

## Verifications and Validations in **Crowd Flow Simulations**

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8 October 2012, Integrated Fire Engineering and Response meeting in Zadar Croatia

**SMART** Crowd Flow Solutions  
Designing Spaces to Enhance Visitor Experience



**London City Airport** baggage reclaim waiting



Lords Cricket Ground during lunch break

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Cardiff city centre after Match day

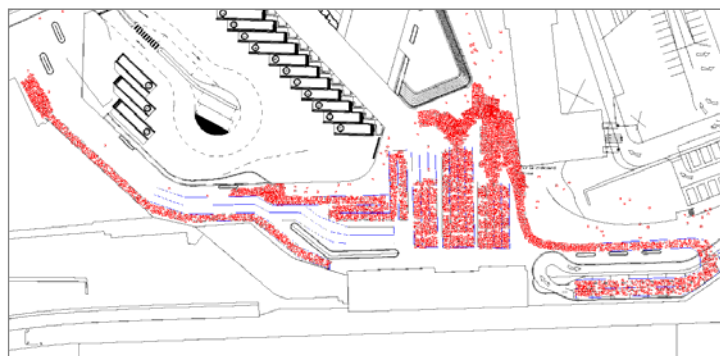
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## Projects – Cardiff Central station crowd management



### Queuing optimisation

- Reduce congestions
- Simplify management
- Clarify wayfinding
- Enable capacity expansion



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Makkah during Hajj

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# Our experience

## Aviation



- London City Airport
- Birmingham Int. Airport
- Jeddah Int. Airport
- Beijing Int. Airport

## Urban / Masterplanning



- Makkah Hajj Pedestrian Corridors
- St. Giles Circus London
- Liverpool Kings Waterfront
- Swiss National Holiday, Basel

## Sports Stadia



- Sochi 2014 Olympics Stadium
- Abu Dhabi National Stadium
- Lords Cricket Ground
- Ascot Racecourse

## Rail



- Kurskyi Station Moscow
- Cardiff Central Station
- Haramain High Speed Rail KSA
- Union Station Los Angeles

## Cultural & Civic



- Cairo Expo City
- Qasr Al Hosn, Abu Dhabi
- Imperial War Museum London
- Louvre Museum Abu Dhabi

## Education



- Thomas Deacon Academy, UK
- Exeter University
- Camden BSF
- DY Patil University, Mumbai

## Hospitality



- Waldorf Astoria Hotel, NY
- Palace Hotel, NY
- Maghrabi & Diyafah Hotel, KSA
- Hotel America, Dubai

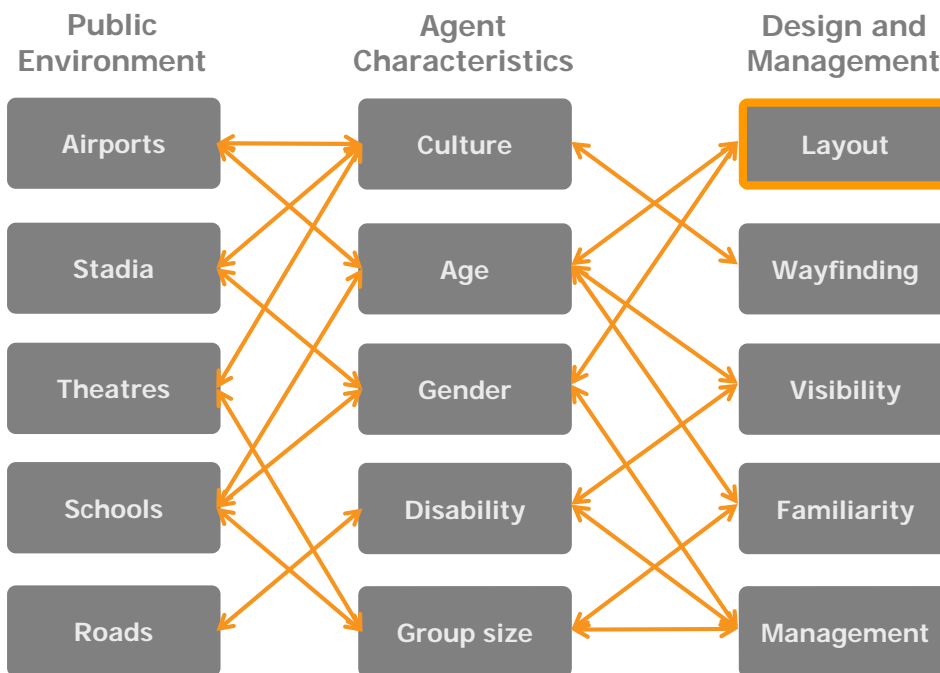
## Healthcare



- Queens Hospital Romford
- RN Orthopaedic Hospital
- Guy & St Thomas Hospital

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## Factors affecting people movement

