FiSAC

Fire Safety Asia Conference
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# Fire Safety & Emergency Management: The Way Forward




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## "Evacuation Process and Outcome Predictions from the Perspective of Emergency Management"

# Introduction

- The core objective of an emergency management plan is to ensure that effective, efficient and safe evacuation is achieved in the event of a real life emergency.

- The success of any evacuation significantly relies on planning and preparedness.

# Introduction

- There are two aspects of emergency evacuation planning which requires careful consideration:
  - assumed sequence of events during an emergency; and
  - the actual sequence of events.
- The objective is to align the assumed and actual sequences as much as possible.

# Introduction

- The objective of this paper is to discuss quantitative methods and approaches that can be adopted to predict the process and outcome of evacuations from the perspective of emergency management.




# Emergency Evacuation/Response Plans and Fire Drills

# Emergency Evacuation/Response Plans / Drills

- Emergency evacuation plans are developed to ensure the safest and most efficient evacuation for all residents of a structure, precinct or region.

# Emergency Evacuation/Response Plans / Drills

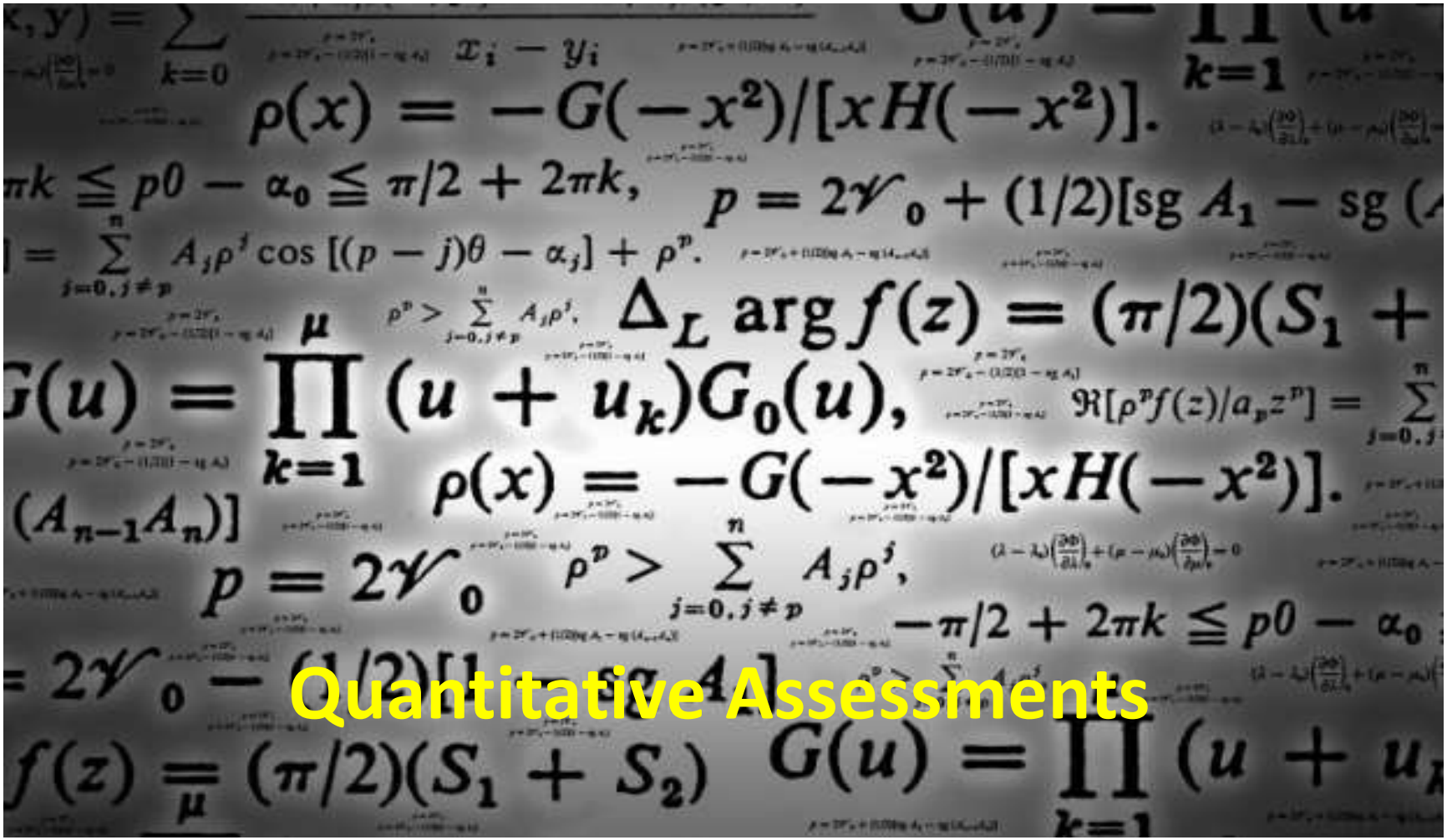
- Singapore Civil Defence Force Guidelines
- NFPA 101®, Life Safety Code
- The Australian Standard AS3745-2010 "Planning for Emergencies in Facilities"
- BS 9999:2008 "Fire Safety Code of Practice for the Design, Management and Use of Buildings"

# Emergency Evacuation/Response Plans / Drills

- What is the objective?

  *"To be ready, when a real emergency evacuation is required".*

- How to achieve the objective:
  - Quantitative assessment of the aspects of planning that codes and standards overlook:
    - the actual dynamics of the evacuation
    - the effectiveness of the proposed egress paths
    - the number and characteristics of the people being evacuated.


Quantitative Assessments

# Quantitative Assessments

- May be “desk top” or “computer modelling” exercises.

- To evaluate and quantify the pre-evacuation / evacuation / post-evacuation conditions.

# Quantitative Assessments

- The scale of the evacuation may be categorised in three main groups :
  - Single large building evacuations
  - Multi-building/precinct evacuations
  - Large scale (i.e. suburb/town/city) evacuations

# Quantitative Assessments

- Regardless of the scale, evacuations should be evaluated from the following perspectives:
  1. Initial occupant numbers, location and distribution
  2. Final destination location and capacity
  3. Movement paths and directions during the evacuation
  4. Travel patterns
  5. Travel speeds and times

# 3. Movement paths and directions

- The movement paths will need to evaluated from the perspective of:
  - Accessibility
  - Average width
  - Carrying capacity
  - Presence of bottlenecks
  - Presence of obstructions
  - Overall length
  - Counter flow traffic



