VARIABILITY OF BEHAVOURAL PARAMETERS IN EGRESS SIMULATIONS OF STADIUMS

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Notable Stadium Disasters in the Past Three Decades

https://s.hdnux.com/photos/62/15/02/13160578/3/920x920.jpg

2018	Estádio da Luz Stadium (Portugal)
2018	Bendigo Stadium (Australia)
2018	Metlife Stadium (USA)
2017	Scotstoun Stadium (Scotland)
2017	Manchester Stadium (UK)
2012	Port Said Stadium (Egypt)
2010	Chinnaswamy Stadium (India)
2001	Accra Sports Stadium (West Africa)
1992	Armand Cesari Stadium (France)
1991	Oppenheimer Stadium (South Africa)
1989	Hillsborough Stadium (UK)

Causes of Stadium Disasters

Fire

Weather

Terrorism

Structural

Crowd Crush

Stadium Financial and Safety Considerations

Safety Through Design

Adhering to Egress and Capacity Standards and Benchmarks

Procedural Safety

Signage, Staff, Security Measures, etc.

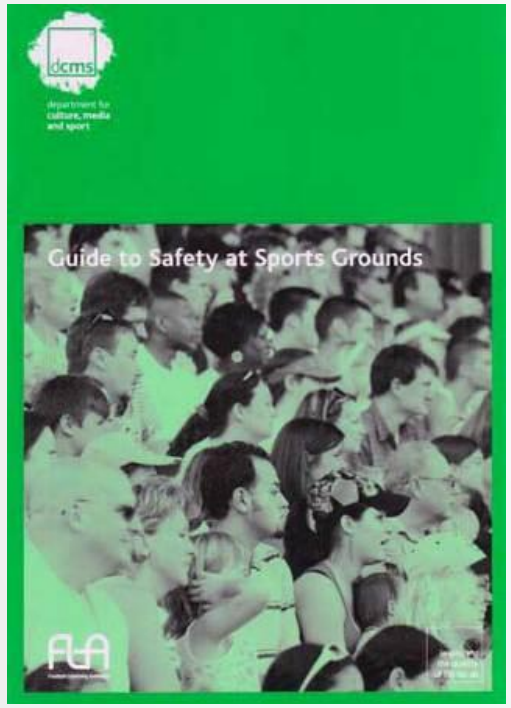
Financial Implications

Larger Capacity = Higher Potential Revenue

Stadium Guidelines and Standards

International

- The Green Guide



https://www.spservices.co.uk/imzages/products/pics/1304951394bo450.jpg

National

- National Fire Protection Association (NFPA 101)

https://www.nfpa.org/

Local Jurisdictions (Ex: Provincial or State)

- Example: Ontario Building Code (OBC)