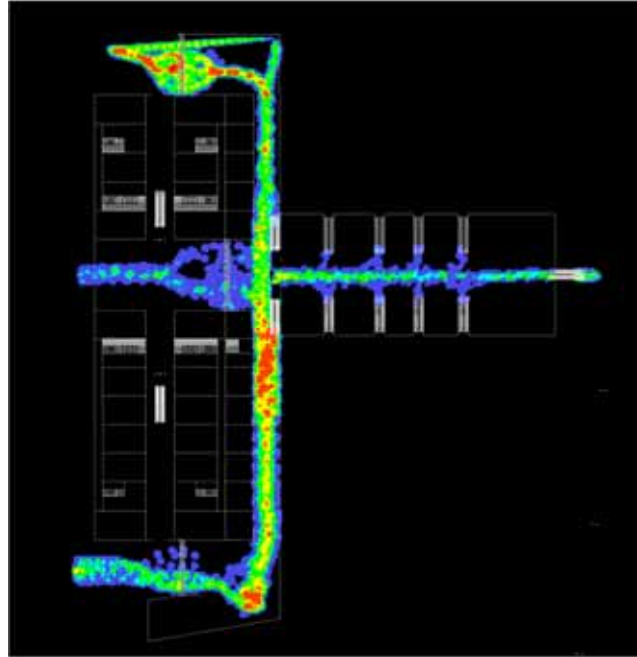


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## Achieving **Comfort** and **Safety** in Movement

### Comfort and safety criteria

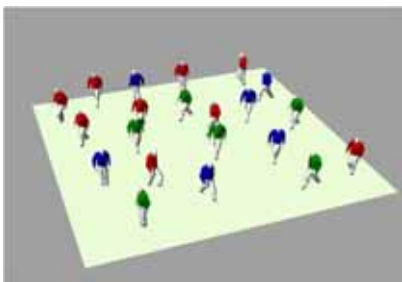
- Journey times
- Travel distances
- Waiting times
- Densities
- Queuing densities
- Flowrates
- (bespoke)...



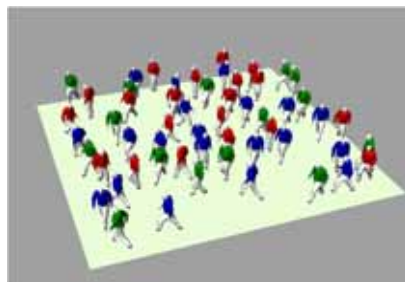
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## Achieving **Comfort** and **Safety** in Movement

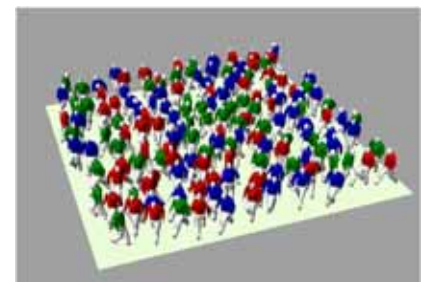
### Fruin Level of Service (LoS)



**Level of Service A**  
> 3.2 m<sup>2</sup>/person  
< 23 p/min/m  
Free flow  
Easy overtaking  
Avoidable crossing conflicts



**Level of Service C**  
1.4-2.3 m<sup>2</sup>/person  
33-49 p/min/m  
Restricted walking  
Restricted overtaking  
Busy but comfortable

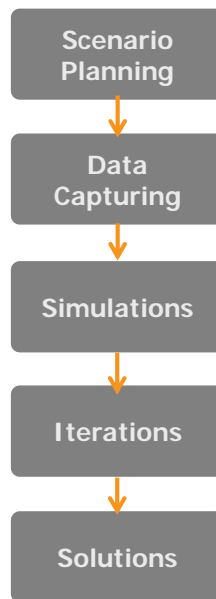


**Level of Service E**  
0.5-0.9 m<sup>2</sup>/person  
66-82 p/min/m  
Unavoidable physical contact  
Very restricted circulation  
Long queuing not sustainable