# Counterflow

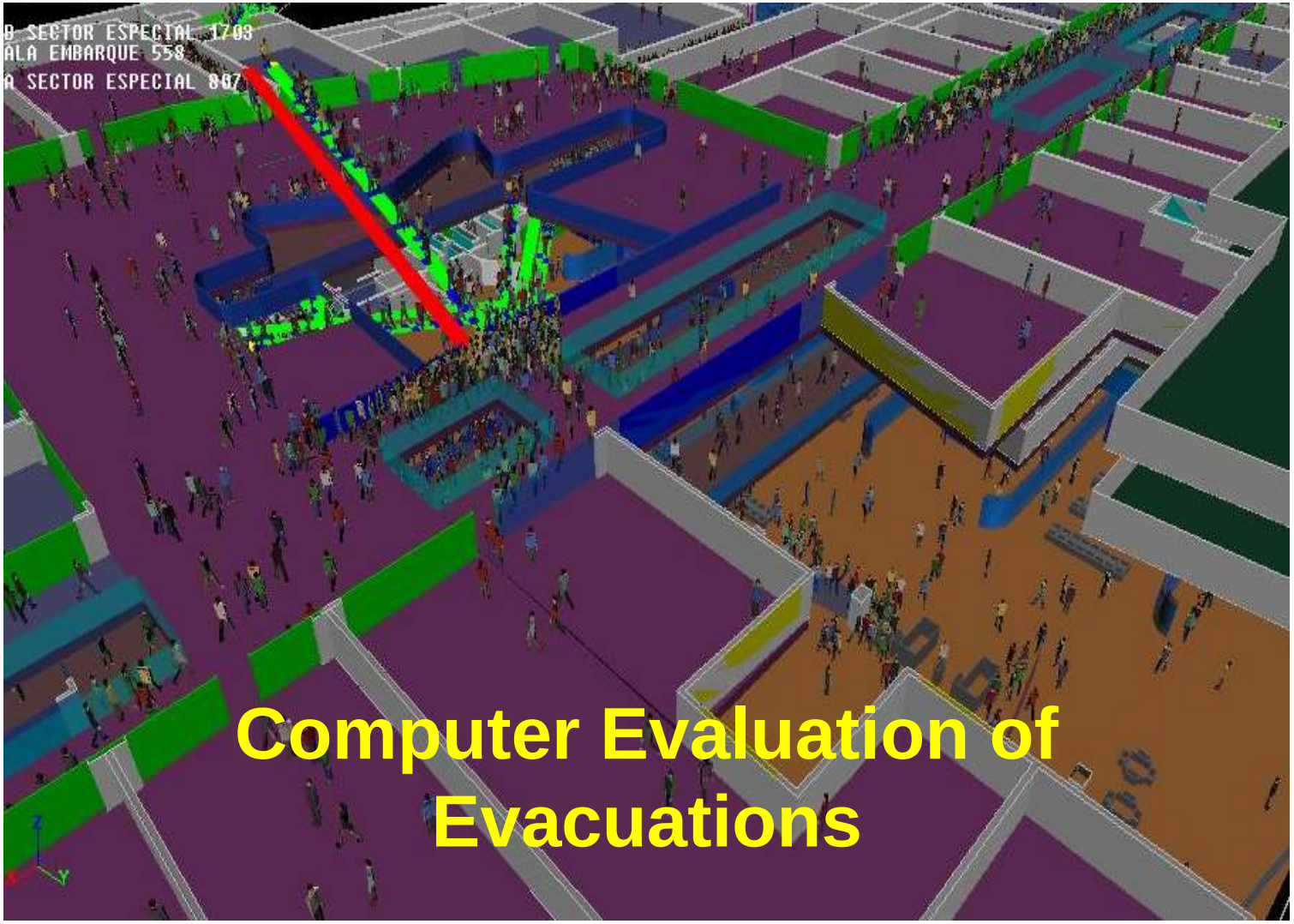
## Hermes Project - Germany



# Crowd Movement Patterns

**University of Northern Carolina Study**






# Computer Evaluation of Evacuations

# Computer Assessments

- Also referred to as “evacuation simulation modelling”.

- The key aim is to evaluate evacuation conditions using special purpose computer modelling software.

# Computer Assessments

- Single large building evacuations – Generic modelling software of varying levels of sophistication.
- Multi-building/precinct evacuations – Sophisticated generic modelling software or purpose developed software.
- Large scale (i.e. suburb/town/city) evacuations – Highly sophisticated purpose developed software.

# Computer Assessments

- Macroscopic models: The behaviour of the crowd as a whole.
- Microscopic models: The behaviour, actions and decisions of individuals within the crowd and their interactions with others.

| Macroscopic Models | Microscopic Models |
|---|---|
| • Regression Models<br>• Route Choice Models<br>• Fluid Dynamics or Gas Kinetics Models | • Rule-Based Models<br>• Social Forces Models<br>• Cellular Automata Models<br>• Agent-Based Models |

# Computer Assessments - Input

- Building floor plans / precinct maps / geographical maps
- Initial occupant numbers, location and distribution
- Final destination location and capacity
- Movement paths and directions during the evacuation
- Multiple occupant types (age, gender, ability)
- Occupant characteristics such as travel speeds
- Behavioural factors such as pre-movement times

# Computer Assessments - Output

- The output can be in one of or the combination of the following formats:
  - Text
  - Graphics
  - Animation
  - Spread sheet “csv” or “Excel” format.

# Computer Assessments - Output

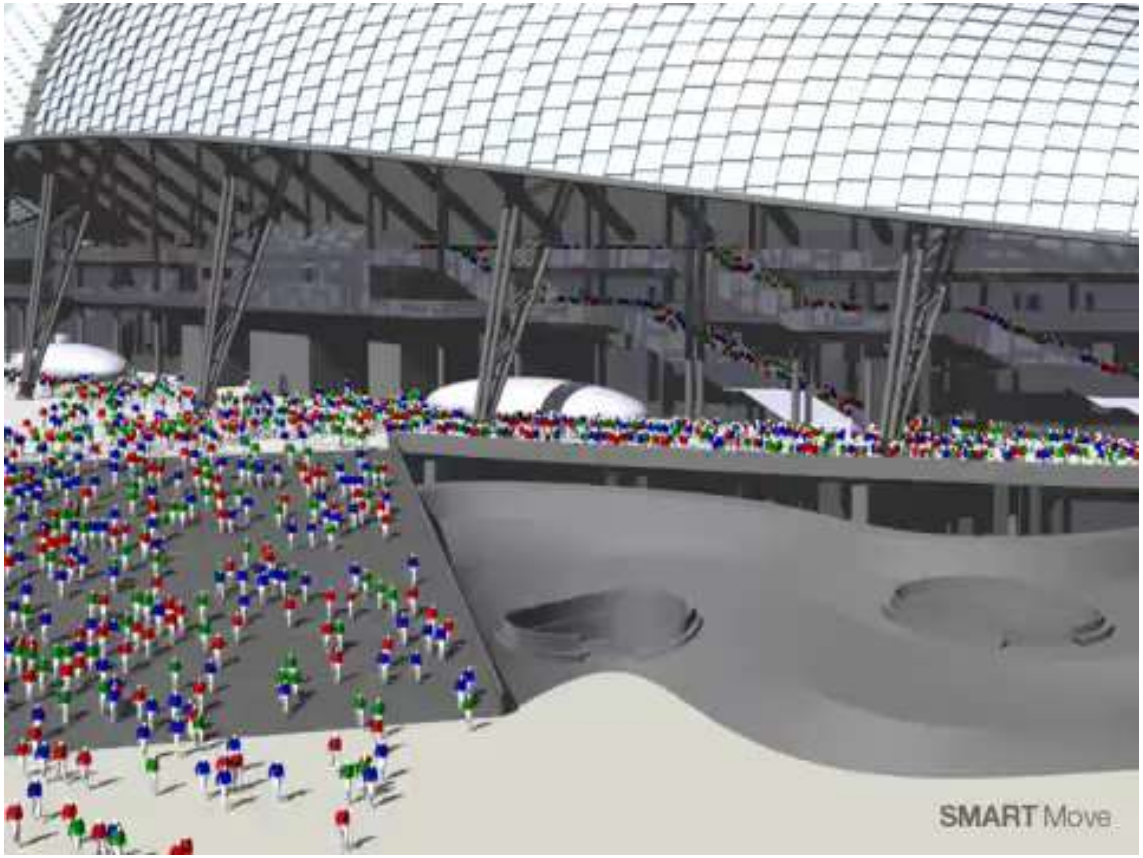
- Typical output information:
  - Evacuation times for each part of a building/precinct/town
  - Overall evacuation times
  - Flow times and rates
  - Occupant movement patterns
  - Queuing
  - Bottlenecking

# Computer evacuation modelling software

- The most popular computer modelling software include the following:
  - Exodus
  - Steps
  - Pathfinder
  - Simulex
  - FDS+Evac

