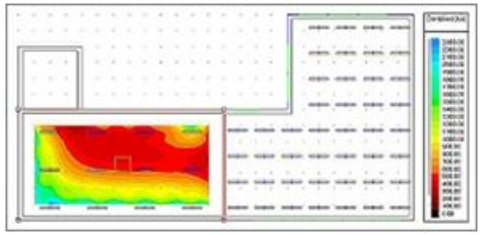
- **> 2,000 cd/m2 too much glare**
- **< 1,000 cd/m2 acceptable in a typically lit room.**

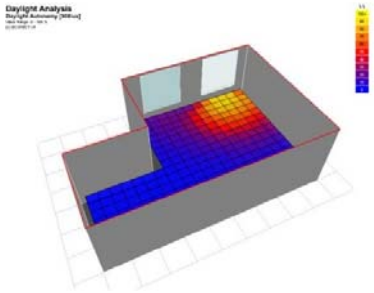
Lighting simulation

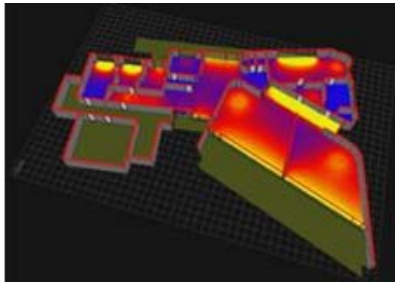
- Daylight analysis.
- Artificial lighting design and analysis.
- Daylight dimming switch modelling.
- Glare analysis.
- Generation of photo-realistic image of building prior to construction.
- Use manufacturer's luminance data.

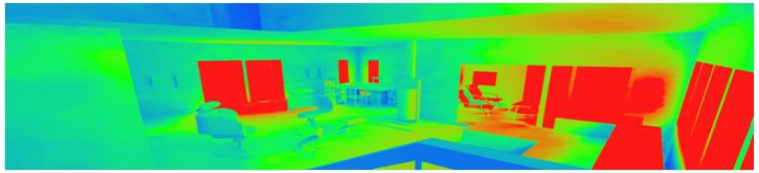












Airflow simulation

Zonal air flow simulation

- Simulation to be coupled with thermal simulation.
- Simulate air flow based on pressure difference, temperature buoyancy etc.
- Some can do bi-directional air flow.

Advantages: Calculate hourly thermal condition inside building.

Disadvantages: Do not take in account building geometry or direction.

Computational Fluid Dynamic (CFD)

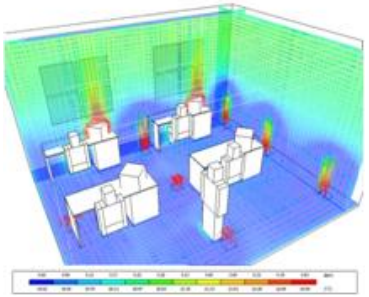
- Break down room/zone into smaller volume/mesh.
- New technique to model fluid movement in the construction industry.

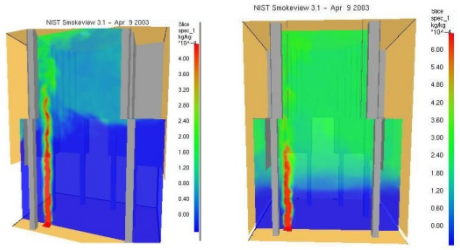
Advantages:
- Represent air flow more accurately.
- Effects of building shape taken into account.
- Visual results.

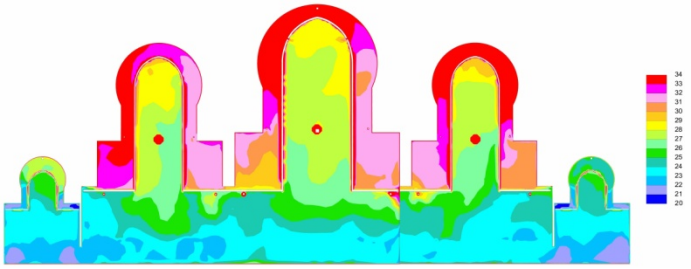
Disadvantages:
- Commonly done in steady state (i.e. selected moment).
- Need to define boundary conditions properly.
- Very time consuming for complex building.

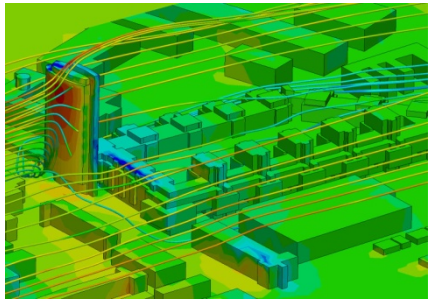
Airflow simulation

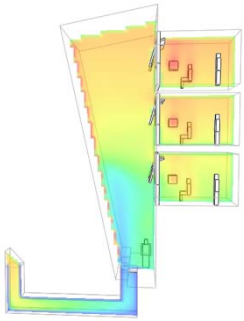
- Natural ventilation/mixed mode modelling.
- Predicting thermal distribution within rooms to prevent hot/cold spots.
- Optimising locations of HVAC system supply grille.
- Pedestrian comfort analysis for urban planning.
- Fire and smoke modelling.