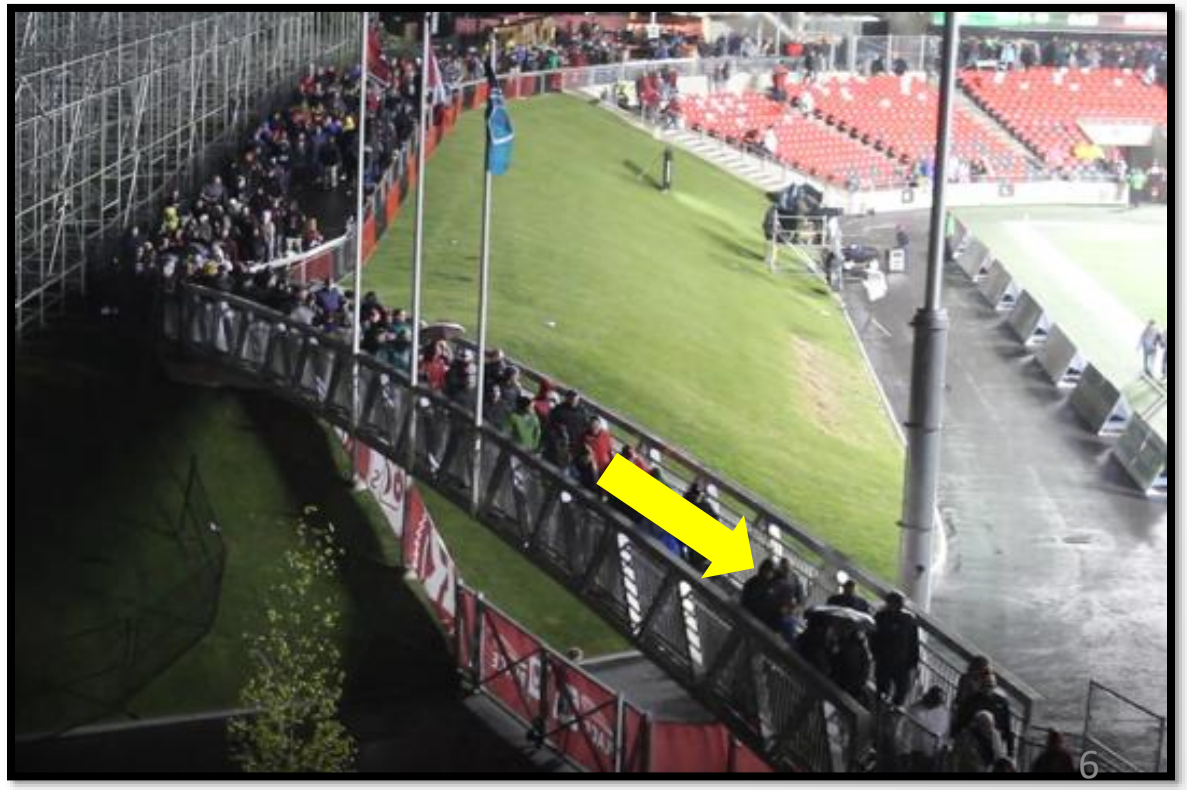
Experimental Trials

High resolution cameras captured egress routes and exits

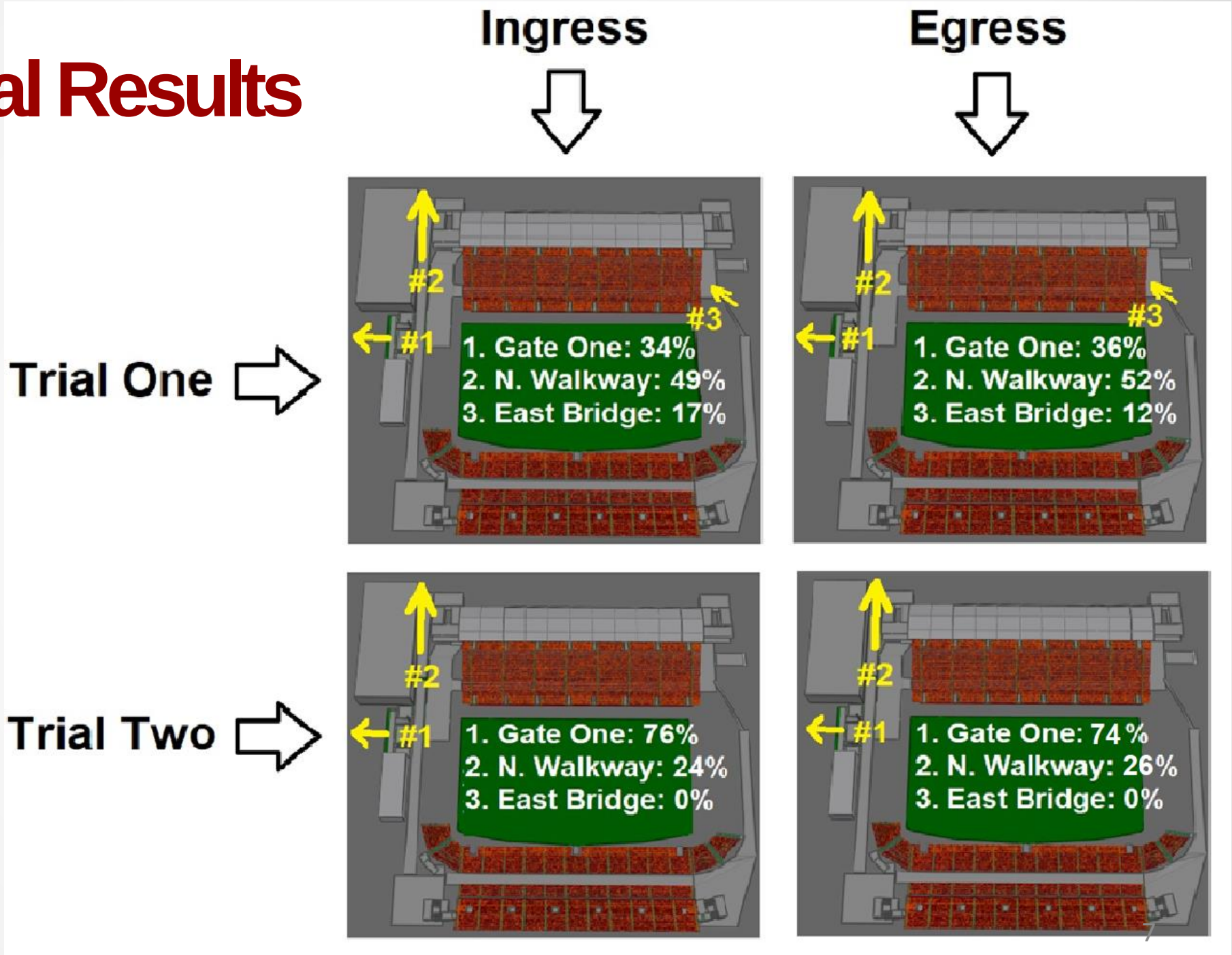
Trial One – Heavy rainfall
Trial Two – One exit closed

Two Trials (attendance 20,000+)
Trial One – 92% capacity
Trial Two – 97% capacity

