THE INFLUENCE OF CALIBRATED MOVEMENT DATA ON MOVEMENT EGRESS TIMES IN COMPUTATIONAL SIMULATION MODELING

7th Fire and Evacuation Modeling Technical Conference
(FEMTC 2024)

GOODHEAD
CONSULTING ENGINEERS

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SPEAKER BIO

Raeshawn Kennedy, PE
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Raeshawn Kennedy is a passionate Fire Protection Engineer who loves learning the science and tools behind fire and egress modeling. Raeshawn is a registered professional Fire Protection Engineer in the United States and has received his Master of Science (M.S.) degree in Fire Protection Engineering from Worcester Polytechnic Institute (WPI). Raeshawn currently works as a Senior Engineer at Goodhead Consulting Engineers.

With close to a decade of technical experience and a high attention to detail, Raeshawn has been involved in complex and large-scale performance-based design projects across a variety of building types and project typologies. Raeshawn holds a high standard of engineering and has a pragmatic approach to complex problem-solving. Some project examples include transportation and large population buildings across North America including Hartsfield-Jackson Atlanta International Airport and Ottawa, Canada's O-Train extension. Raeshawn also has international experience working on large assembly buildings in the Caribbean and Asian markets.

Dedicated to learning and applying his research, Raeshawn has presented his computational egress modeling research at the 2024 Performance-Based Design Conference in Copenhagen, Denmark, and the 2024 Fire and Evacuation Modeling Conference in Kansas City, MO.

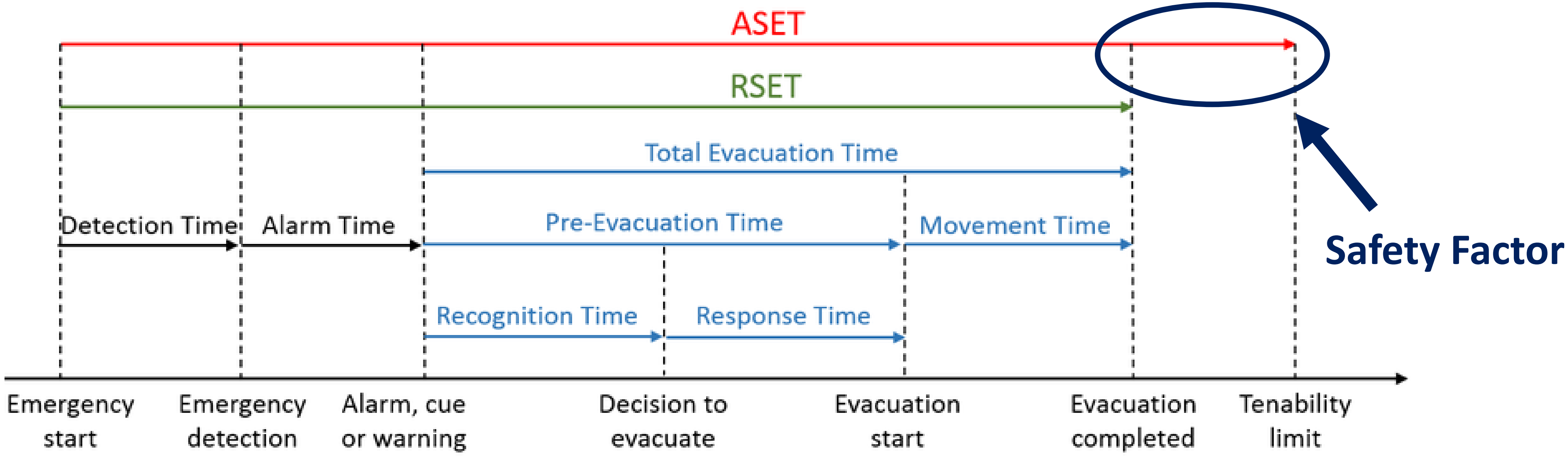
Why?

- **Egress Movement times** calculated using calibrated occupant physical parameters can be **up to 100% longer** than movement times calculated using default settings.

Movement Egress Times were Doubled (2x)!

