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Fire risk modeling of 6- and 12-storey wood buildings

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Outline

- NEWBuilDS project objective
- CUrisk description and recent developments under NEWBuilDS project
- Full-scale room fire tests on combustible constructions
- FII project: Fire risk modeling of 6- and 12-storey wood buildings

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NEWBuilDS Project Objectives

- Theme 3: Project T3–1–C7: Fire Risk Analysis
  - to develop new and modify existing CUrisk sub-models for integration into CUrisk
  - evaluate fire risks in mid-rise or high-rise wood/hybrid buildings.
  - Use of findings from Project T3–3–C7 (Fire Behaviour of Cross Laminated Timber Panels)

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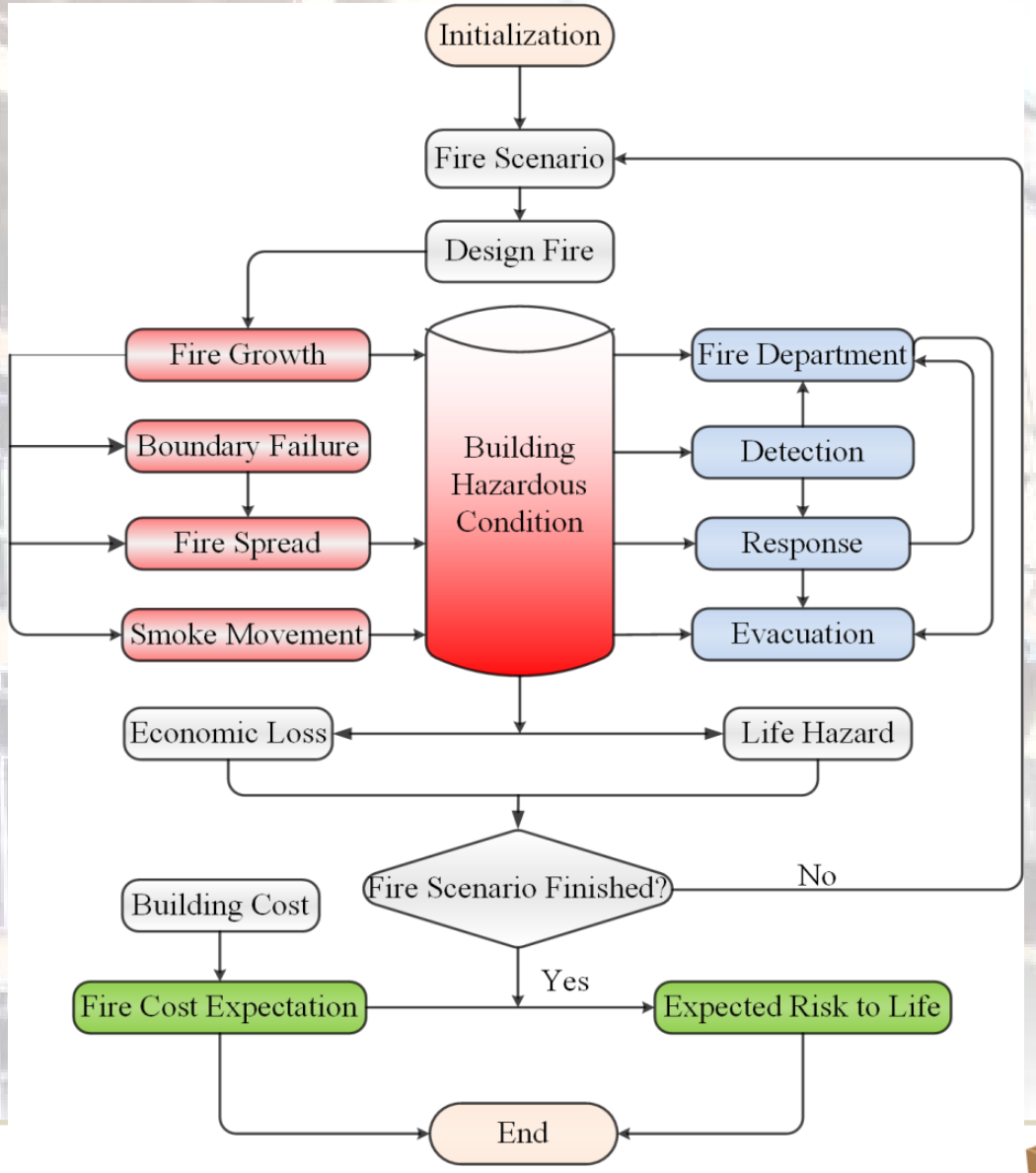
CUrisk - a fire risk analysis model