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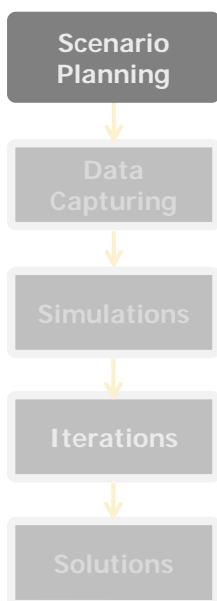
## Our modelling **approach**

### From Problem to Solution

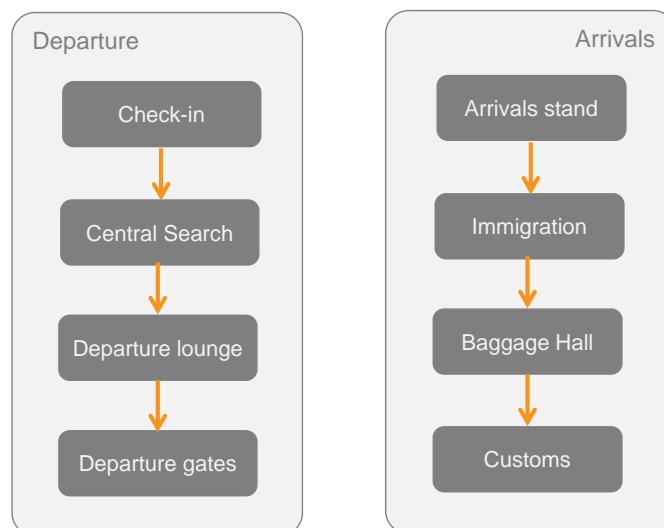


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### **Scenario** planning



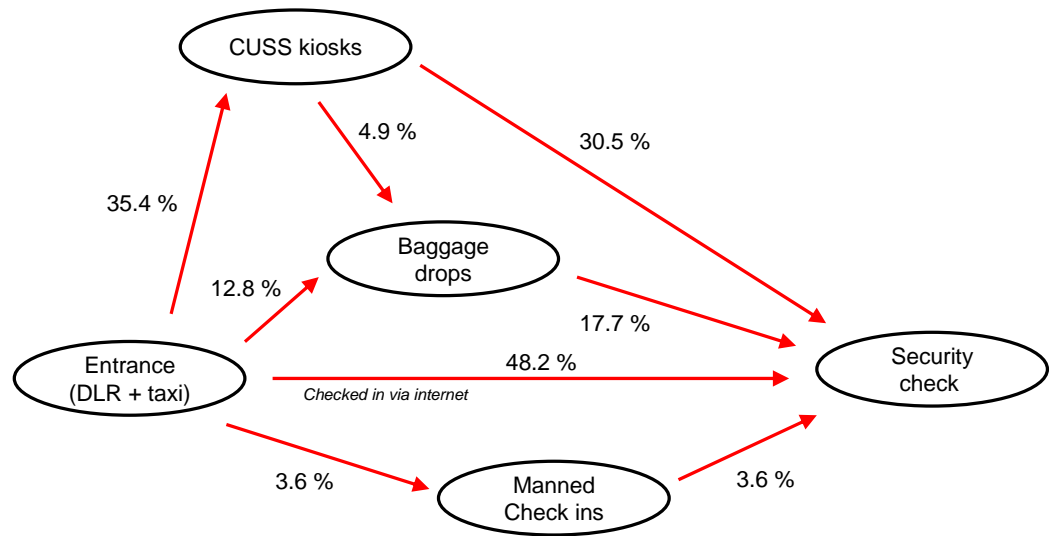
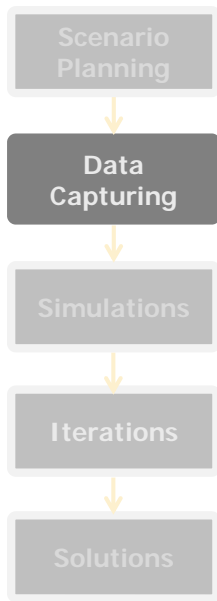
- Present vs future demand
- Peak vs off-peak
- Peak arrivals vs peak departures ...