# Computer model examples

## Smart Move/ Smart Space – Burro Happold Engineering



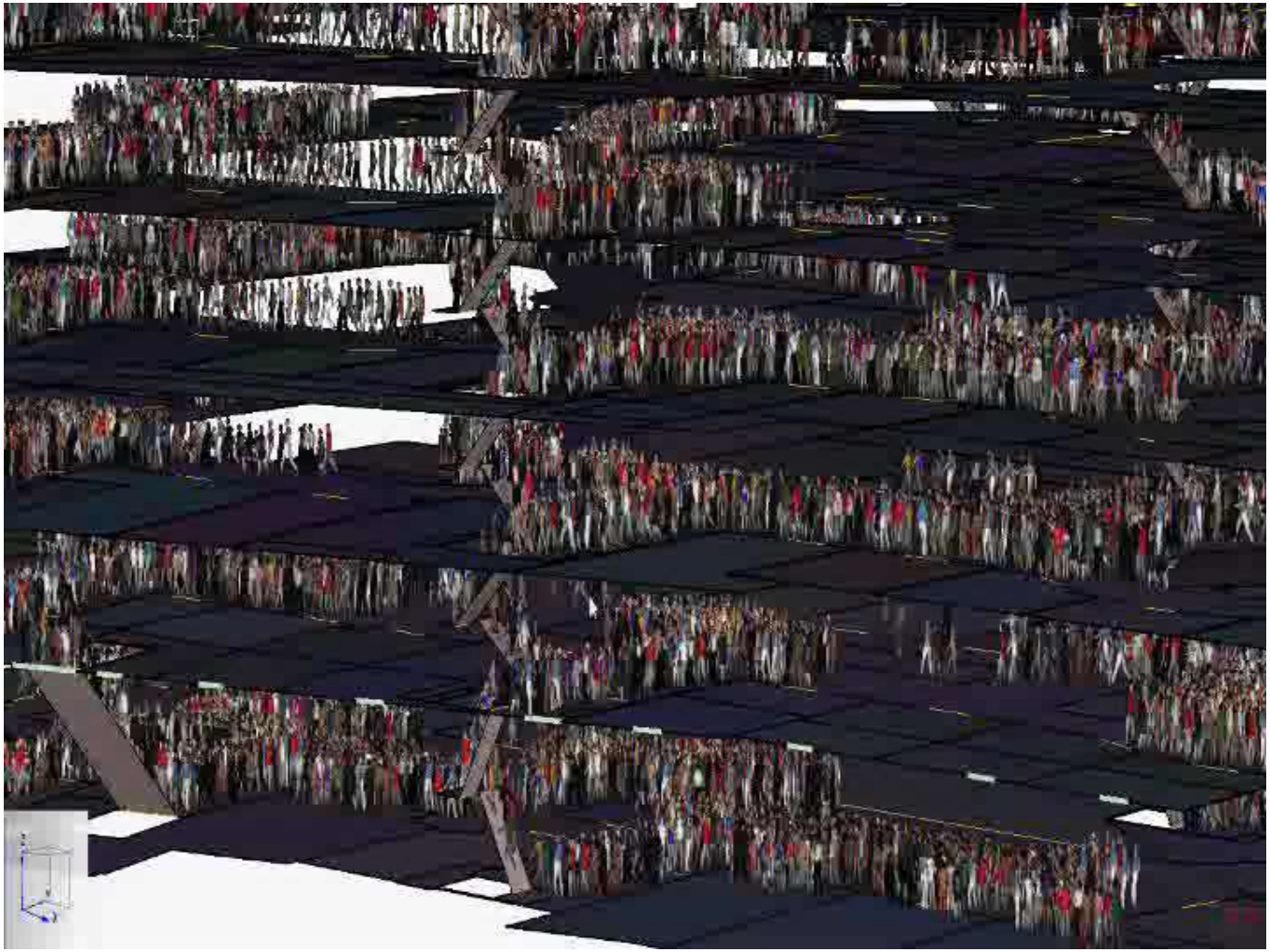
# Case Study 1



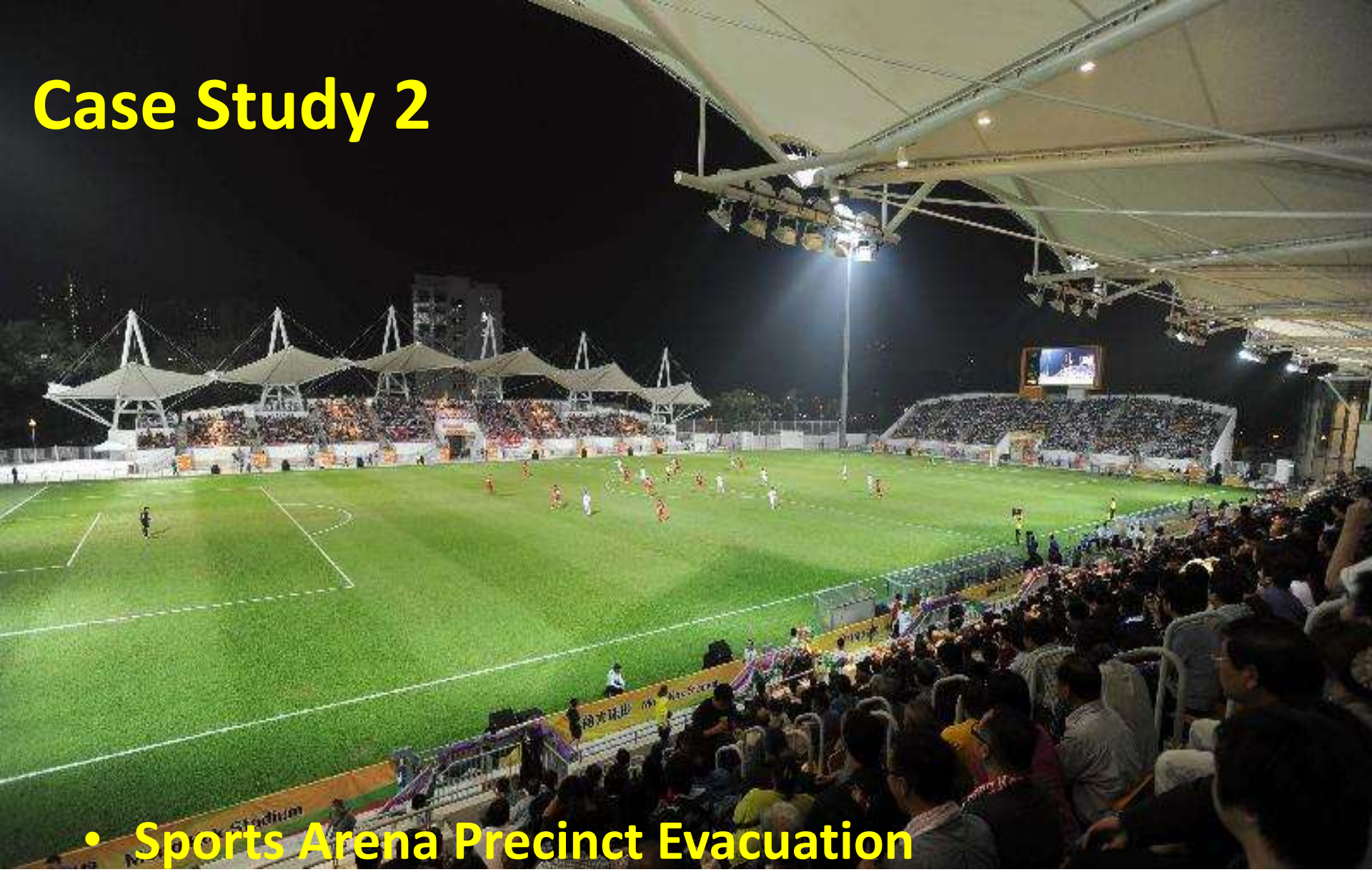

## Individual Building Evacuation – Shopping Mall

# Case Study 1 - Individual building modelling

1. Shopping Centre Evacuation
   - This example is based on the evacuation modelling of a large shopping centre.
   - Modelling has ben conducted using the Pathfinder modelling software.
- Outcome:
   - The modelling demonstrated that the evacuation times for 24,000 occupants located in different parts of the shopping centre would vary between 200 and 1100 seconds.