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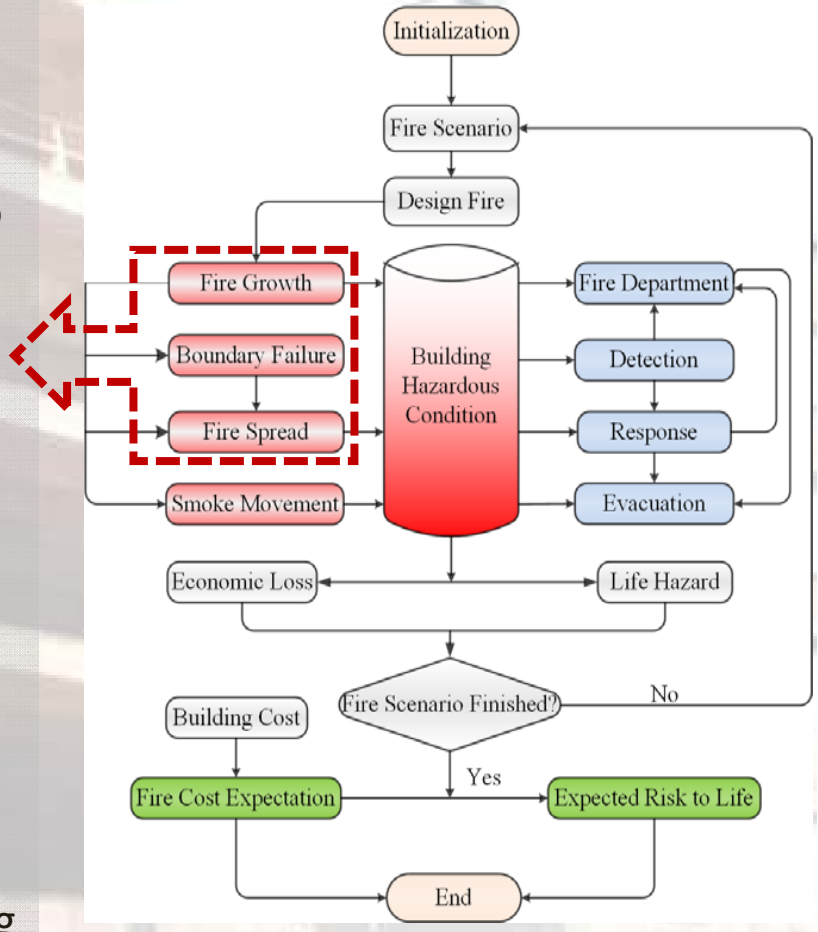
CUrisk-recent developments

- The Fire Growth submodel
  - creation of design fire in combustible constructions
  - contribution of timber structure to room fire severity
- The Barrier Failure submodel
  - based on heat transfer and component response in fire
  - consider any fire severity and various fire-separating fire barriers
- The Fire Spread submodel
  - Based on Bayesian network
  - probability of fire spread in all the compartments of a building versus time