**Airport** example

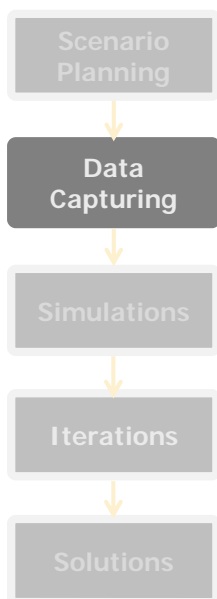
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## Data capturing: flow patterns

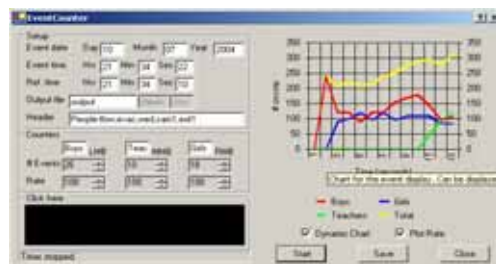


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## Data capturing: in-house technology



**SMART** Counter



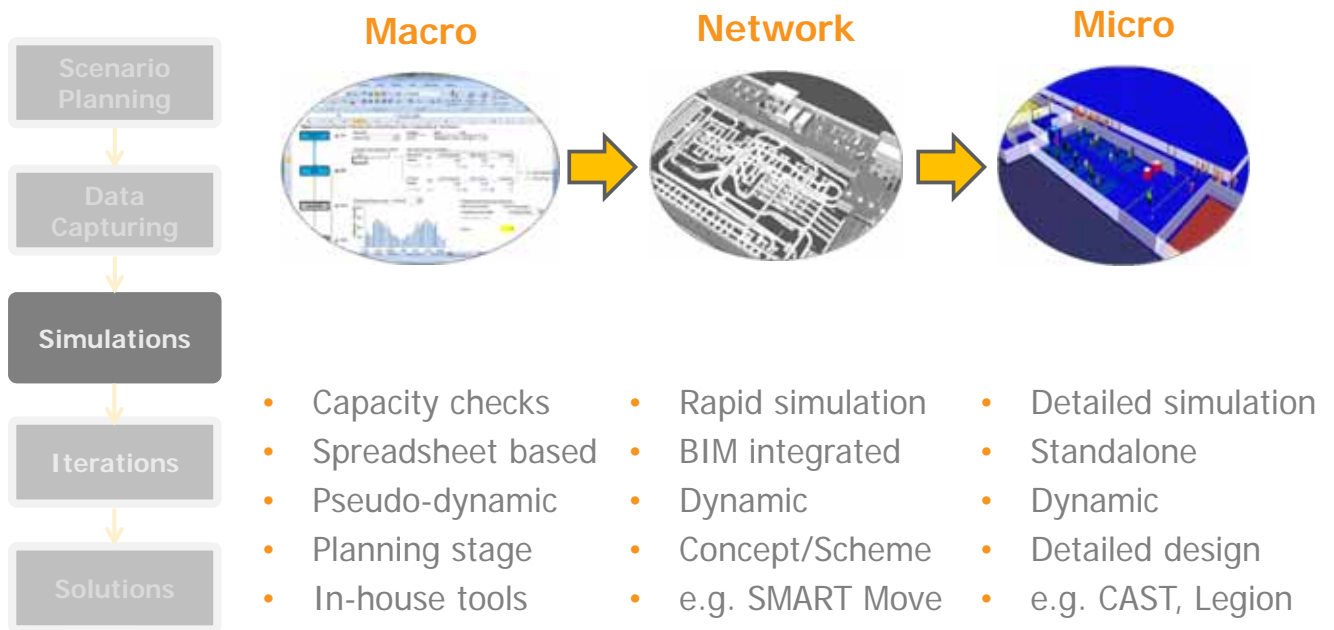
**Event** Counter



**Blue** Counter

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## Multi-resolution Modelling



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## Merging behaviour at stairs