# Case Study 2



- **Sports Arena Precinct Evacuation**

# Sports Arena Precinct Evacuation

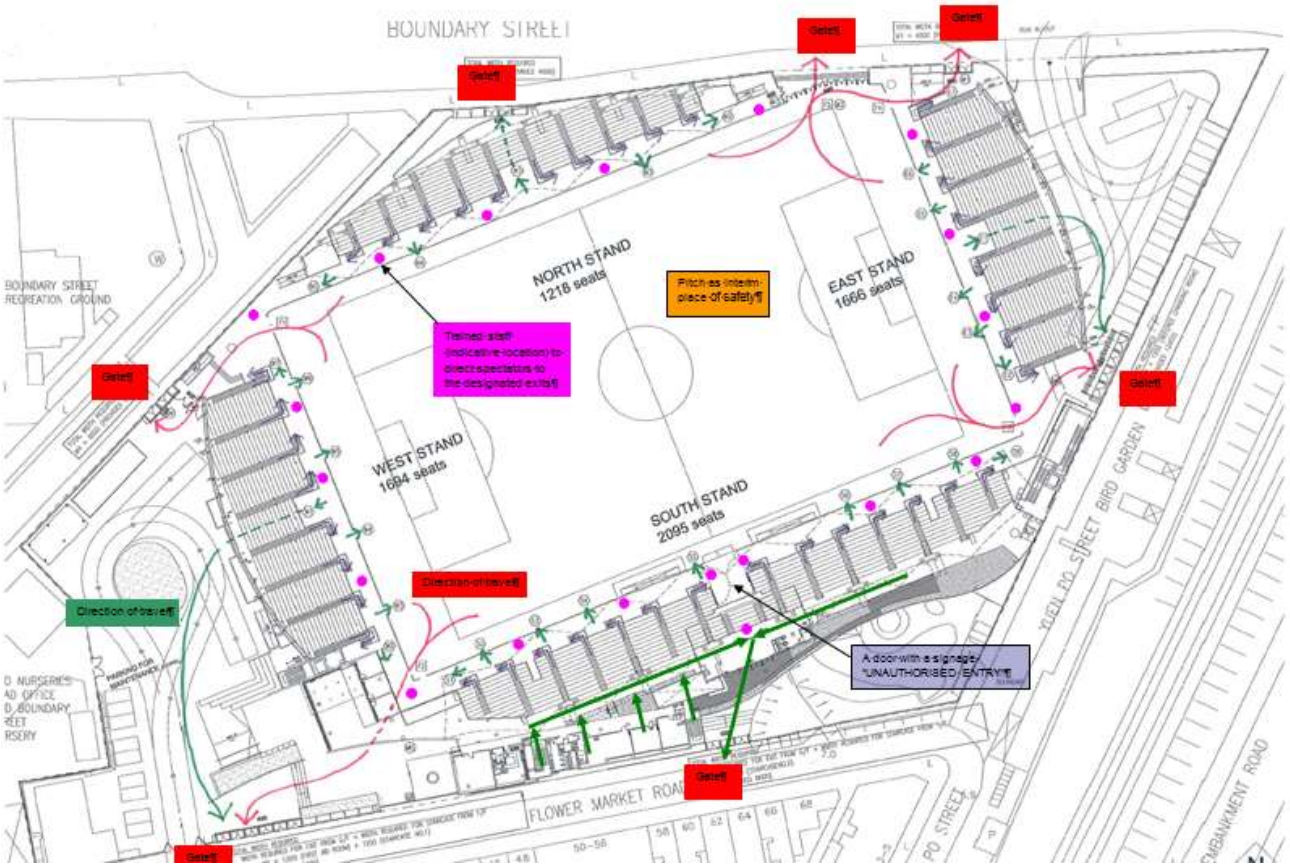
- The subject Stadium with the current holding capacity of about 7,700 seats.
- An improvement works will be carried out to increase the capacity by about 6,600 more seats
- Evacuation analysis using Simulex software was conducted to investigate the impact of the stadium occupants during an emergency evacuation on the local area.