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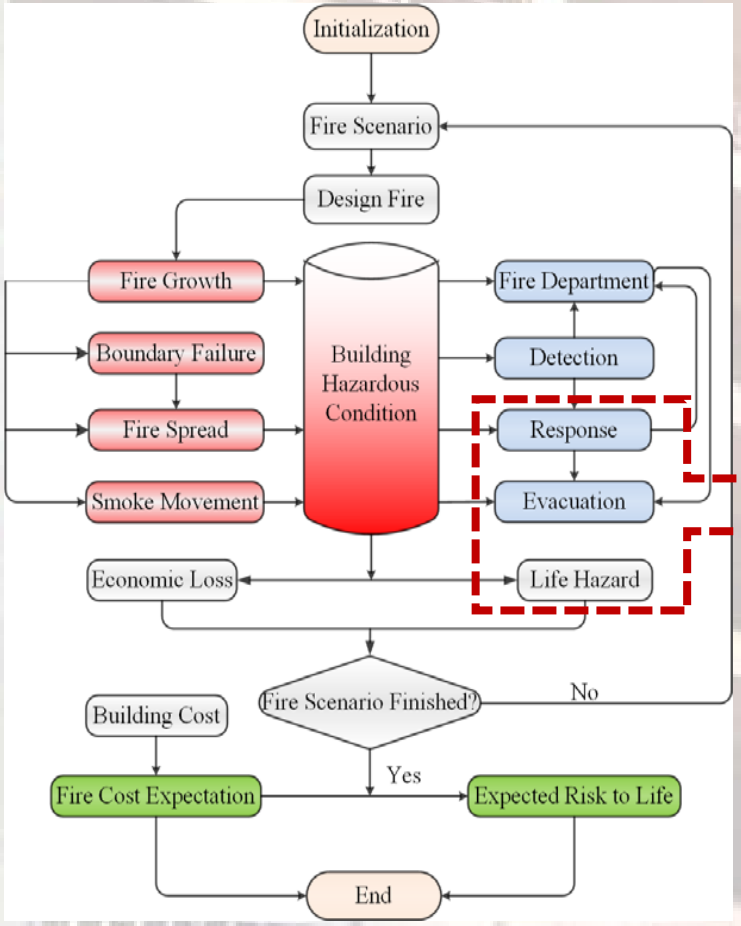
CUrisk-recent developments



- The Occupant Response submodel
- The Occupant Evacuation submodel
  - based on Monte Carlo method
  - Random variables: Gender, Age, Speed, Exit selection, Pre-evacuation time, Distance to be traveled to exit the initial compartment
- The Life Hazard submodel
  - Considers probability of death due to fire spread
  - Produces statistical results of Monte Carlo simulations

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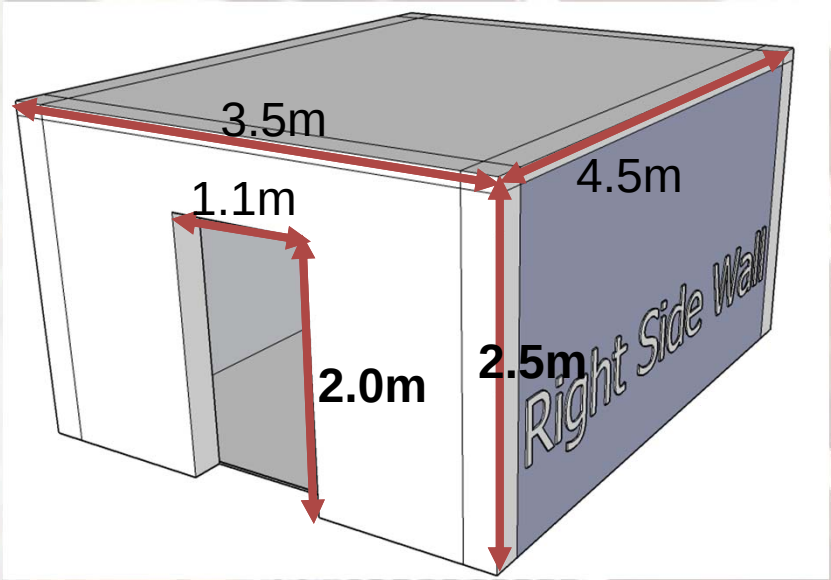
Full scale room fire tests