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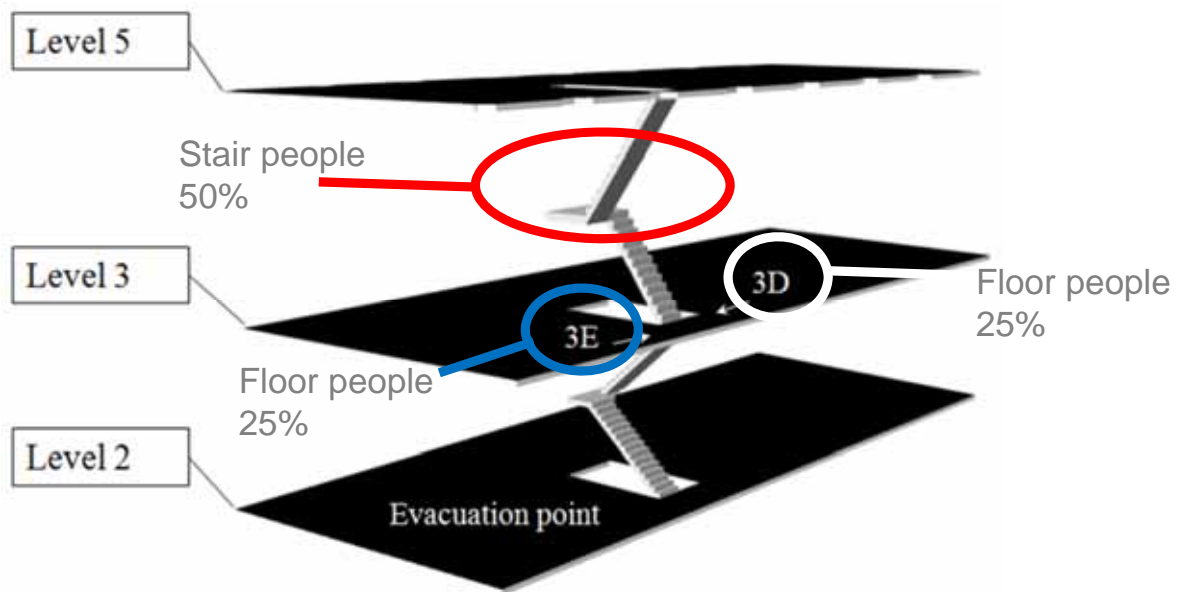


Stair configurations studied in this paper<sup>a.)</sup>



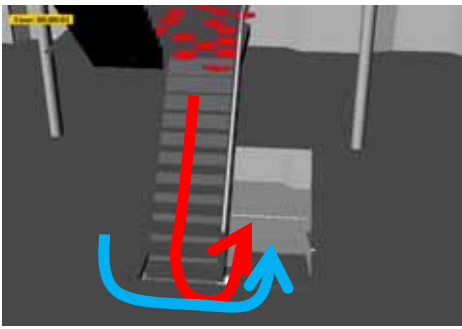
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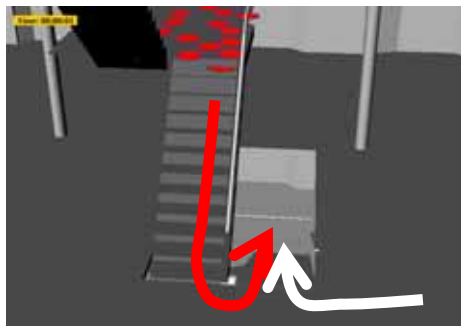


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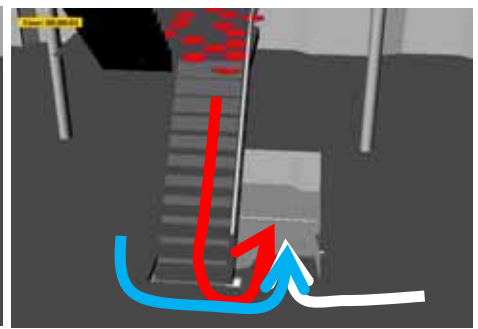
## Three Evacuation Experiments



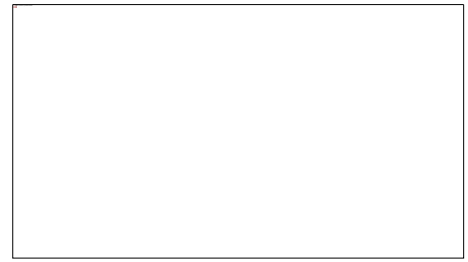
I  
In-line merge



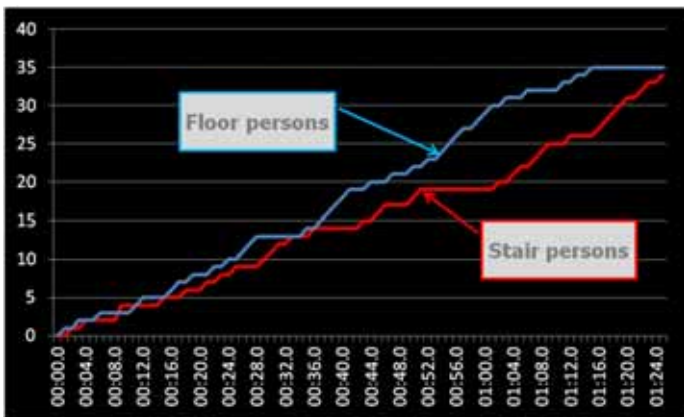
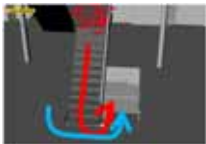
II  
Opposing merge