If the model showed a movement egress time of **7 minutes** using default settings, that is actually **14 minutes** when using calibrated data.

ASET vs. RSET Performance Based Design Analysis



Lovreglio, R., "Modelling Decision-Making in Fire Evacuation based on Random Utility Theory," PhD Thesis, 2016. https://doi.org/10.13140/RG.2.1.1695.5281/1.

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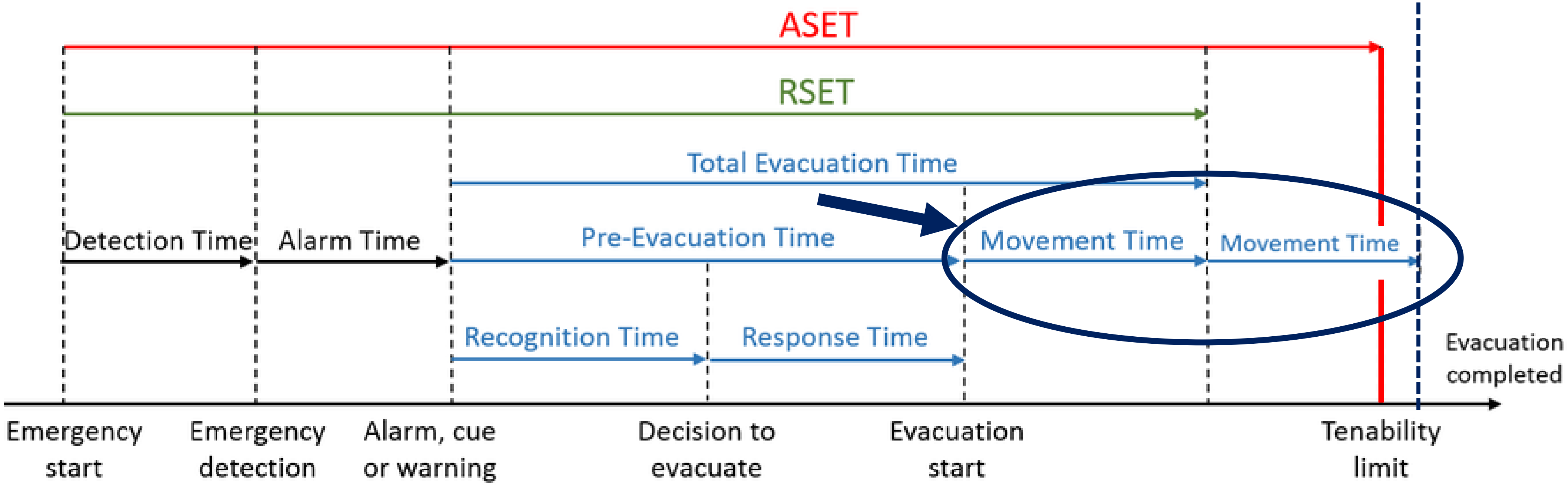

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100% (2x) IS A BIG ERROR IN FIRE SAFETY.

Purpose and Goal

Purpose: Quantify egress movement time errors introduced by,

- Default settings for Speed, Diameter, Reduction Factor, and Personal Distance (Phase 1)
- Using calibrated occupant data from a different geographic location (Phase 2)

Goal: Understand the importance of obtaining calibrated occupant data for generating accurate egress model simulation results

Phase 1 Research

Default vs. Calibrated Physical Occupant Characteristics

Where do default settings come from?