- **Eleven** (11) full scale room fire tests were conducted
  - Fully protected and unprotected CLT rooms (5 tests)
  - Partially protected CLT rooms (3 tests)
  - Protected light timber/steel frame rooms (3 tests)
- Fire source: **propane** or real **furniture** sets

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Summary of test findings

- Natural fires could be very different than the standard fire
- Room temperature is not affected by the area of exposed timber panels
  - ranging 1000 to 1200 Celsius during fully developed period
- Fully unprotected mass-timber-panel room (e.g. CLT):
  - Higher fire growth rate >> ultra-fast
  - contribute to the room fire significantly:

    >60% of total heat release from CLT panels
  - Almost 2/3 of the heat release occurred outside the room during the fully developed period

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Summary of test findings

- Area of exposed mass timber panels (e.g. CLT) affect fire intensity:
  - The fire in the room with two facing exposed CLT walls contributes more to room fire than the room with two adjacent exposed walls
  - With only one CLT wall exposed in the room, the fire intensity is similar to the fully protected room
- Delamination of CLT panels increase charring rates and fire intensity (even a 2nd flashover)
- Wood studs in light timber frame walls (one layer gypsum board protection) contribute to fire during the decay phase

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Summary of test findings

- One layer gypsum board protection on light frame walls
  - stayed in place more than 60 min on LTF walls
  - collapsed shortly after 20 min due to deflection of steel studs on LSF walls
- Timber charring rates during the real fire could be much higher than the standard charring rate of 0.65 mm/min
  - CLT in Unprotected CLT room: 1 mm/min in 60 minutes period
  - Wood studs in LTF room: 1.2 mm/min in 30 mm charring depth

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FII Project: Case Studies

- **Funding Agency:** Forestry Innovation Investment (BC) through its Wood First Program
- **Research Network:** NEWBuildS (Network for Engineered Wood-based Building Systems)
- **Carleton University:** Dr. Xia Zhang & Prof. George Hadjisophocleous
- **CHM Fire Consultants Ltd:** Dr. Jim Mehaffey

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Objectives of the Study - 1

- Use CUrisk to assess the risk-to-life in six- and twelve-storey residential and office buildings
  - Six-storey code compliant buildings of wood-frame, massive timber and non-combustible construction
  - Twelve-storey code compliant buildings of non-combustible construction.

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Objectives of the Study - 2

- Use CUrisk to develop efficient alternative solutions permitting construction of mid-rise (6 storey) and high-rise (12-storey) residential and office buildings of wood construction.
  - Six-storey buildings of wood-frame or massive timber construction
  - Twelve storey buildings of massive timber construction

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CURisk

- CUrisk is a comprehensive fire risk assessment computer model developed at Carleton Univ.
- CUrisk determines how fire protection provisions in a building (detection & alarm systems, structural fire resistance, compartmentation, flame-spread ratings, sprinklers, evacuation routes, firefighter response, etc.) work together to ensure life safety
- The key metric is the ***expected risk to life***

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6-Storey Residential Buildings

- Maximum permitted building areas
  - Sprinklers in conformance with (NFPA 13)
  - One-hour structural fire resistance ratings

Jurisdiction	Combustible or Hybrid Construction	Noncombustible Construction
British Columbia	1,200 m^2	6,000 m^2
Ontario	1,500 m^2	6,000 m^2
National	1,500 m^2	6,000 m^2

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6-Storey Residential Buildings
British Columbia Building Code

Requirement	Combustible, Hybrid or Noncombustible Construction
Structural Fire Resistance Rating	**1 hour**
Sprinklers[1]	**NFPA 13**
Fire Resistance Rating Fire Separations	**1 hour**
Doors (fire-protection rating) between apt & public corridor	**20 minutes**
Min width of public corridor	**1,100 mm**
Max Travel Distance apt door to exit	**45 m**
Doors (fire-protection rating) between public corridor & exit	**45 minutes**