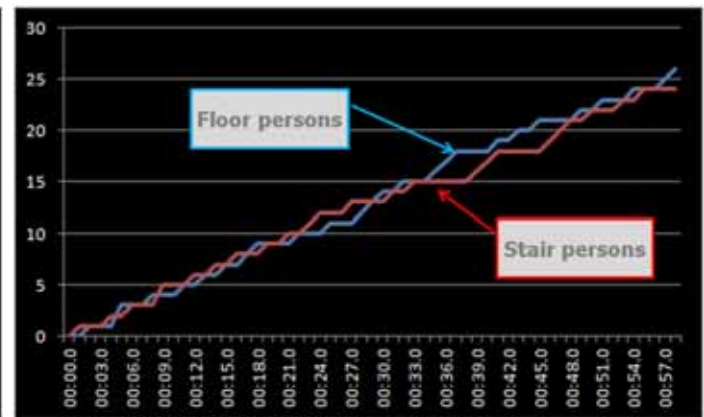
III  
3-way merge



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Experiment I (In-line Merge)



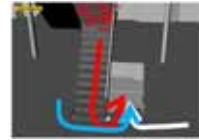
Experiment II (Opposing Merge)

Roughly equal deference.

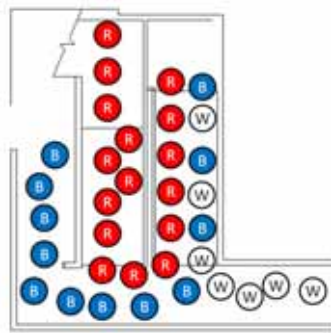
1 stair person merges with 1 floor person.

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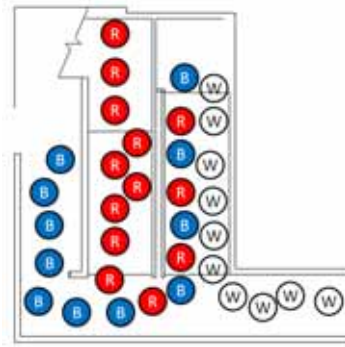
### Experiment III (3-way Merge)



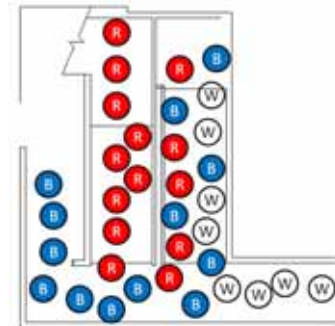
<span style="color: red;">●</span> R	Level 5 occupants
<span style="color: blue;">●</span> B	Level 3E occupants
<span style="color: grey;">●</span> W	Level 3D occupants



50 : 50



25 : 75

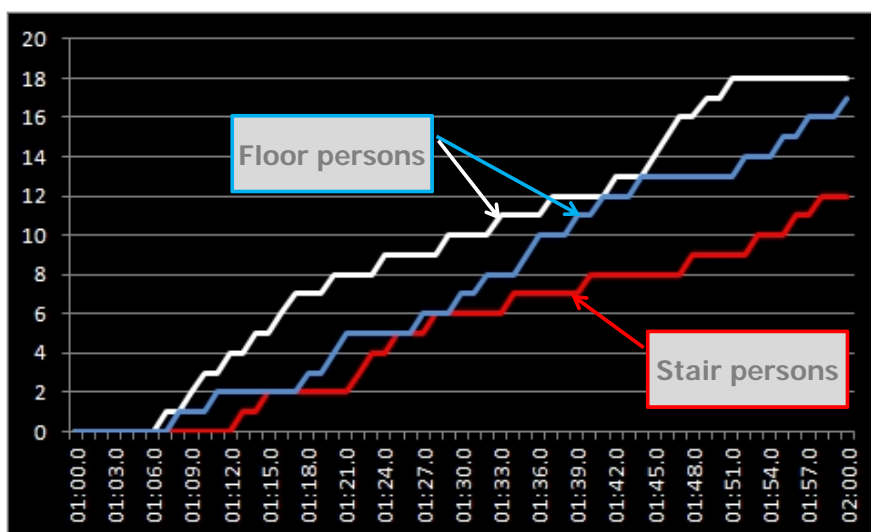
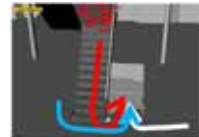