# Sports Arena Precinct Evacuation



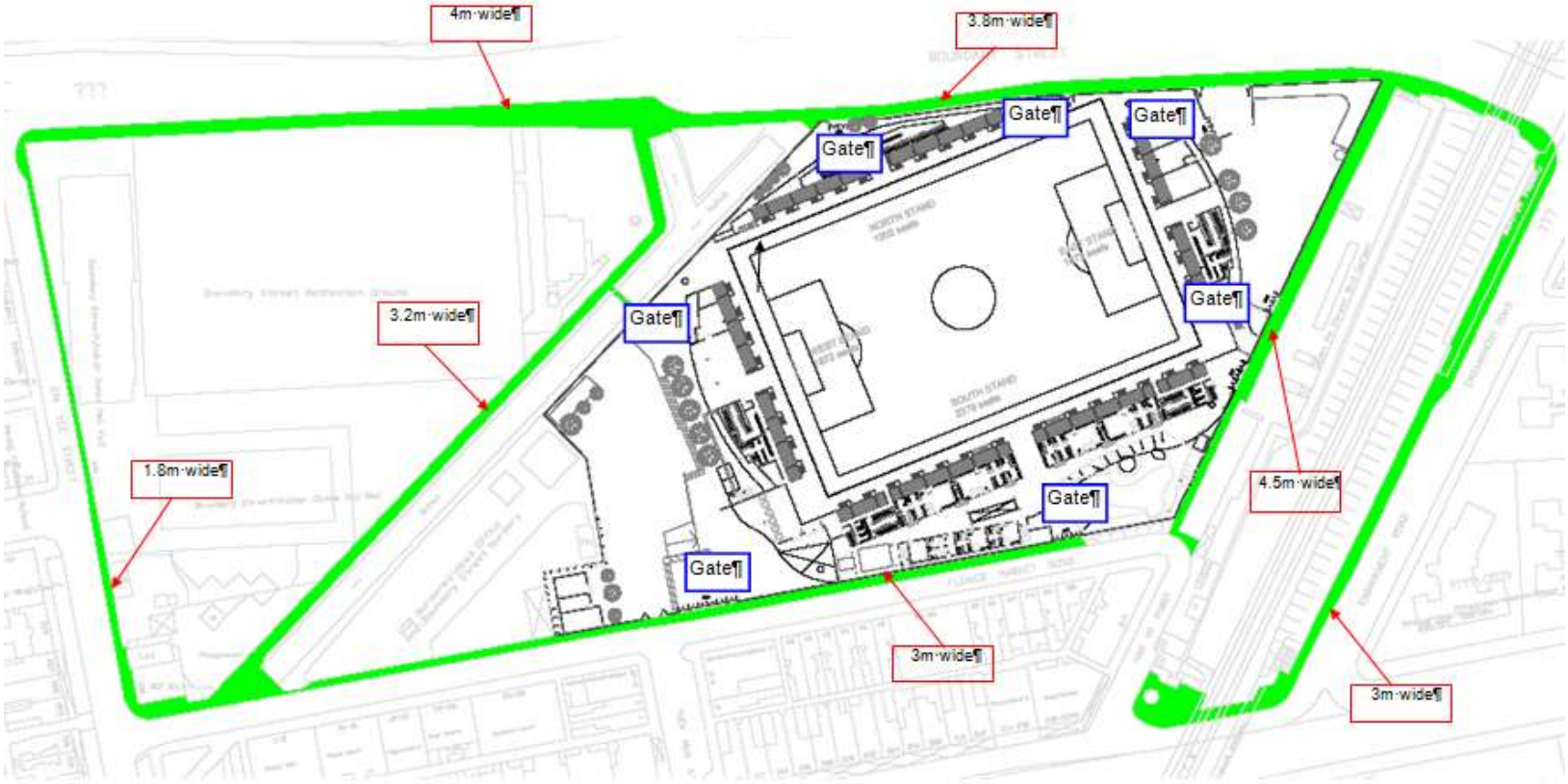
# Sports Arena Precinct Evacuation

- Occupant flows



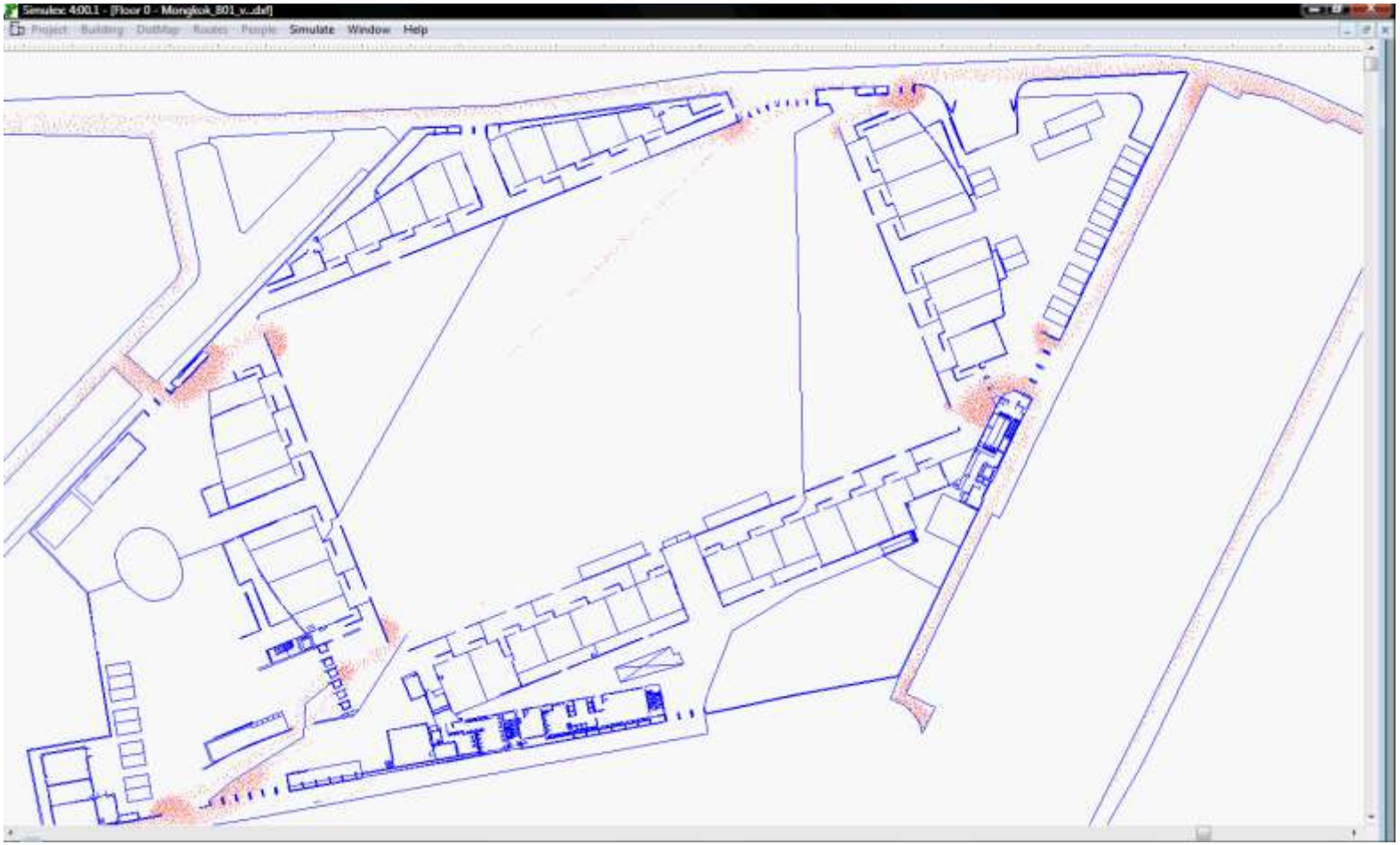
# Sports Arena Precinct Evacuation

- The stadium and its surrounds:



# Sports Arena Precinct Evacuation

- Outcome:
  - The available evacuation holding reservoir provides an adequate level of life safety with respect to emergency egress from Stadium in the event of a fire.


Project
Building
DotMap
Routes
People
Simulate
Window
Help


Case Study - 3
High Rise Building
Evacuation Muster Point Analysis

# The Building

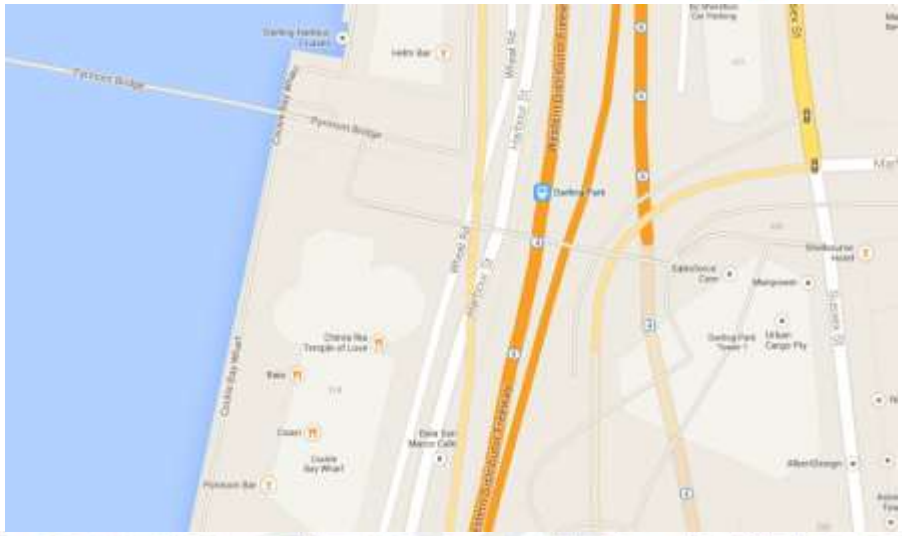
- A mass evacuation modelling assessment was conducted for a 30 storey office building in Sydney, Australia accommodating approximately 4000 occupants.

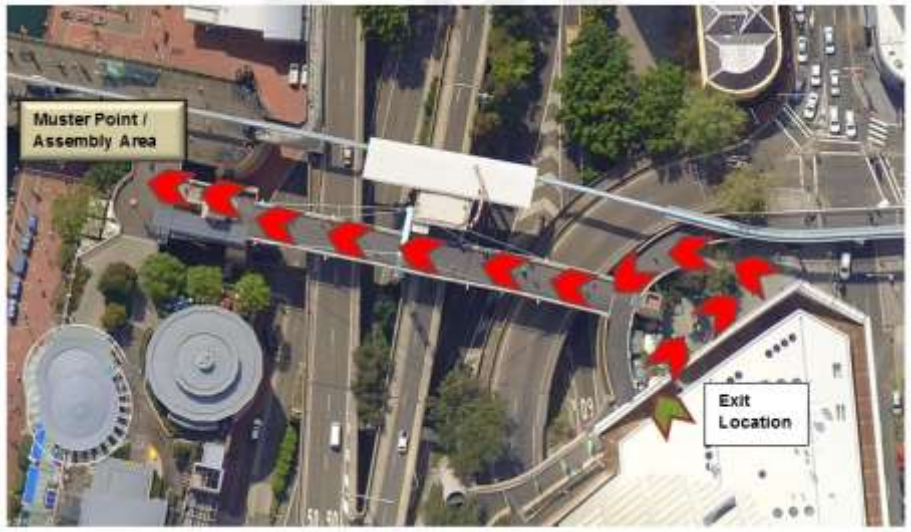




# Current Muster Point

- Occupants required to evacuate by means of the two stairs located in the building core.
- The occupants then proceed to the muster point/assembly area located adjacent to the Pyrmont Bridge.





# Current Muster Point

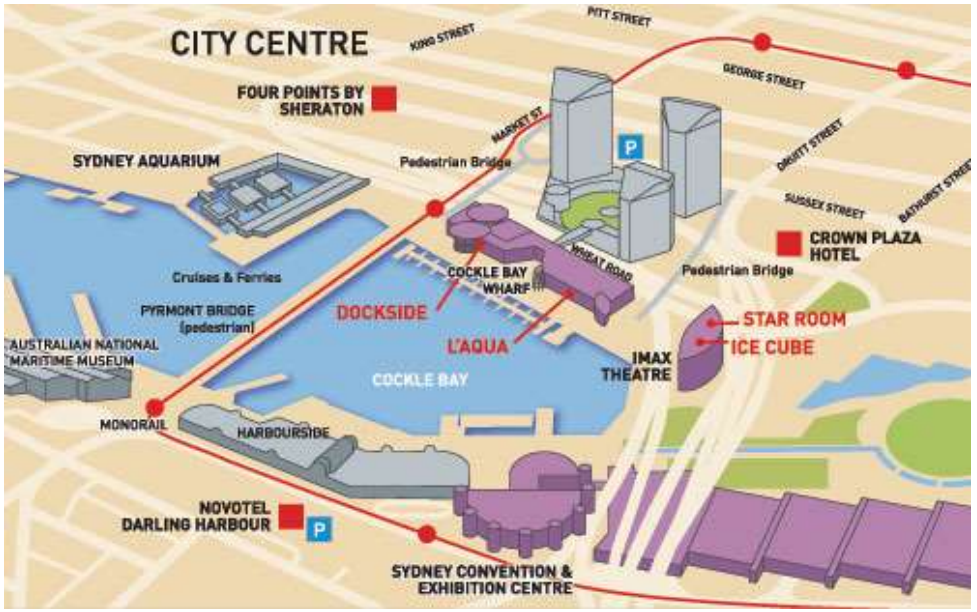
- Problems with the existing location:
  - Large numbers of occupants occupying large segments of a public pedestrian bridge and blocking the general pedestrian traffic.
  - The wide spread nature of the crowd make it difficult for wardens to communicate instructions.
  - Muster point a bicycle path





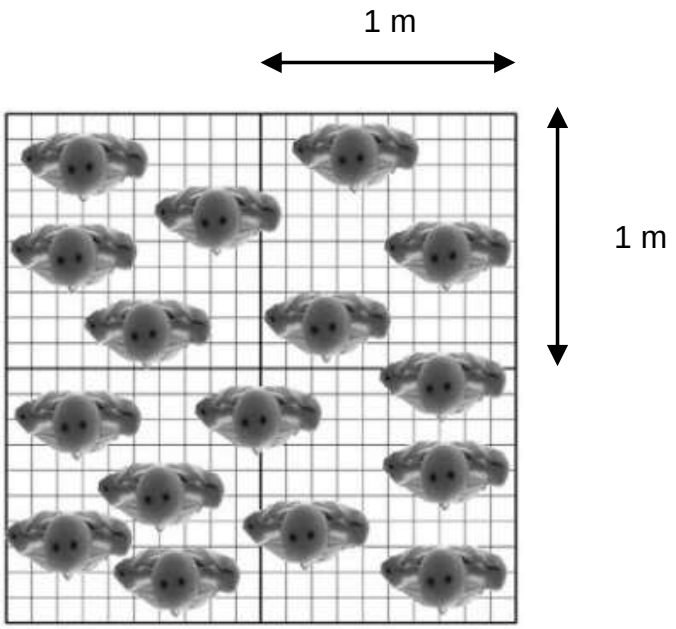
# Alternative Muster Point Assessment

- The courtyard outside the Australian National Maritime Museum (ANMM) is considered as an alternative muster point
  - Scarcely populated open area with minimum number of obstructions.
  - The travel path between the Tower building and the ANMM is sufficiently wide and clear of significant obstructions.