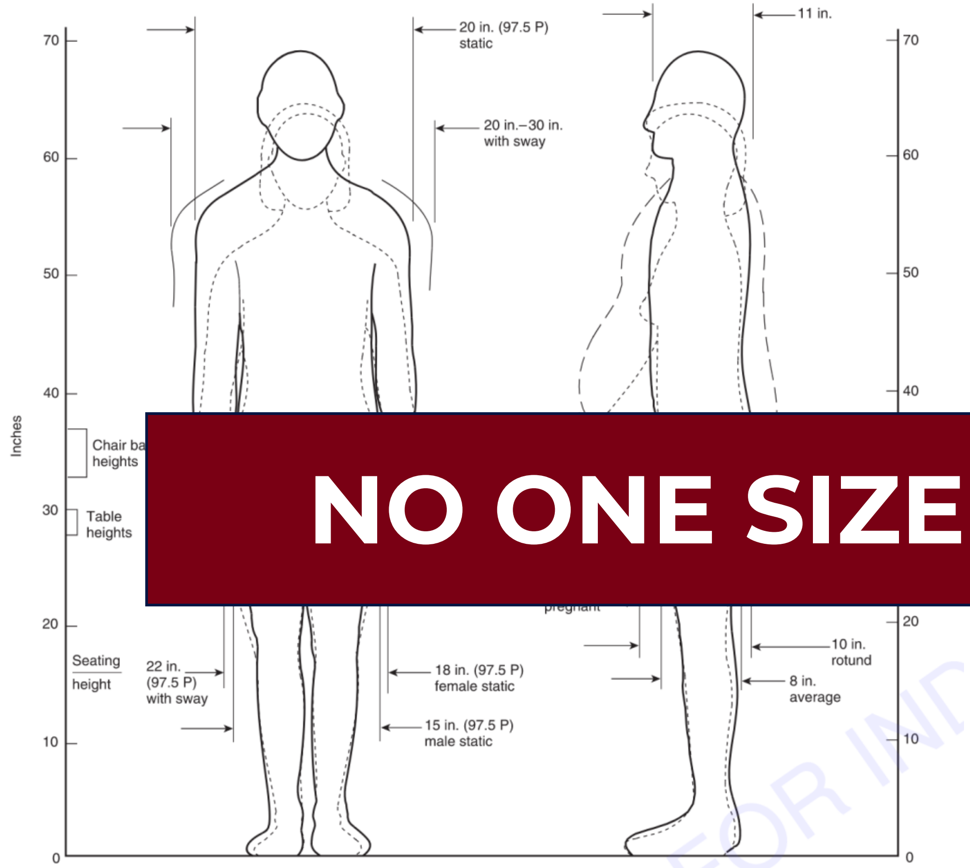


FIGURE A.7.3.4.1.1(a) Anthropometric Data (in in.) for Adults; Males and Females of Average, 50th Percentile, Size; Some Dimensions Apply to Very Large, 97.5 Percentile (97.5 P), Adults.

NFPA 101 Life Safety Code (2018 Edition): Figure A.7.3.4.1.1(a)

1005.3 Required capacity based on occupant load. The required capacity, in inches (mm), of the *means of egress* for any room, area, space or *story* shall be not less than that determined in accordance with Sections 1005.3.1 and 1005.3.2.

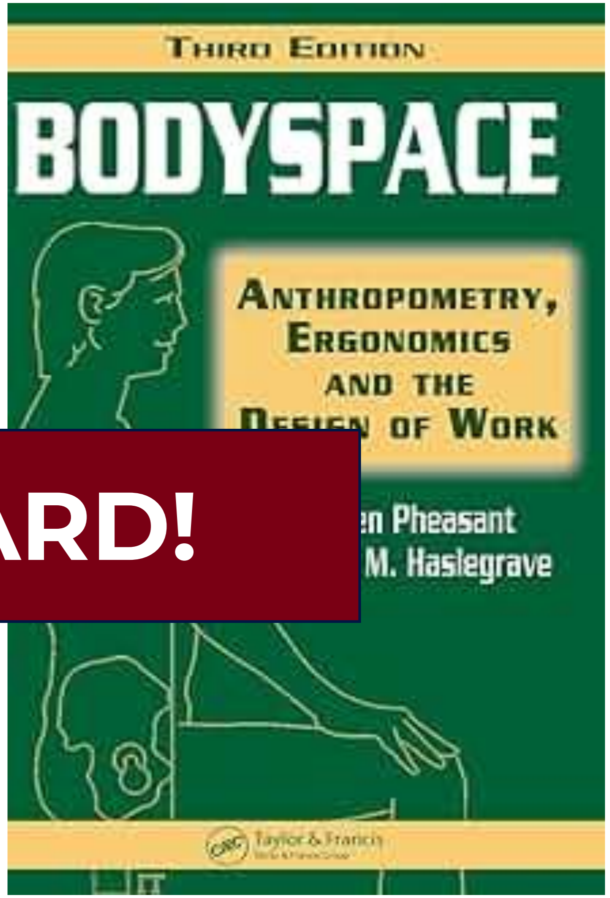
The traditional unit of measurement of egress capacity was based on a “unit exit width” that was to simulate the body ellipse with a basic dimensional width of 22 inches (559 mm)—approximately the shoulder width of an average adult male. This unit exit width was combined with assumed egress movement