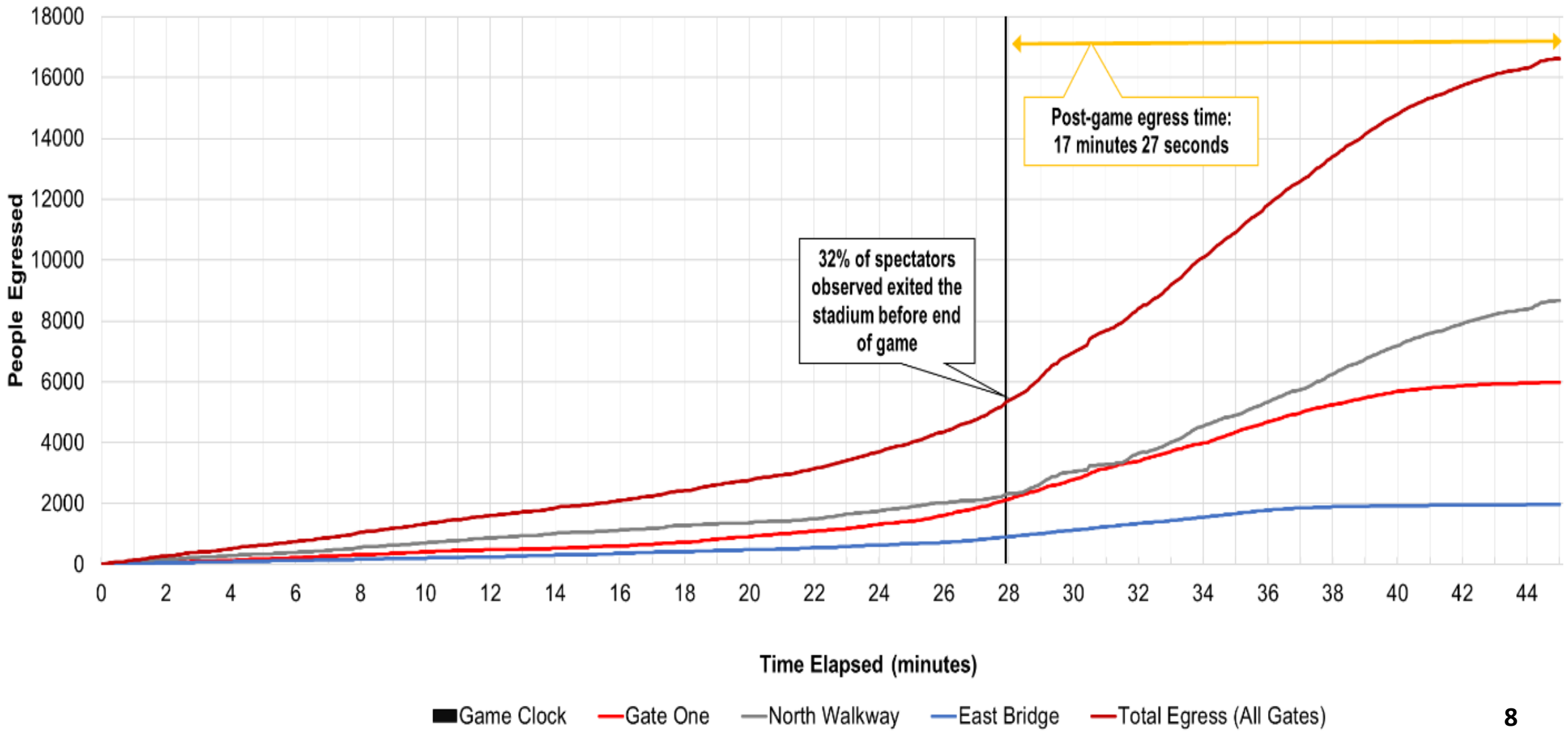
Three Exit Points



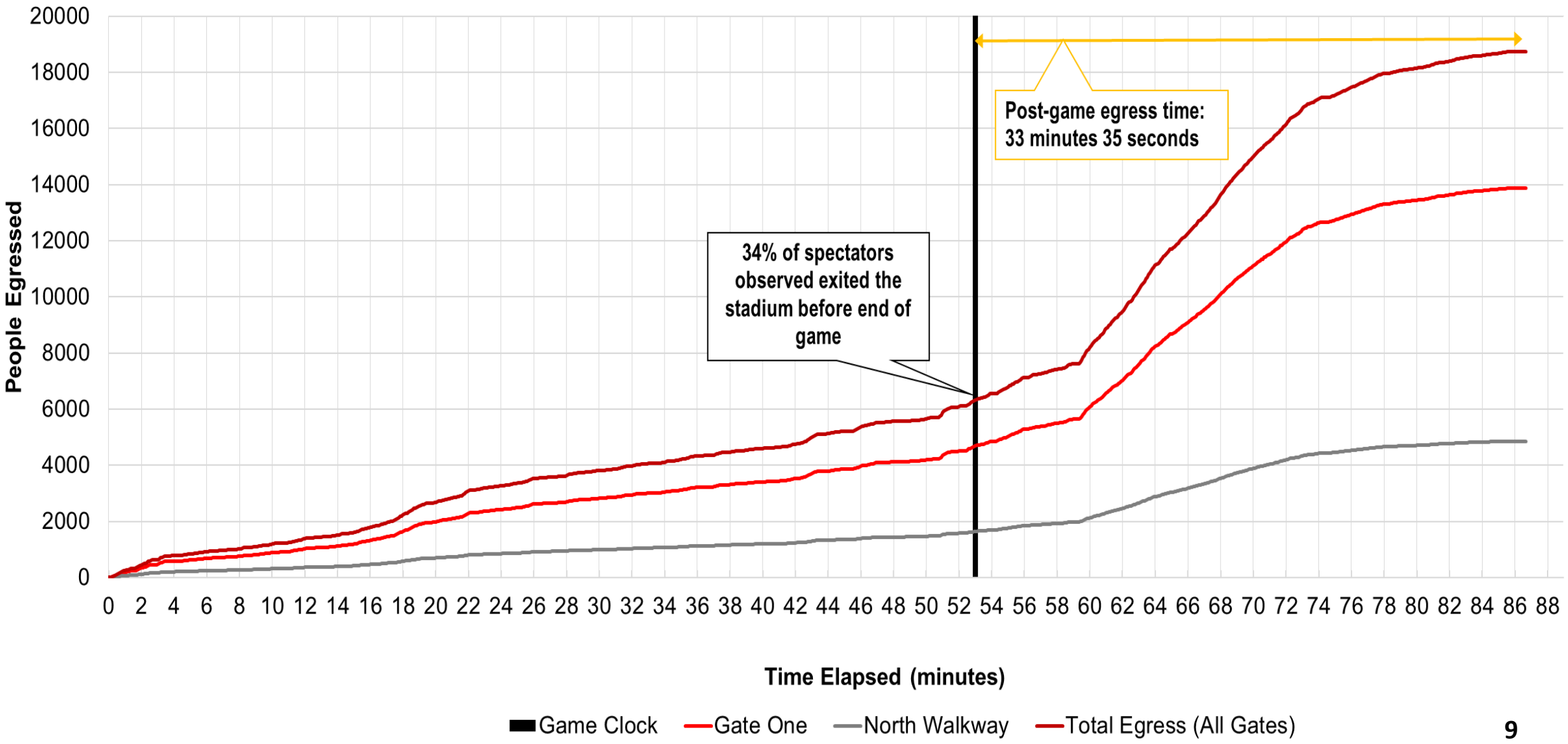
Experimental Results



Experimental Results (Trial One)



Experimental Results (Trial Two)

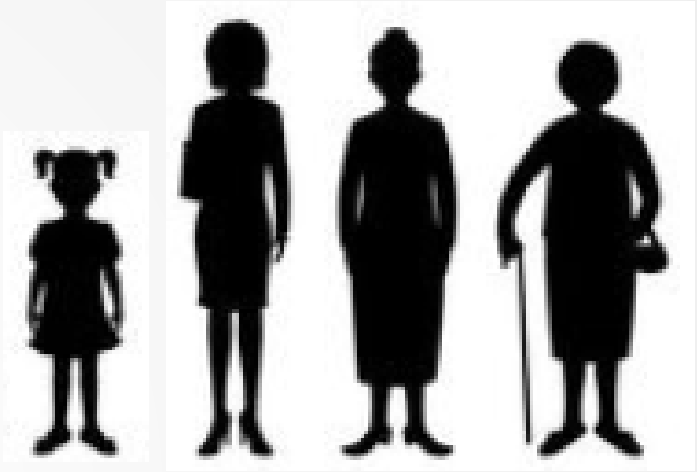