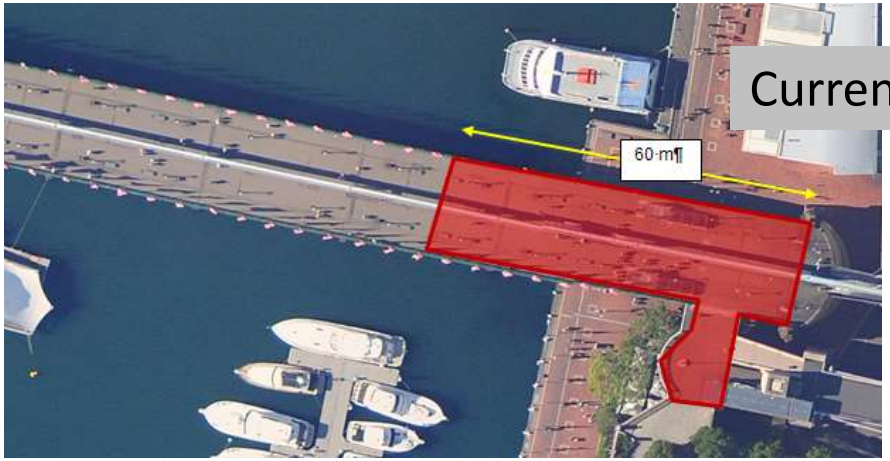


# Qualitative Evaluation

- The Muster Point/Assembly Area Capacities:
  - Based on the average occupant density of 4 persons/$m^2$, the area required to accommodate approximately 4000 occupants is 1000$m^2$



# Qualitative Evaluation




Current muster area location



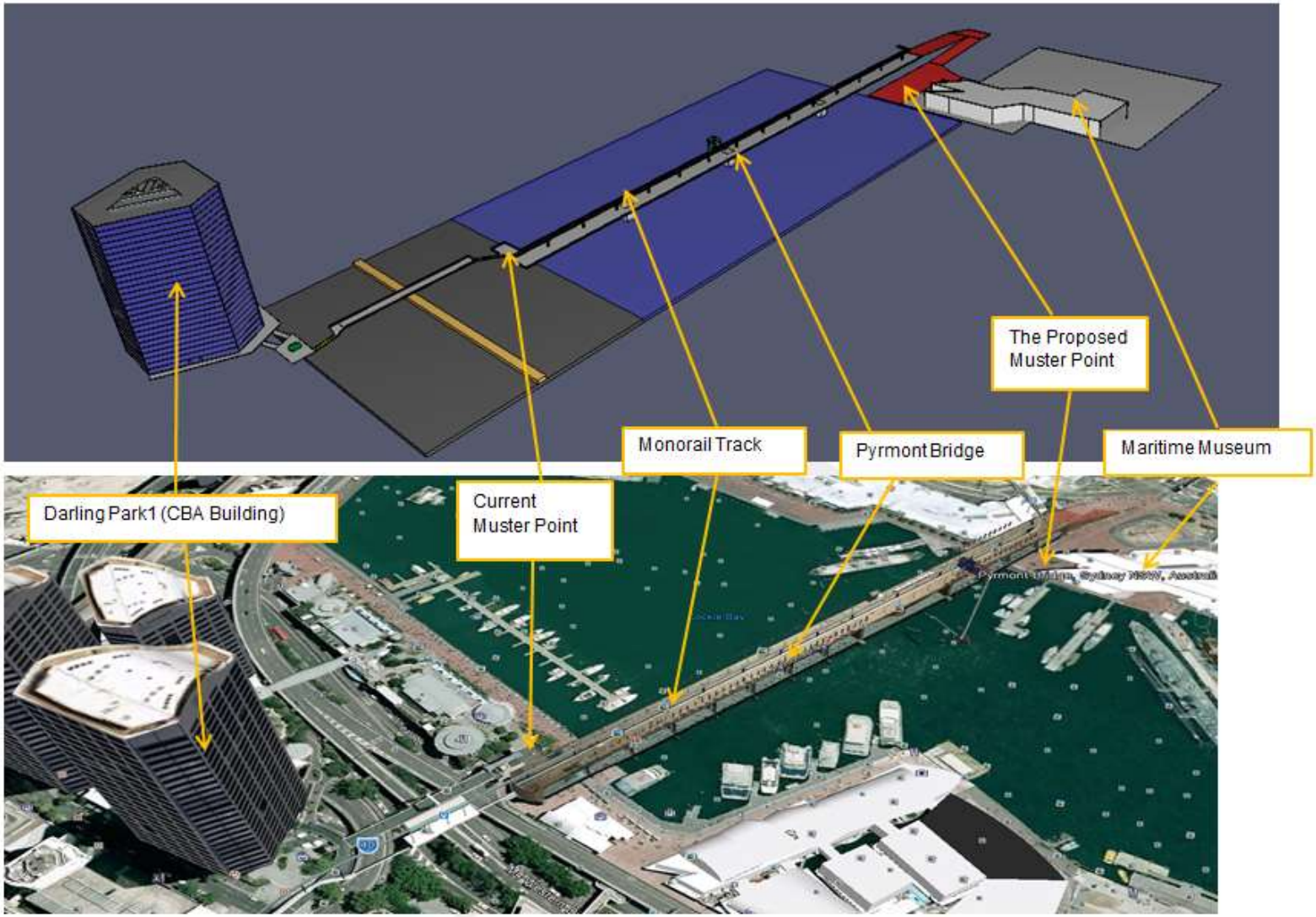

Proposed muster area location

# Evacuation Modelling

- To analyse and simulate a full evacuation of the Tower 1 building computer modelling has been conducted using the Pathfinder software.

- The model was constructed to estimate the time required for all occupants to:
  - travel to the mustering point;
  - back to the DP1 building; and
  - return to the work places within the DP1 building, only using lifts.

# Evacuation Modelling



# Evacuation Modelling Results

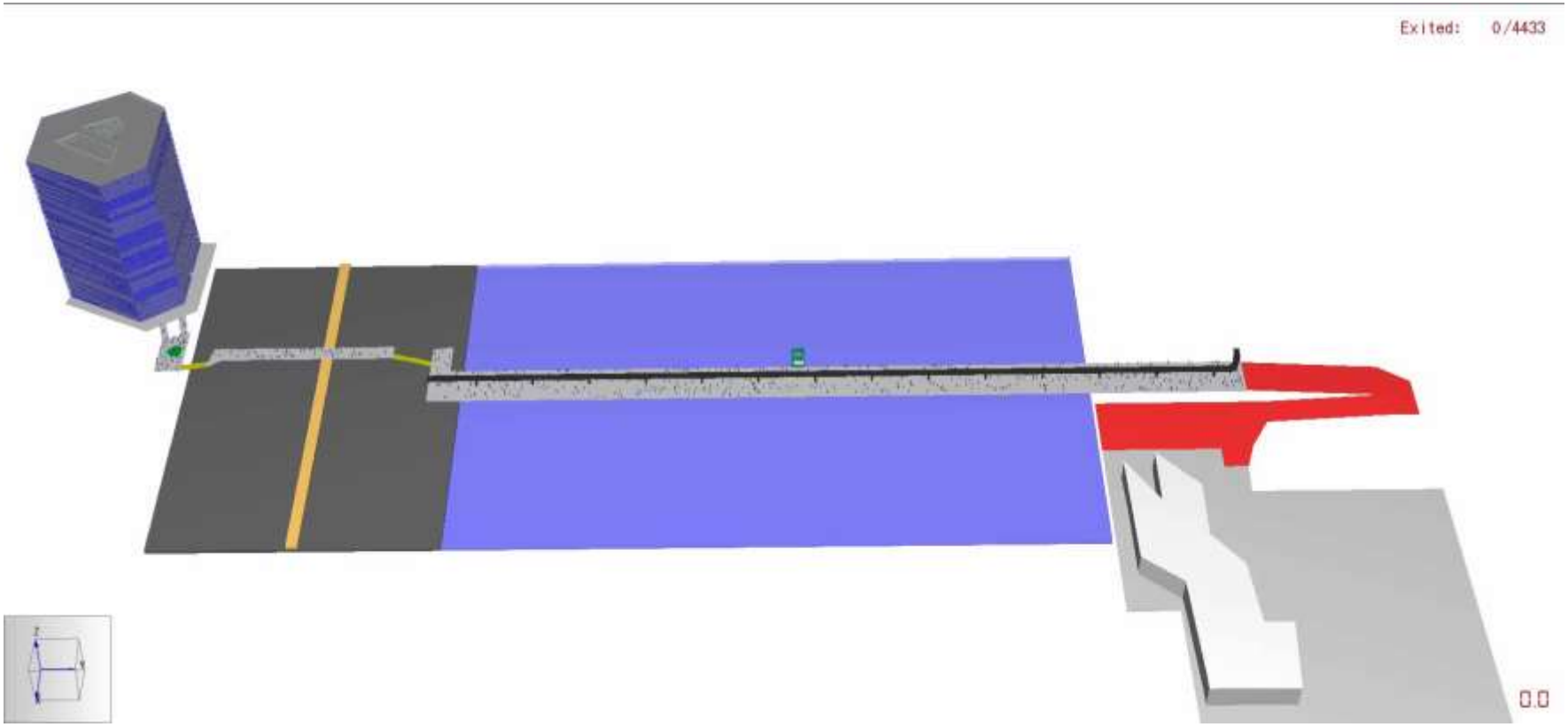
| | Occupants | Number of Occupants | Event times |
|---|---|---|---|
| **Stage 1: DP1 to Assembly Area** | Leaving the DP1 Building and arriving at the assembly area | 3840 | 1820 seconds (approximately 30 minutes) for the last occupant to leave the building |
| | | | 2700seconds (approximately 44 minutes) for the last occupant to arrive at the assembly area |
| **Stage 2: Assembly Area to DP1 (including lift travel back to office levels)** | Leaving the assembly area and arriving back at the DP1 Building | 3840 | 570 seconds for the first occupant to arrive back at DP1 (occupants start using the lifts to return to their floors). |
| | | | 7770 seconds for the last occupant to arrive back at the floor of origin |