33 : 66

Merging Ratio

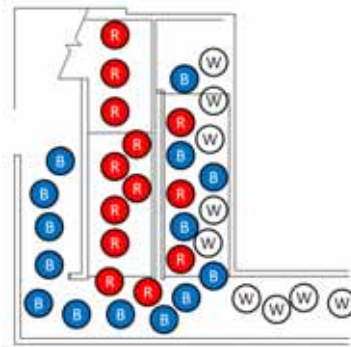
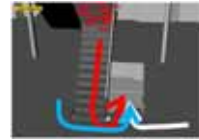
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### Experiment III (3-way Merge)



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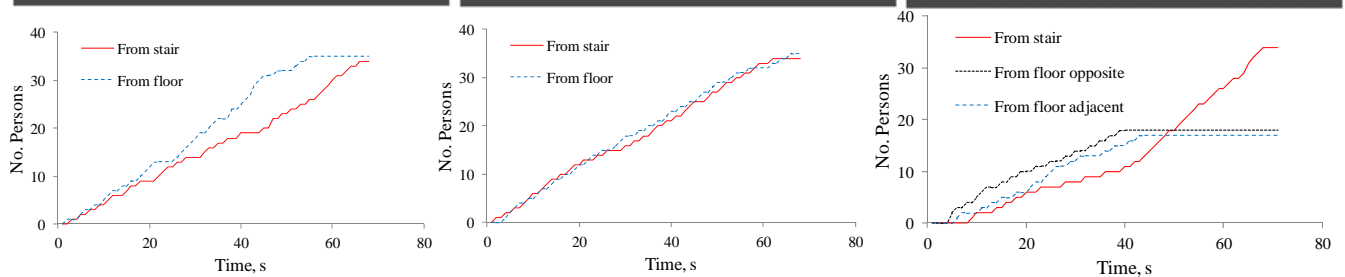
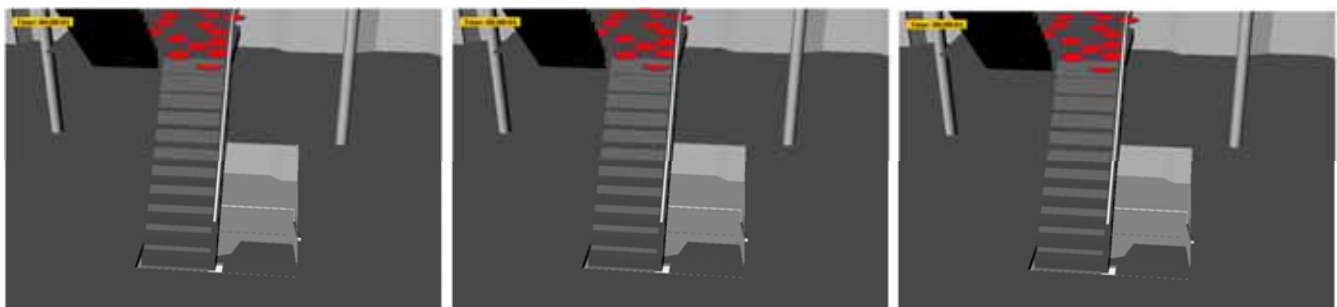
<span style="color: red;">●</span> R	Level 5 occupants
<span style="color: blue;">●</span> B	Level 3E occupants
<span style="color: white;">●</span> W	Level 3D occupants

#### Merging Ratio

Stairs (Red)	Opposite (White)	Adjacent (Blue)
24.5%	40%	35.5%

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### Evacuation time measured (ignoring pre-movement time)



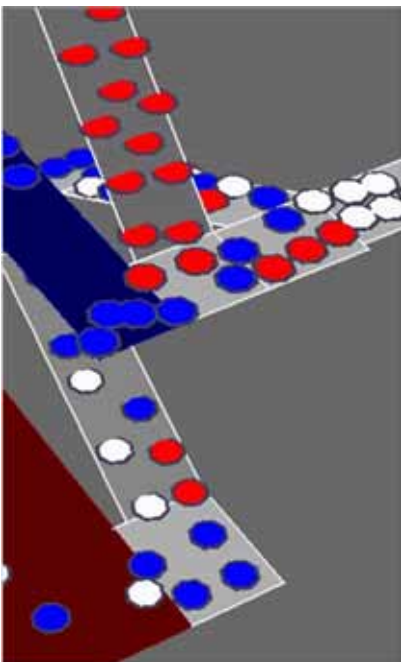
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## Deference modelling with SMART Move