Modeling With MassMotion Pedestrian Software

Walking Speeds

Fruin, Ando

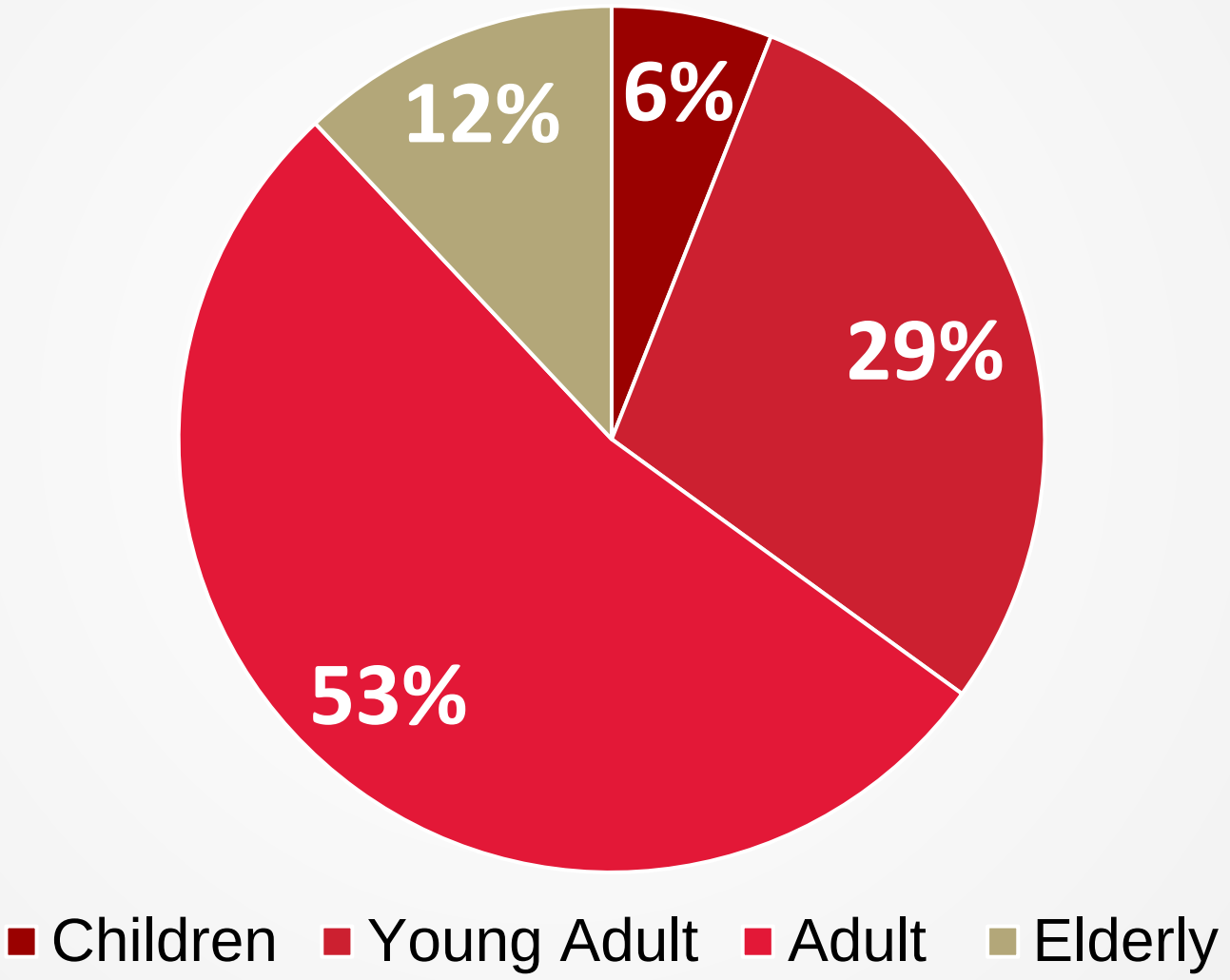
% Spectators that had started Egress	Time (s)
Minimum	5
10%	10
30%	17
50%	26
70%	38
90%	57
Maximum	70