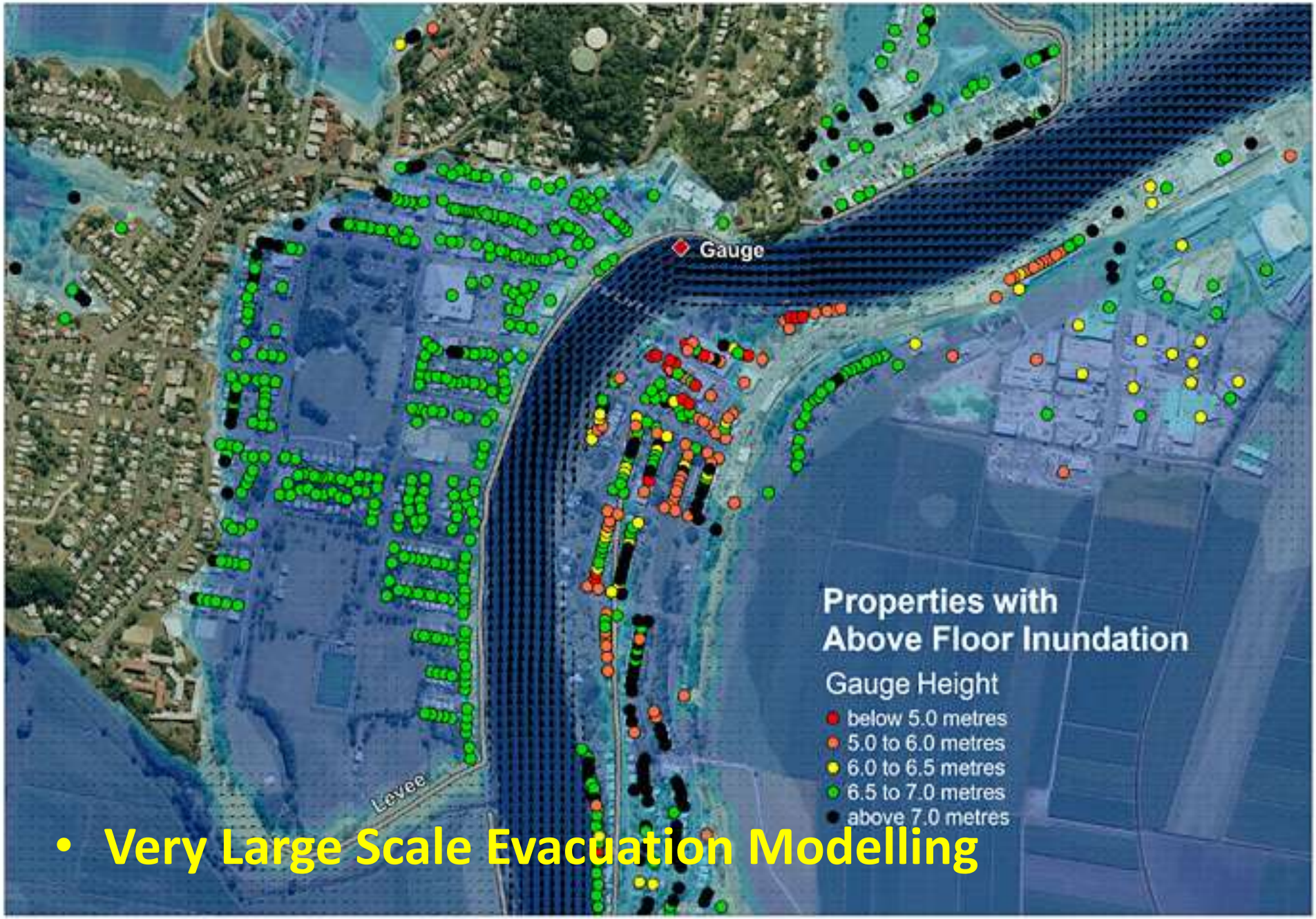
# The Outcome

- As a consequence of the qualitative evaluation and the modelling it was concluded that the proposed muster area adjacent to the ANMM would satisfy both the life safety and the business continuity objectives.



# Evacuation simulation






- **Very Large Scale Evacuation Modelling**

# Introduction

- Very sophisticated high-end computer models.

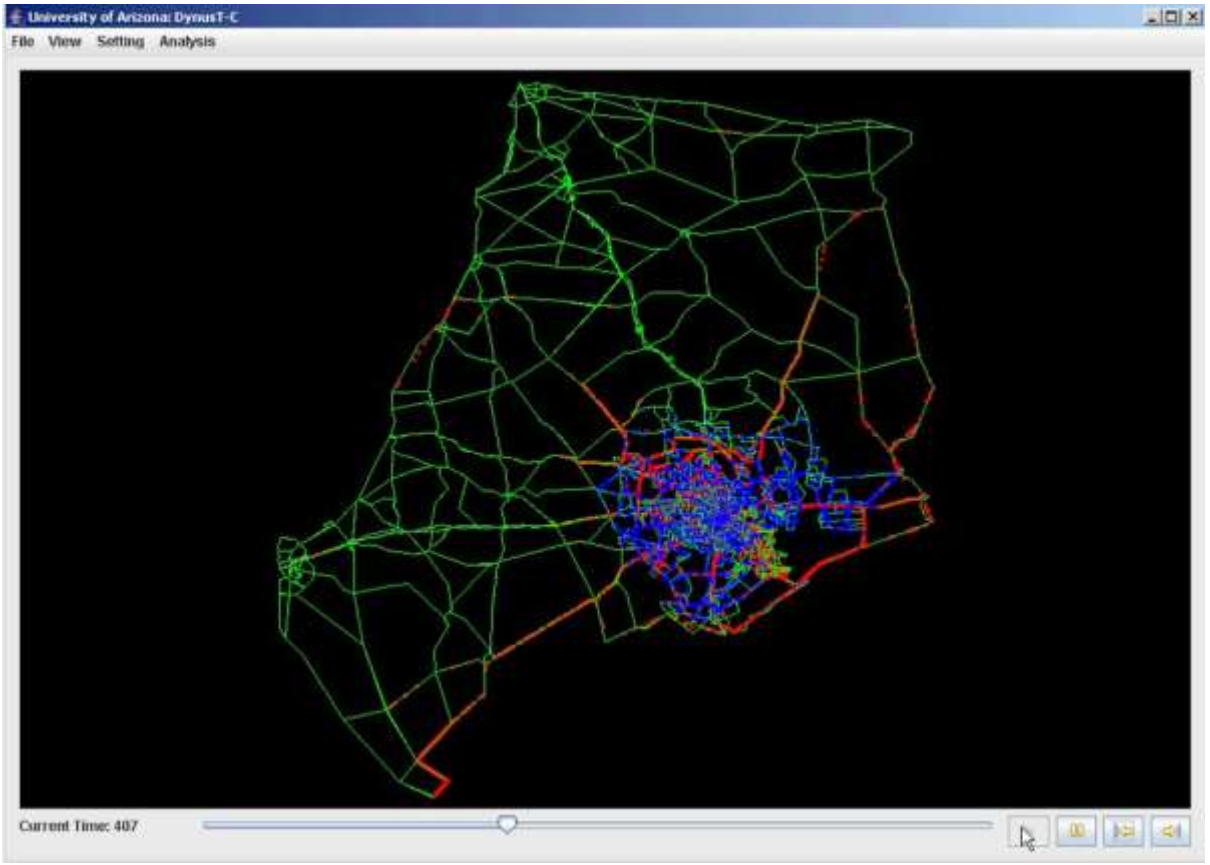
- Maybe specific to a particular area or may be applicable to different areas.