1. NFPA 13 has additional provisions for buildings of combustible construction (e.g. concealed spaces)

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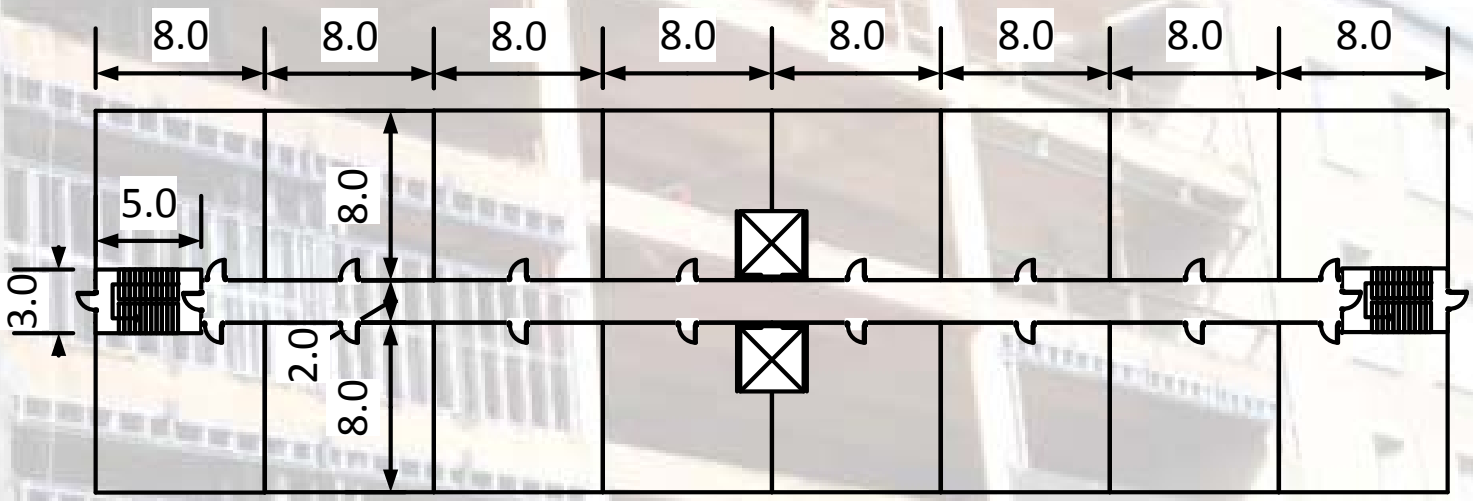
6-Storey Residential Building # 1 (R6S)



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6-Storey Residential Building # 1 (R6S)

- The building area is 1,152 m^2
- Max permitted building area is 1,200 m^2 for a residential bldg of combustible construction in BC
- 16 apartments per storey
- Number of occupants:
  - 4 in each apartment
  - 64 on each storey
  - 384 in the building

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6-Storey Residential Building # 1 (R6S)

- CUrisk has been employed to compute the expected risk to life in buildings of
  - Light-frame construction (R6S - LWF)
  - Mass wood construction (R6S - CLT)
  - Mass wood construction with more reliable sprinklers (R6S - CLT - SP)
  - Noncombustible construction (Reinforced concrete structure with steel-frame fire separations) (R6S - NC)