Pre-Movement Time

Situation Specific Set

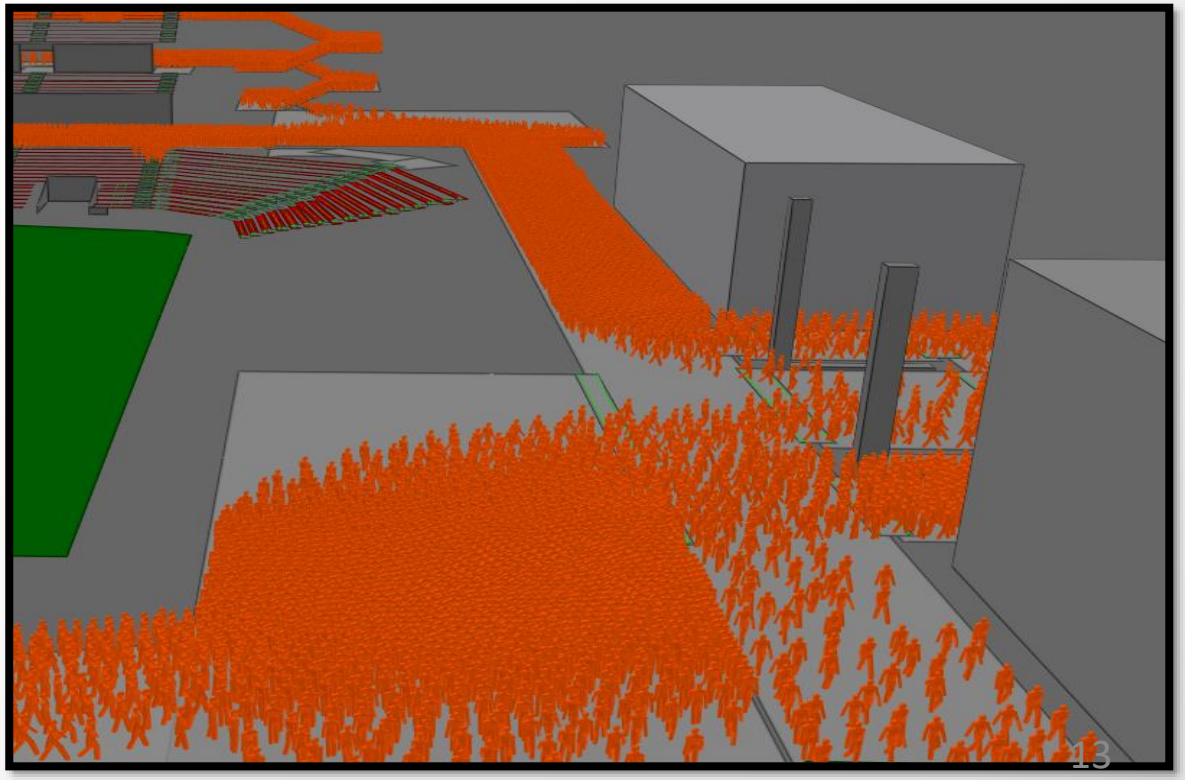
Demographics of Trials



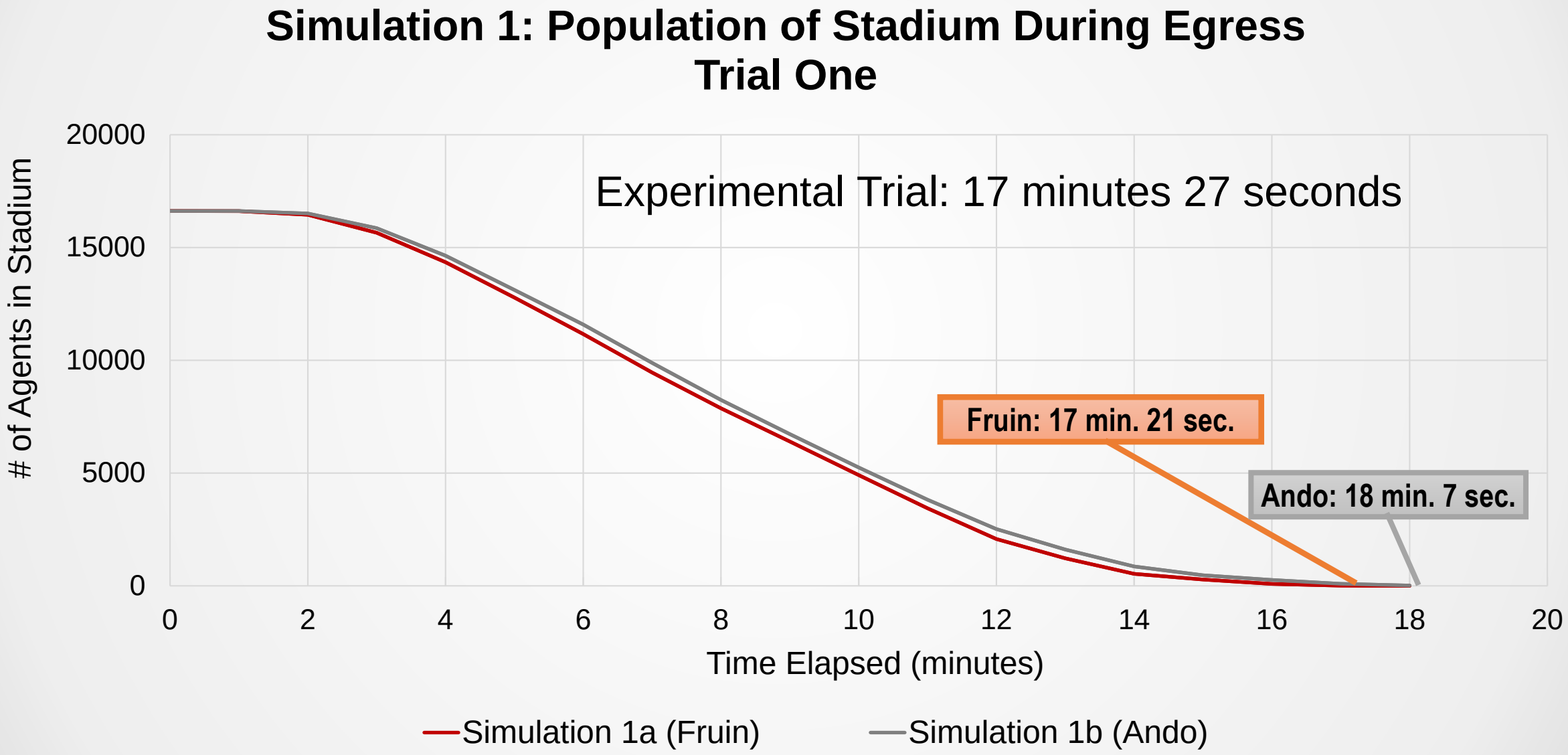
Validation Simulations

Simulation Number	Agent Speeds Applied	Demographics	Population Count	Exits Open or Closed
1a	Fruin	n/a	Trial One event actual number of spectators left in stadium at final game buzzer	All open
1b	Ando	As observed at events	Trial One event actual number of spectators left in stadium at final game buzzer	All open
2a	Fruin	n/a	Trial Two event actual number of spectators left in stadium at final game buzzer	East bridge closed
2b	Ando	As observed at events	Trial Two event actual number of spectators left at in stadium at final game buzzer	East bridge closed