# Introduction

- Mass evacuation tools used for a range of hazards worldwide, (including technological hazards such as nuclear accidents):
  1. Behavioural based simulation models
  2. Traffic simulation models
  3. Time-line/critical path management diagrams

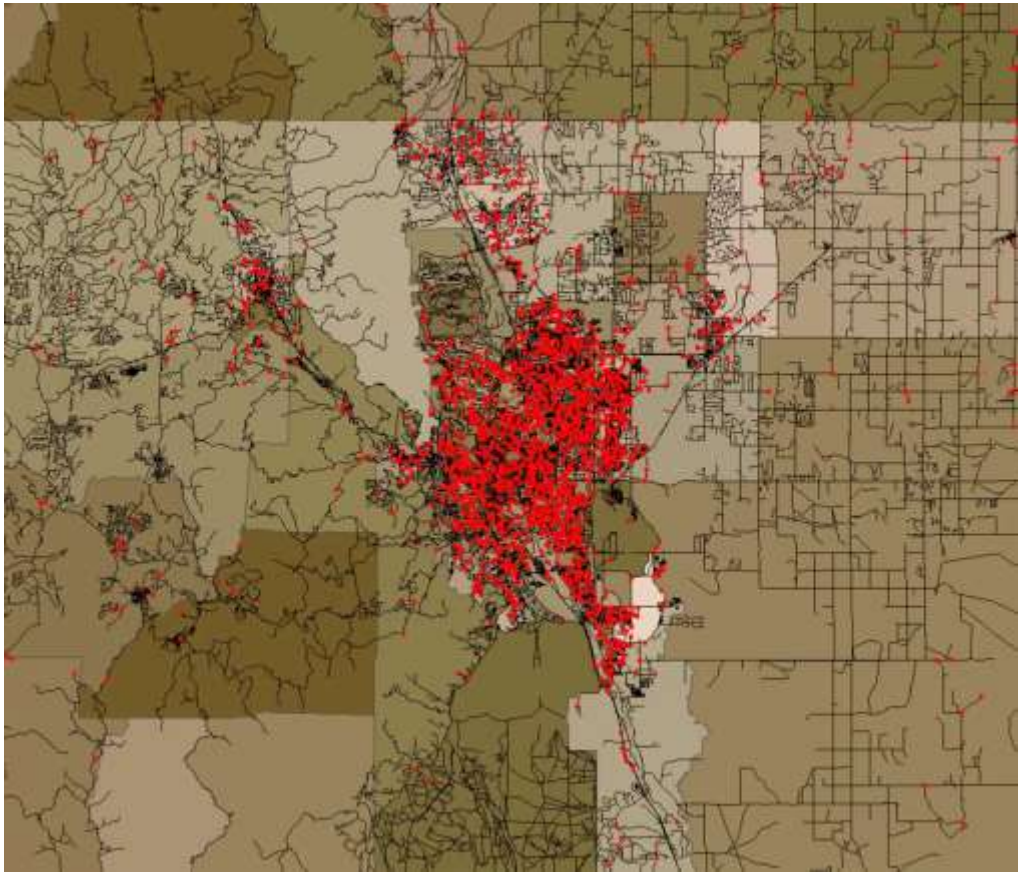
# Various Model Examples

## Central Texas Hurricane Rita Evacuation



# Various Model Examples

## 2012 Colorado Springs Wild Fires Evacuation



# Various Model Examples

## University Of California Santa Barbara Campus Evacuation 1



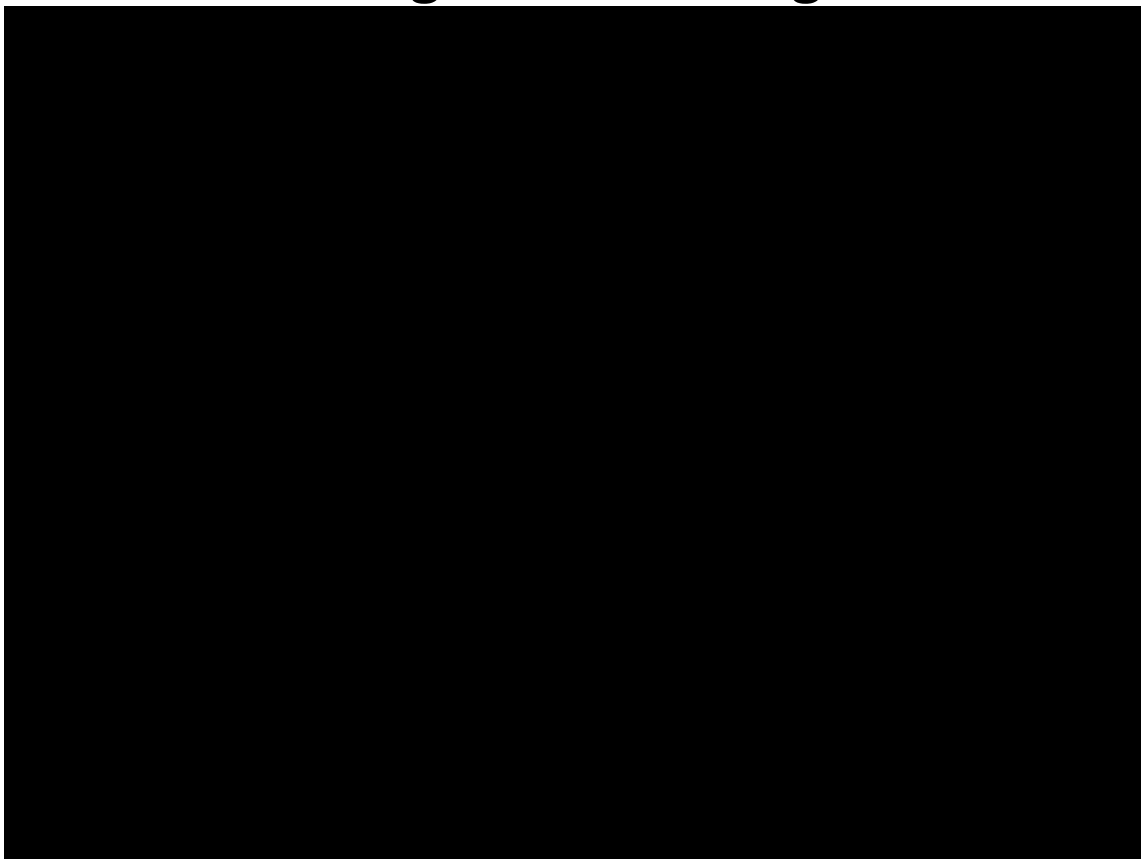
# Various Model Examples

## University Of California Santa Barbara Campus Evacuation 2



# Various Model Examples

**Tsunami Evacuation Simulation for Disaster Awareness Education and Mitigation Planning of Banda Aceh**



# Conclusions

- It is a responsibility of all parties involved in the design, development and management of buildings that an appropriate emergency evacuation plan is not only developed but also tested and analysed.
- The codes and regulations establish a minimum benchmark in relation emergency evacuation plans.

# Conclusions

- Developing a plan based on codes and regulations will ensure that all legal requirements are satisfied.

- But, it is a duty of care requirement that the efficacies of these plans are further assessed.

# Conclusions

- Evacuation modelling software may be adopted for the purpose of further analysis.
- Use of such software is not limited to individual buildings.
- They may provide invaluable information in relation to precinct or even larger area evacuations.

# And finally……

An old Chinese proverb:

*"When one blind man leads several blind men, before long all will fall into a **fire** pit"*