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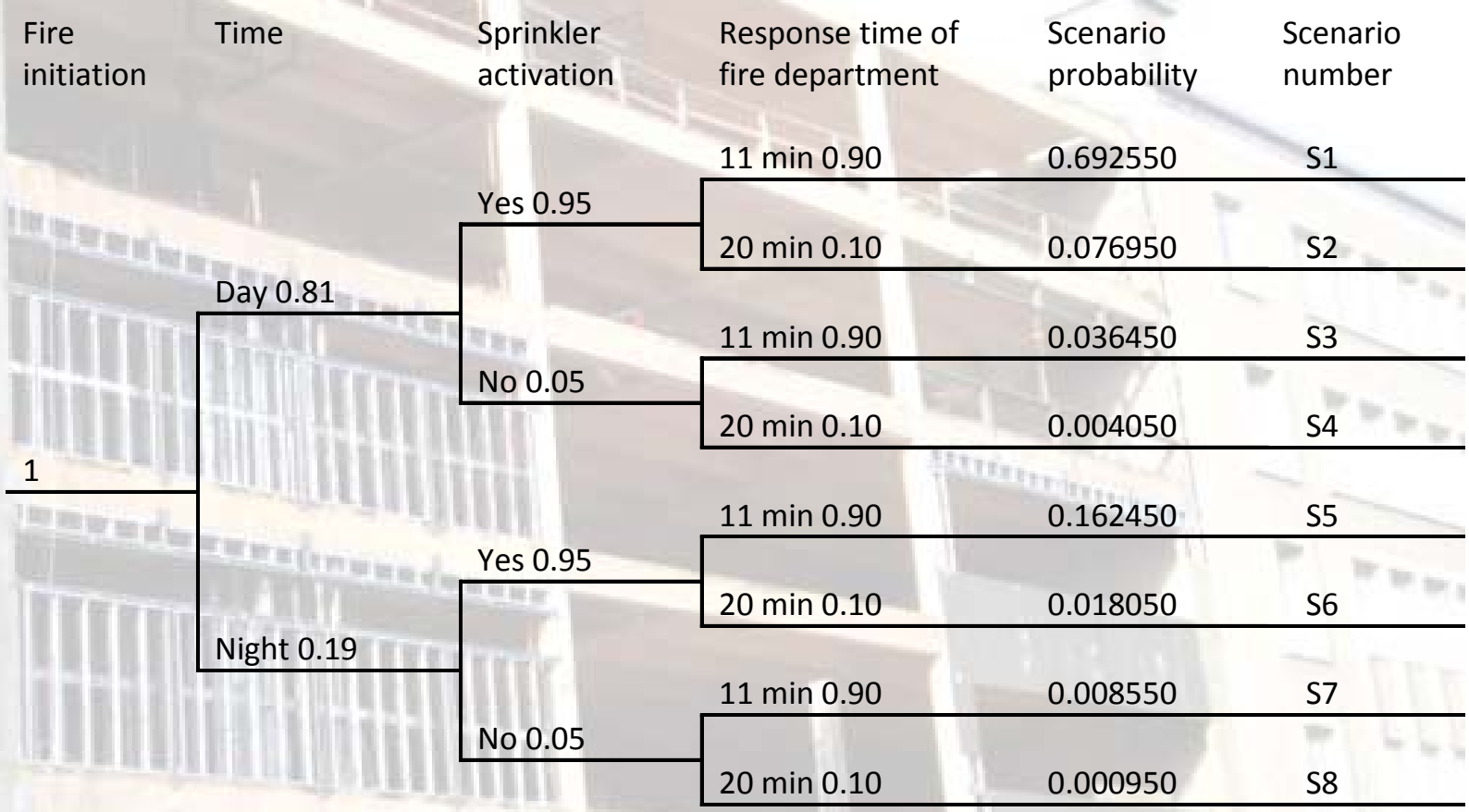
Design Fire Scenarios & Probabilities



