Hybrid modelling for the examination of heat and smoke spread in complex buildings

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Cause of fire deaths?

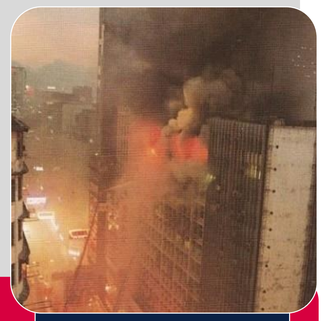
Total building system affects fire growth and spread[4]

MGM Grand Hotel, USA, 1980

- *85 fatalities*

First Interstate Bank, USA, 1988

- *$50m damage*



Garley Building, HK, 1995

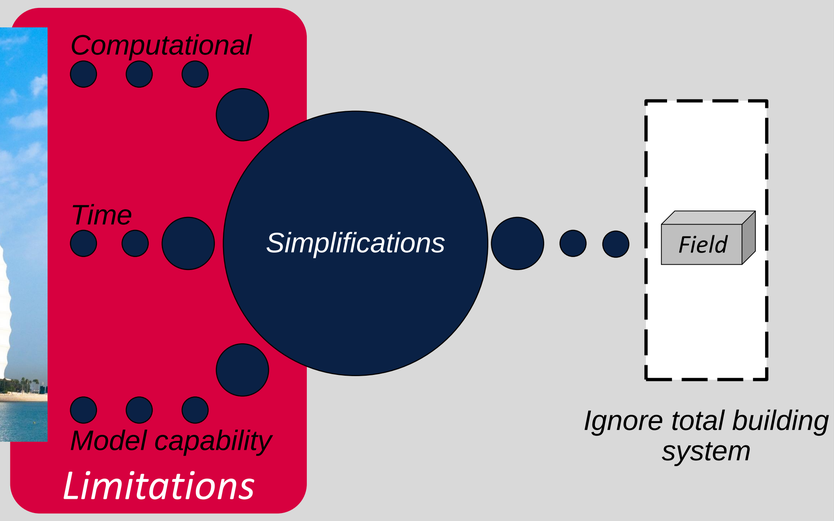
- *40 fatalities*

Fire fatalities which occur outside of the room of fire origin

UK[1]	US[2]	Australia[3]
Over 50%		

"Does the analysis method address these risks?"

Typical fire safety engineering modelling paradigm



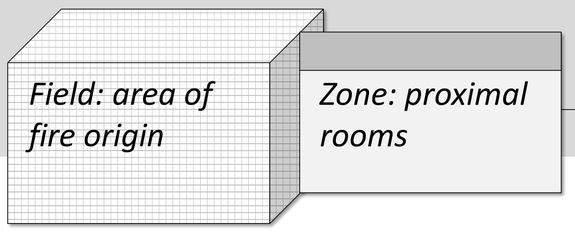
Ignore total building system

"How can we overcome the limitations but address the risk?"

Use coupled hybrid modelling

Couple different fire and smoke models together

- Exchange information at the model interfaces
- Interface conditions: pressure, fluxes, temperature, density, etc.



Computational cost

Expanding the coupled hybrid capability of Fire Dynamics Simulator (FDS)

1D network model in FDS Version 5.5 onwards

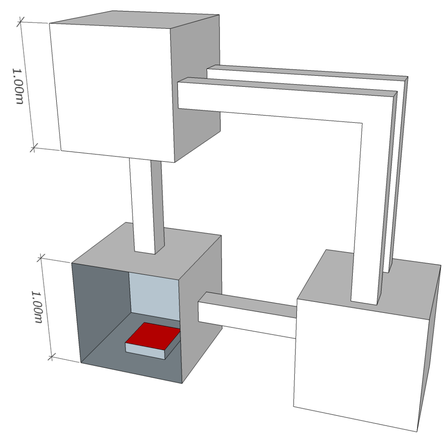
- No mass storage
- No transient species or energy conservation
- No heat loss or transfer
- No node volume or filling time

Project has implemented expanded capability

- HVAC_MASS_TRANSPORT available from FDS Version 6.5.2 onwards, includes:
  - *Mass is stored in network model*
  - *Transient transport species, energy and mass*
- Future updates will include:
  - *Heat loss and heat transfer between the field and network model*
  - *Expanded capability to enable nodes to act as rooms and ducts to act as corridors*

Under the hood of HVAC_MASS_TRANSPORT…

- Explicit Runge-Kutta conservation of species and energy
- Finite difference Euler method with Godunov upwinding scheme
- Courant-Friedrichs-Lewy met via substepping of FDS time step
- Numerically verified in accordance with ASTM E 1355
- Forms part of the NIST continuous integration fds-smv project



Sketch of planned experimental set up

Next steps for project

- Further expand HVAC_MASS_TRANSPORT
- Experiments to validate hybrid model capability and to investigate the two-way interaction of a total building system and a fire
- Examine how changes in natural and mechanical ventilation in the far field affect the fire

1. Department for Communities and Local Government, 2013. Fire Statistics: Great Britain April 2012 to March 2013.
2. Ahrens, M., 2016. Home structure fires, Quincy, MA: National Fire Protection Association.
3. Hasofer, A.M. & Thomas, I., 2006. Analysis of fatalities and injuries in building fire statistics. Fire Safety Journal, 41(1), pp.2–14.
4. Quintiere, J. & Wade, C., 2016. "Compartment Fire Modeling," in SFPE Handbook of Fire Protection Engineering, pp. 981–995

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