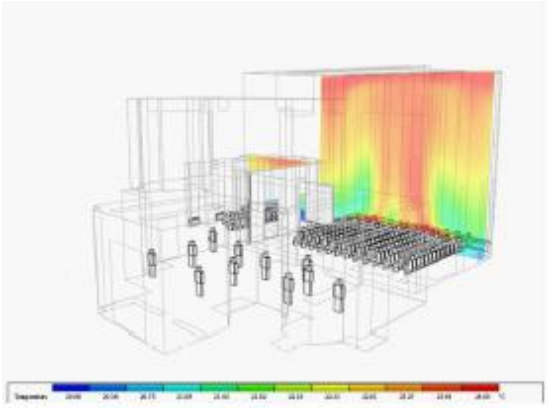


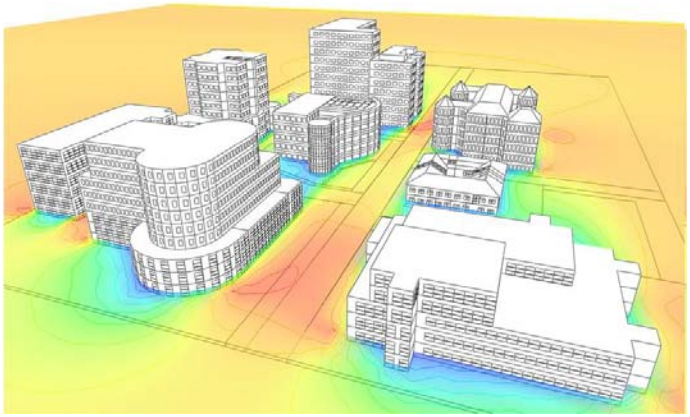










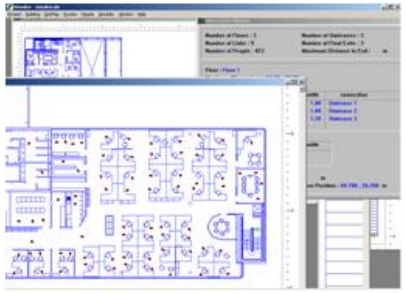


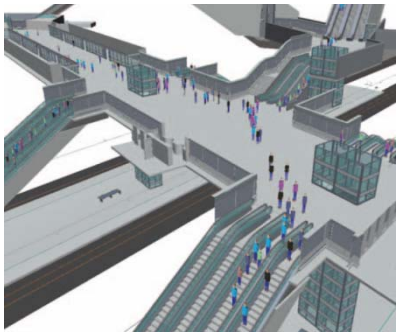
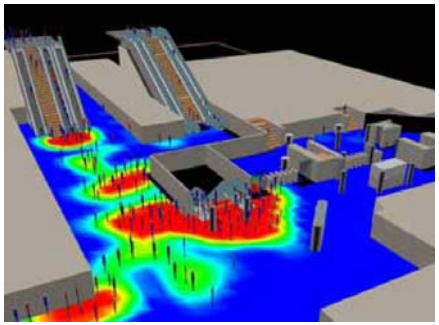
Other simulations

Egress simulation

Prediction of occupant movement within the building under normal condition or emergency situation.

- **Steps**
- **Simulex**



Green Building Index compliance

The following credit in the GBI rating system will/may require involvement of computer simulation.

Non Residential New Construction (NRNC)

- EE4 Renewable Energy	5 points
- EE5 Advanced EE Performance	15 points
- EQ6 Thermal Comfort: Design & Controllability of Systems	2 points
- EQ7 Air Change Effectiveness	1 point
- EQ8 Daylighting	2 points
- EQ9 Daylight Glare Control	1 point
- EQ10 Electric Lighting Levels	1 point
- EQ13 Internal Noise Levels	1 point

Residential New Construction (RNC)

- EE2 Renewable Energy	5 points
- EQ2 Daylighting	2 points

greenbuildingindex

Conclusion

- **Overall simulations are used to analyse building design.**

- **Help designer to understand how their design will perform with low initial cost.**

- **Optimise building design for better sustainability potential.**

- **Model is still just a model. It is just a prediction of the building performance and may vary in reality.**

- **Factors affecting reality results:**
    - **External weather**
    - **Construction quality**
    - **Operation**
    - **and many uncertainties….**

Thank you for your attention!!

Any question??

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