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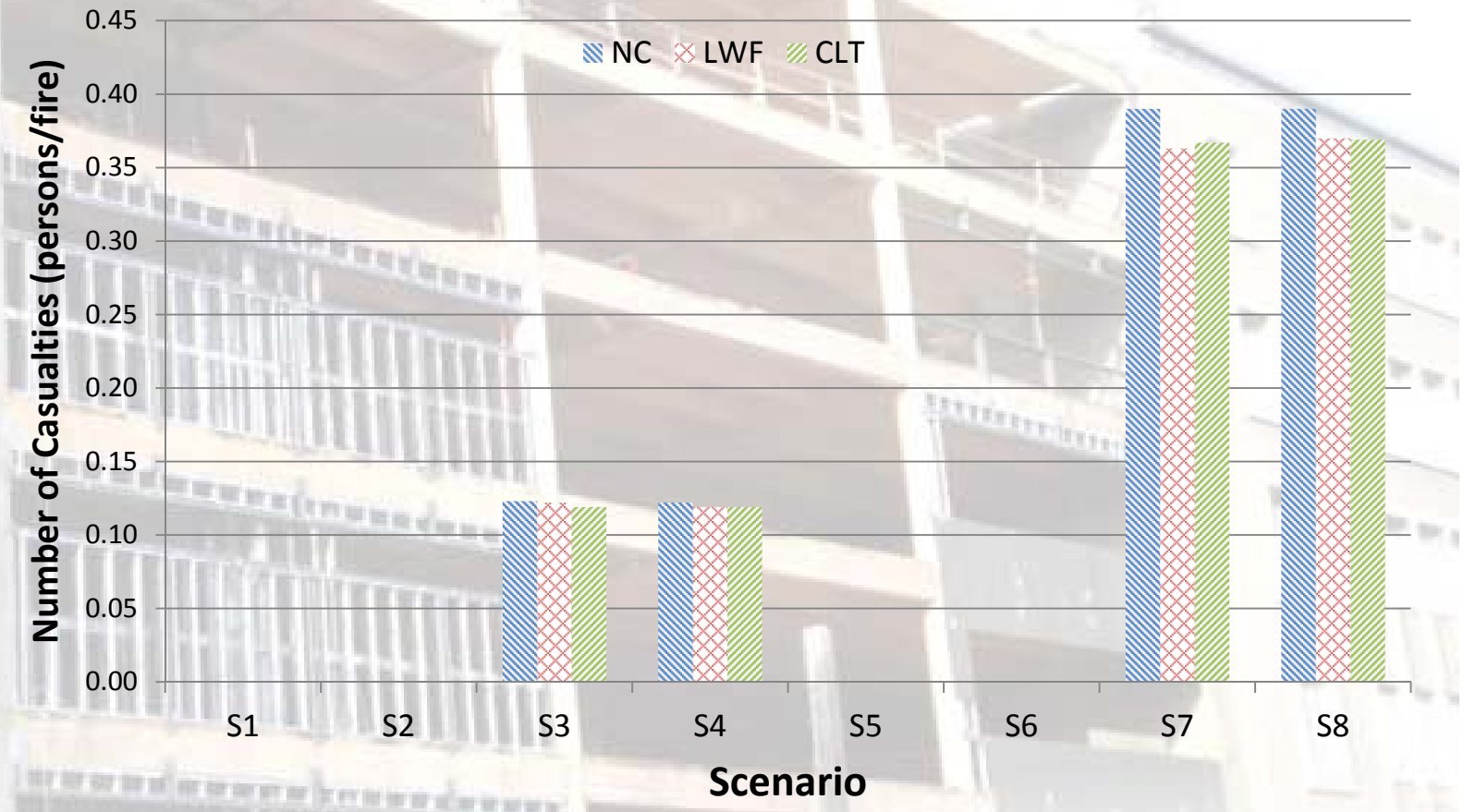
Casualties/Fire in Each Scenario (R6S)



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Relative Risk of Casualty (R6S)

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FII Project Conclusions

- Life safety in buildings depends more on the design solutions as a whole rather than the construction type
- In compartmented buildings, casualties occur predominantly in the room of fire origin
- Since active fire protection systems play a significant roll in delivering life safety, they must be designed, installed, inspected and maintained properly

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Thanks for your attention

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