...

predictable movements. As traditionally used in the codes, the method of determining capacity per unit of clear width implies a higher level of accuracy than can realistically be achieved. The resulting factors preserve the features of the past practices that can be documented, while providing a more straightforward method of determining egress capacity.

International Building Code (Code and Commentary, 2021 Edition): Section 1005.3

NO ONE SIZE FITS ALL STANDARD!



Pathfinder User Guide: Pheasant, Stephen, and Christine M. Haslegrave. 2005. Bodyspace: Anthropometry, Ergonomics and the Design of Work. 3rd ed. CRC Press.

Key Observations

TABLE 1: DEFAULT PATHFINDER VALUES VS. CALIBRATED EASTERN UNITED STATES AIRPORT [1] OCCUPANT DATA (SELECT PROFILES)

PROFILES	SPEED (m/sec)		% CHANGE FROM DEFAULT	SHOULDER WIDTH (m)	% CHANGE FROM DEFAULT	REDUCTION FACTOR	% CHANGE FROM DEFAULT	PERSONAL DISTANCE (m)	% CHANGE FROM DEFAULT
DEFAULT	**CONSTANT:**	**1.19**		**0.46 (18 in.)**	**-**	**0.70**	**-**	**0.08**	**-**
SINGLE WITH ROLLER BAG	MIN:	0.80	-33%	0.91 (36 in.)	98%	0.70	0%	0.91	1038%
	MAX:	3.35	182%						
	MEAN:	1.28	8%						
	STD DEV:	0.32	-						
GROUP / FAMILY	MIN:	0.47	-60%	0.61	33%	1.00	43%	0.46	475%
	MAX:	1.47	24%						
	MEAN:	0.98	-18%						
	STD DEV:	0.20	-						
MOBILITY IMPAIRED - SELF PROPELLED	MIN:	1.27	7%	0.91 (36 in.)	98%	1.00	43%	0.91	1038%
	MAX:	1.83	54%						
	MEAN:	1.49	25%						
	STD DEV:	0.24	-						

[1] S. Goodhead and S. Strege, "People Movement Study of Large Airport Data Generation, Flow Dynamics and Coupled Analysis," 2015.

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Author's Questions

1. What is the effect of using default physical occupant parameters on calculated movement time compared to calibrated occupant user data?

2. Which of the four identified physical parameters has the most influence on calculated movement times?
   - Speed, Diameter (Shoulder Width), Reduction Factor, and Personal Distance (previously known as Comfort Distance)