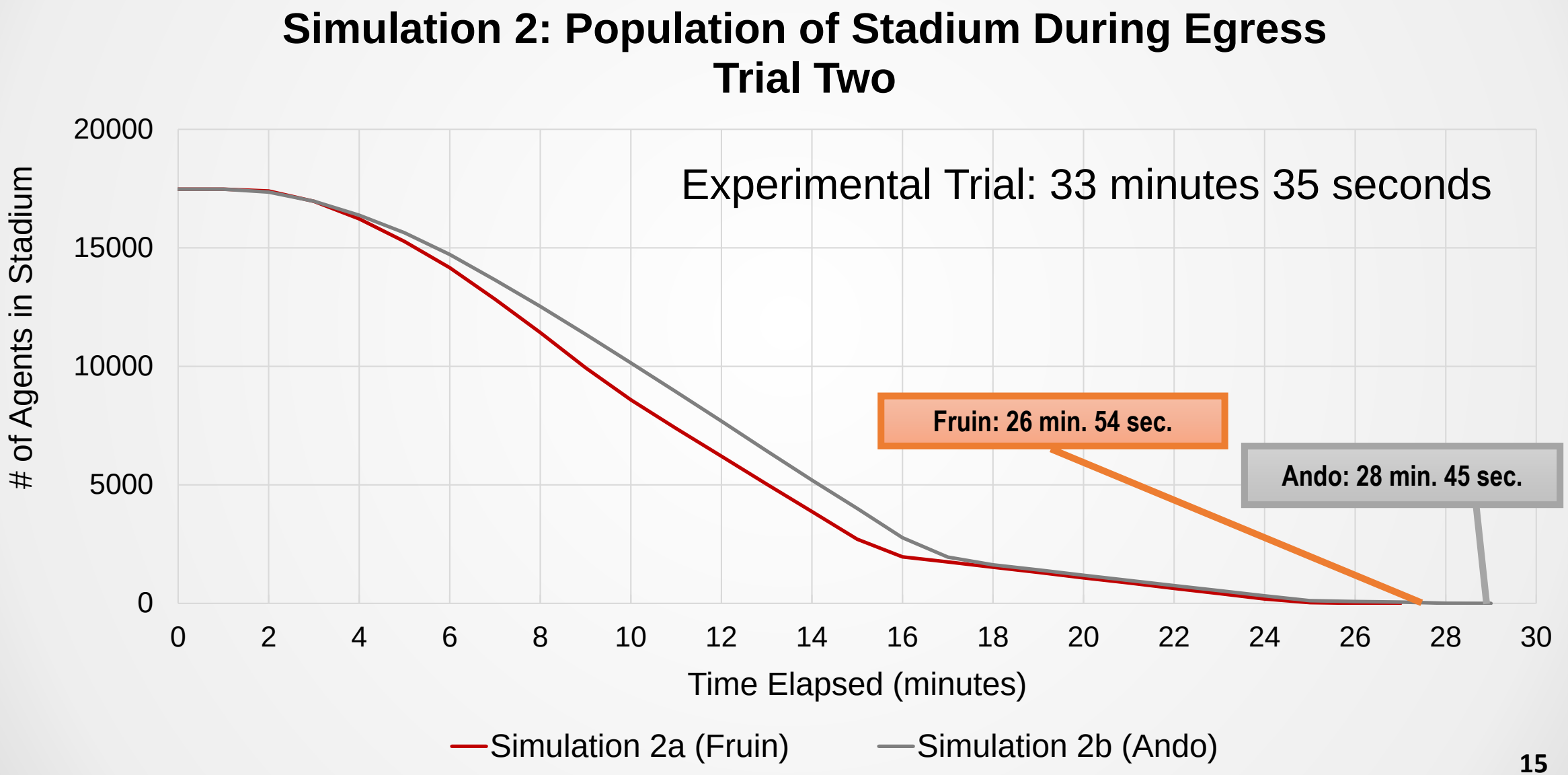
Modeling Qualitative Validation



Validation Simulations



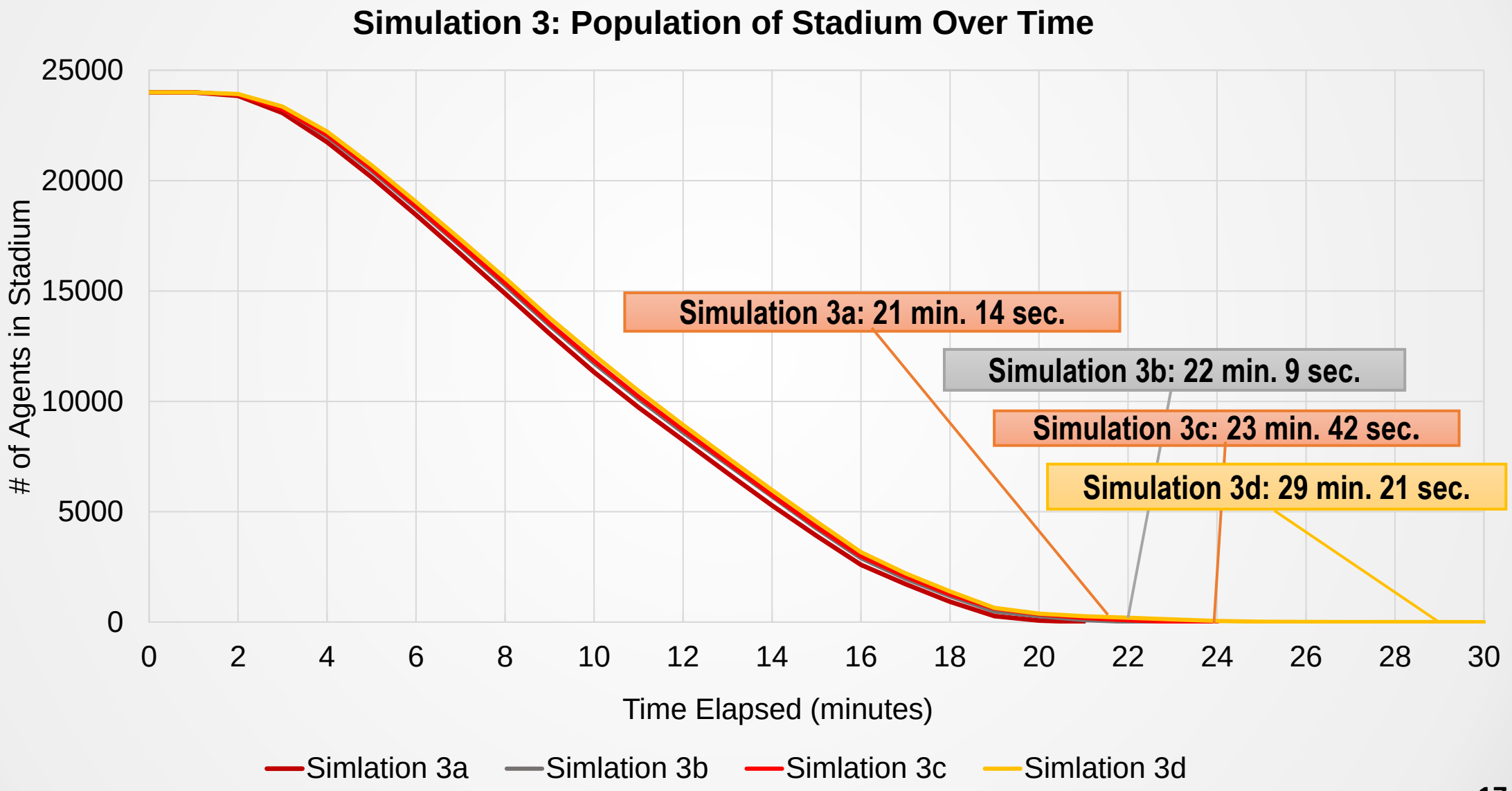
Validation Simulations



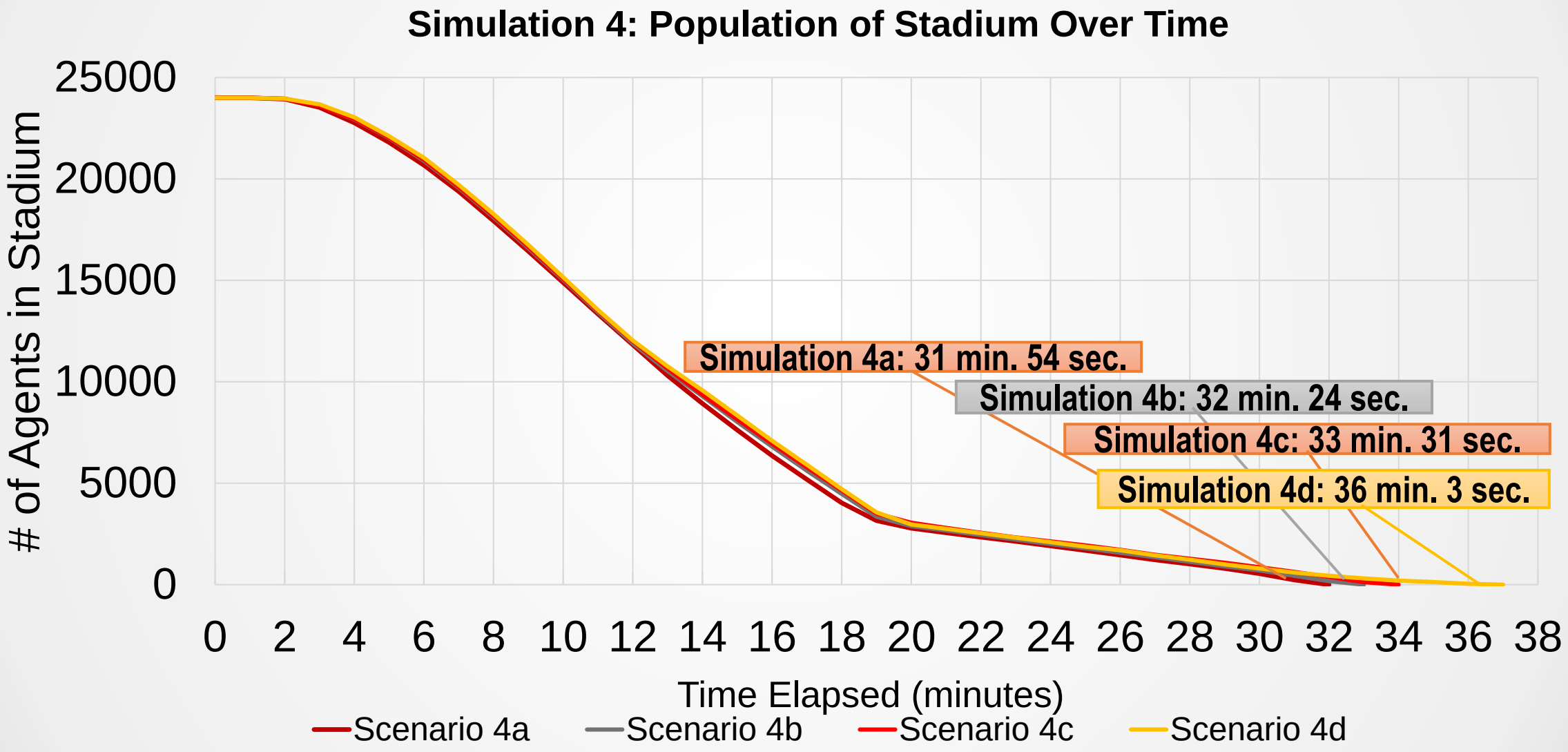
Predictive Simulations

	Simulation Number	Agent Speeds Applied	Demographics	Population Count	Exits Open or Closed
Testing at full capacity	3a	Fruin	n/a	At full capacity	All open
	3b	Ando	As observed at events	At full capacity	All open
	3c	Ando	Higher distribution of young people: 30% children, 45% young adult, 20% adult, 5% elderly	At full capacity	All open
	3d	Ando	Higher distribution of elderly: 5% children, 20% young adult, 30% adult, 45% elderly	At full capacity	All open
Testing impact of one main exit closure at full capacity	4a	Fruin	n/a	At full capacity	East Bridge closed
	4b	Ando	As observed at events	At full capacity	East Bridge closed
	4c	Ando	Higher distribution of young people: 30% children, 45% young adult, 20% adult, 5% elderly	At full capacity	East Bridge closed
	4d	Ando	Higher distribution of elderly: 5% Children, 20% Young Adult, 30% Adult, 45% Elderly	At full Capacity	East Bridge closed

Predictive Simulations



Predictive Simulations



Preliminary Conclusions and Future Work

1. All egress times in excess of 8 minutes
2. Egress was not of high-stress state
3. For this stadium - egress times governed by architecture not demographics

Acknowledgements

ARUP UK Fire Group

ARUP North Americas Group

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