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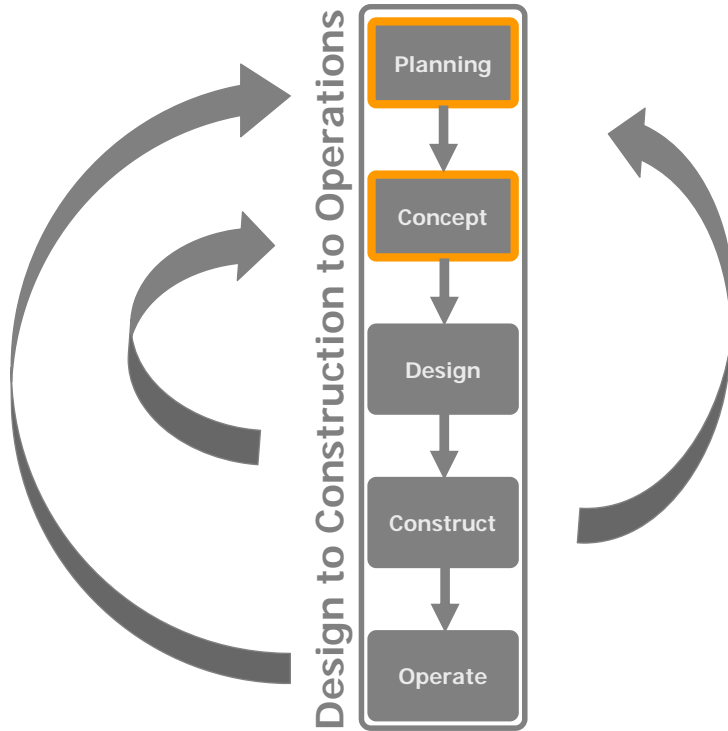


Test case	Group	Number of occupants	Merge Ratio	Time to evacuate
1	Stair	30	25%	89 sec
	Floor	30	75%	66 sec
2	Stair	60	21%	139 sec
	Floor	60	79%	73 sec
3	Stair	150	18%	331 sec
	Floor	150	82%	218 sec

**25:75** Deference (3-way)

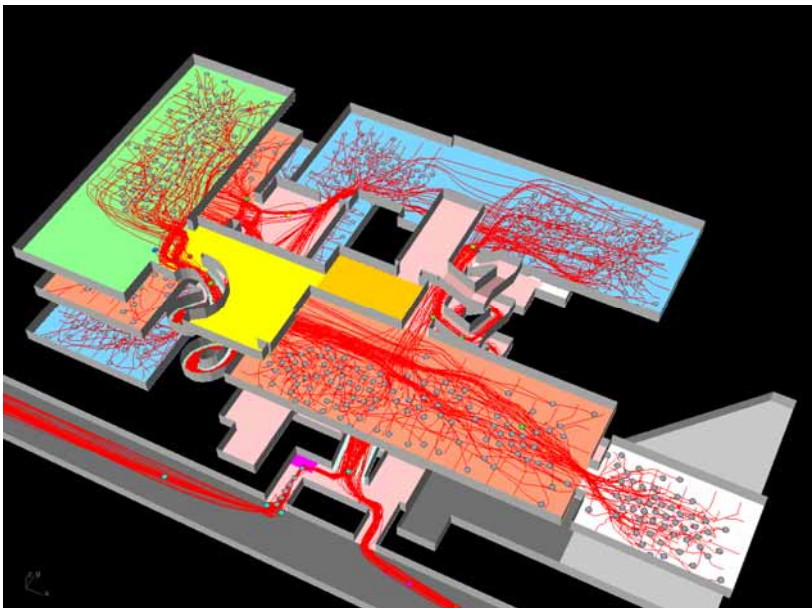
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## Rapid iterations for **conceptual** design and planning



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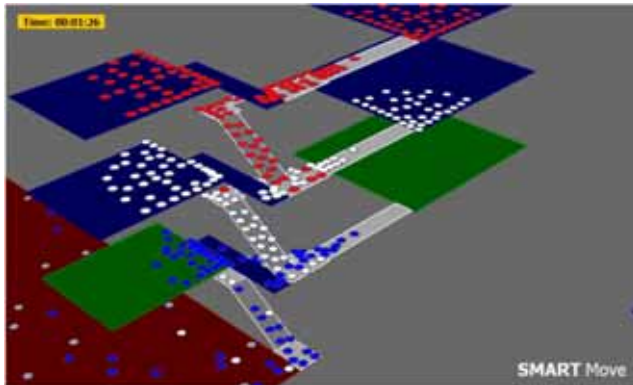
## Download **SMART** Move



[www.smart-solutions-network.com](http://www.smart-solutions-network.com)

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Thank you!



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[smart.burohappold.com](http://smart.burohappold.com)

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