Methodology

TABLE 2: INFLUENCE OF DEFAULT PHYSICAL OCCUPANT PARAMETERS ON EGRESS MOVEMENT TIMES

PATHFINDER SIMULATION	OCCUPANT PROFILES	SPEED	DIAMETER SHOULDER WIDTH	REDUCTION FACTOR	PERSONAL DISTANCE	NOTES
1	DEFAULT	DEFAULT	DEFAULT	DEFAULT	DEFAULT	BASELINE DEFAULT RUN
2	DEFAULT	DEFAULT	DEFAULT	OFF	DEFAULT	
3	CALIBRATED	DEFAULT	DEFAULT	DEFAULT	DEFAULT	
4	CALIBRATED	DEFAULT	DEFAULT	DEFAULT	CALIBRATED	
5	CALIBRATED	DEFAULT	DEFAULT	CALIBRATED	DEFAULT	
6	CALIBRATED	DEFAULT	DEFAULT	CALIBRATED	CALIBRATED	
7	CALIBRATED	DEFAULT	CALIBRATED	DEFAULT	DEFAULT	
8	CALIBRATED	DEFAULT	CALIBRATED	DEFAULT	CALIBRATED	
9	CALIBRATED	DEFAULT	CALIBRATED	CALIBRATED	DEFAULT	
10	CALIBRATED	DEFAULT	CALIBRATED	CALIBRATED	CALIBRATED	
11	CALIBRATED	CALIBRATED	DEFAULT	DEFAULT	DEFAULT	
12	CALIBRATED	CALIBRATED	DEFAULT	DEFAULT	CALIBRATED	
13	CALIBRATED	CALIBRATED	DEFAULT	CALIBRATED	DEFAULT	
14	CALIBRATED	CALIBRATED	DEFAULT	CALIBRATED	CALIBRATED	
15	CALIBRATED	CALIBRATED	CALIBRATED	DEFAULT	DEFAULT	
16	CALIBRATED	CALIBRATED	CALIBRATED	DEFAULT	CALIBRATED	
17	CALIBRATED	CALIBRATED	CALIBRATED	CALIBRATED	DEFAULT	
18	CALIBRATED	CALIBRATED	CALIBRATED	CALIBRATED	CALIBRATED	BASELINE CALIBRATED RUN
19	CALIBRATED	CALIBRATED	CALIBRATED	OFF	CALIBRATED	
20	CALIBRATED	MEAN	CALIBRATED	CALIBRATED	CALIBRATED	

Results

TABLE 3: INFLUENCE OF DEFAULT PHYSICAL OCCUPANT PARAMETERS ON EGRESS MOVEMENT TIMES – RESULTS

PATHFINDER SIMULATION	EGRESS TIME (H:MM:SS)	PERCENT CHANGE FROM SIMULATION #1 (DEFAULT)
1 (DEFAULT)	0:06:02	-
2	0:06:32	8%
3	0:06:05	1%
4	0:06:54	14%
5	0:06:15	4%
6	0:07:20	21%
7	0:09:50	63%
8	0:10:46	79%
9	0:09:28	57%
10	0:10:35	75%
16	0:11:47	95%
17	0:10:32	75%
18 (CALIBRATED)	0:12:11	102%
19	0:12:22	105%
20	0:10:52	80%

EVEN A SENSITIVITY ANALYSIS COULD NOT HAVE PREDICATED THE DIFFERENCE.

Results

TABLE 4: INFLUENCE OF DEFAULT PHYSICAL OCCUPANT PARAMETERS RANKED (1 = MOST INFLUENCE, 4 = LEAST INFLUENCE)

SPEED	SHOULDER WIDTH	REDUCTION FACTOR	PERSONAL DISTANCE
3	1	4	2

Phase 2 Research

Comparison of Geographically Disparate Airport User Data

Key Observations

Table 5: USER GROUP CHARACTERISTICS COMPARISON – WESTERN VS. EASTERN UNITED STATES AIRPORT (SELECT USER GROUPS)

OCCUPANT PROFILES	SINGLE WITH ROLLER BAG	SINGLE W/O ROLLER BAG	MOBILITY IMPAIRED – SELF PROPELLED
WESTERN UNITED STATES SHOULDER WIDTH (m)	0.69	0.5	0.49
EASTERN UNITED STATES SHOULDER WIDTH (m)	0.91	0.61	0.91
PERCENT DIFFERENCE	**-27%**	**-21%**	**-60%**

Key Observations

Table 6: EASTERN AND WESTERN UNITED STATES AIRPORT OCCUPANT PROFILE COMPARISON (GENERALIZED)

OCCUPANT PROFILES	WESTERN UNITED STATES AIRPORT	EASTERN UNITED STATES AIRPORT
SINGLE OCCUPANTS	57.4%	64.2%
GROUPS AND FAMILIES	38.8%	23.0%
MOBILITY IMPAIRED	3.9%	12.8%

Author’s Question

1. What effect does using calibrated data from similar user groups with a different geographic location have on calculated movement times?

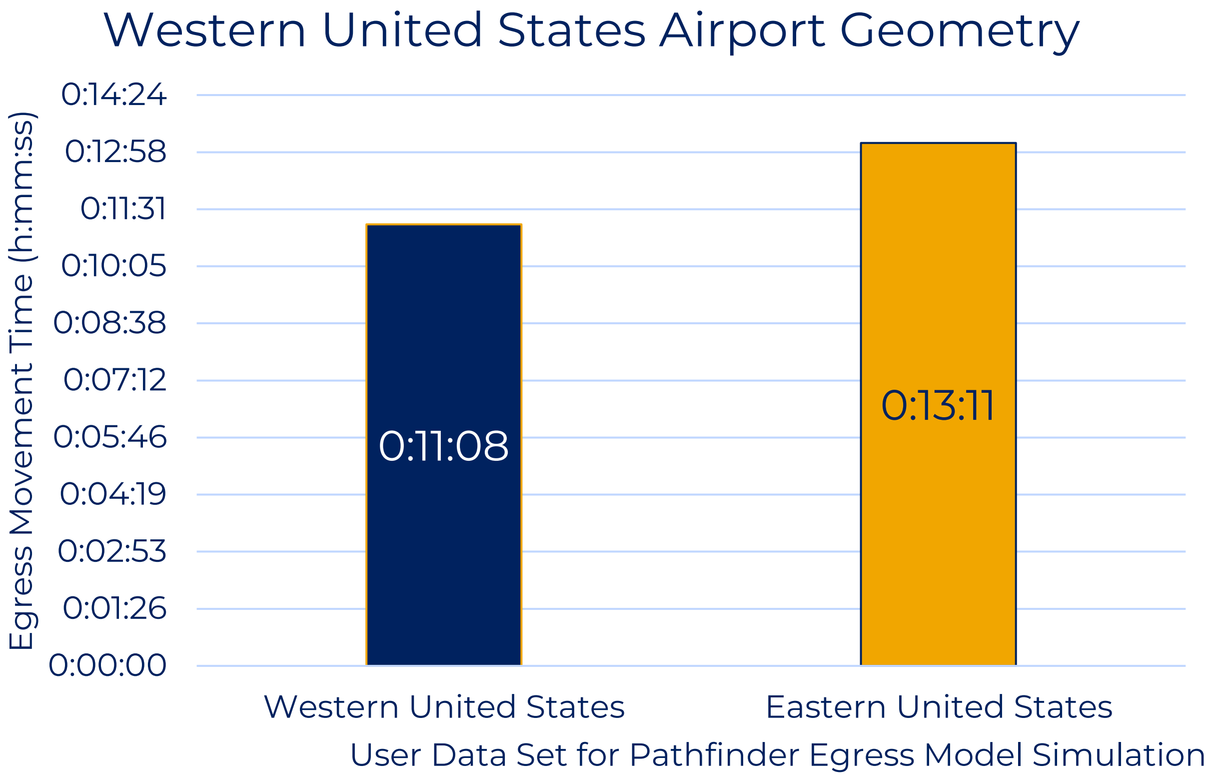


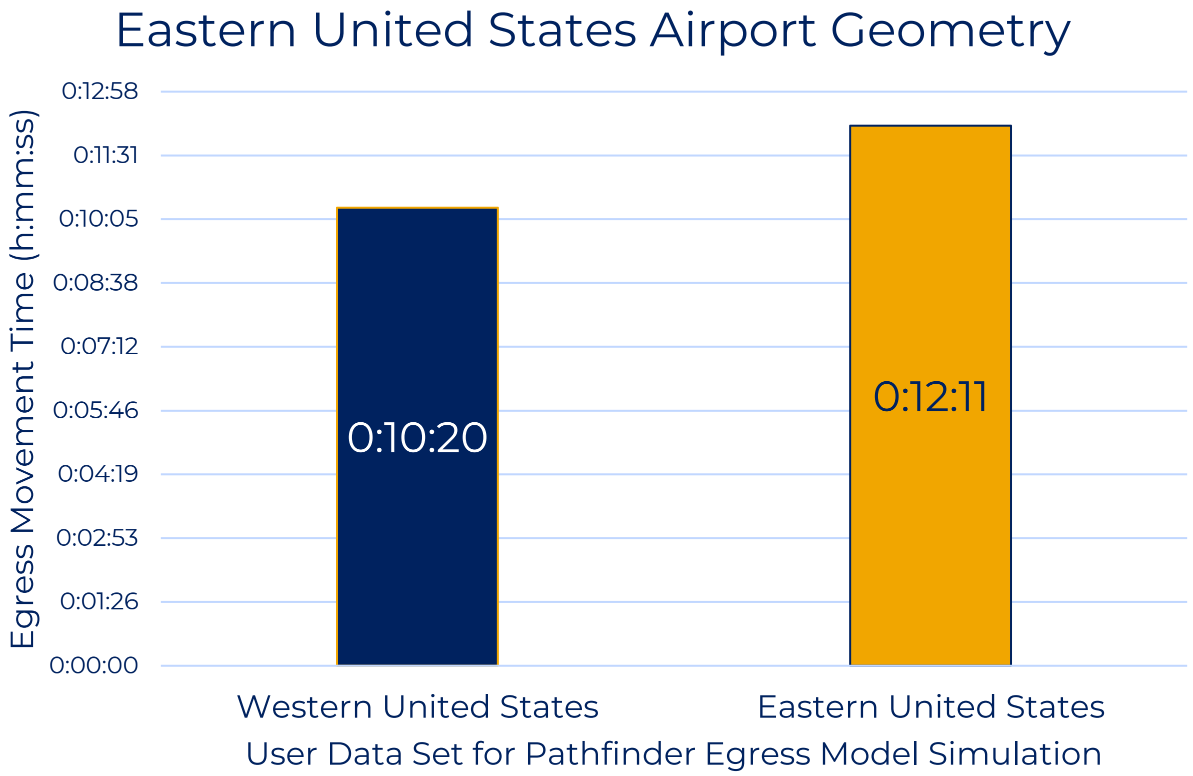
Methodology

TABLE 7: PHASE 2 METHODOLOGY – OCCUPANT GEOGRAPHIC INFLUENCE ON MOVEMENT TIMES

RUN	LOCATION (UNITED STATES)	OCCUPANT PROFILES	SPEED	SHOULDER WIDTH	REDUCTION FACTOR	PERSONAL DISTANCE	NOTES
1	WESTERN	WESTERN	WESTERN	WESTERN	WESTERN	WESTERN	BASELINE WESTERN US RUN
2	WESTERN	DEFAULT	DEFAULT	DEFAULT	DEFAULT	DEFAULT	DEFAULT WITH INITIAL OCCUPANT POSITION AS RUN #1
3	WESTERN	EASTERN	EASTERN	EASTERN	EASTERN	EASTERN	EASTERN US OCCUPANT DATA
4	WESTERN	DEFAULT	DEFAULT	DEFAULT	DEFAULT	DEFAULT	DEFAULT WITH INITIAL OCCUPANT POSITION AS RUN #3
5	EASTERN	EASTERN	EASTERN	EASTERN	EASTERN	EASTERN	BASELINE EASTERN US RUN
6	EASTERN	DEFAULT	DEFAULT	DEFAULT	DEFAULT	DEFAULT	DEFAULT WITH INITIAL OCCUPANT POSITION AS RUN #5
7	EASTERN	WESTERN	WESTERN	WESTERN	WESTERN	WESTERN	WESTERN US OCCUPANT DATA
8	EASTERN	DEFAULT	DEFAULT	DEFAULT	DEFAULT	DEFAULT	DEFAULT WITH INITIAL OCCUPANT POSITION AS RUN #7

Egress Movement Time Comparison





EGRESS MOVEMENT TIMES VARIED UP TO 18%

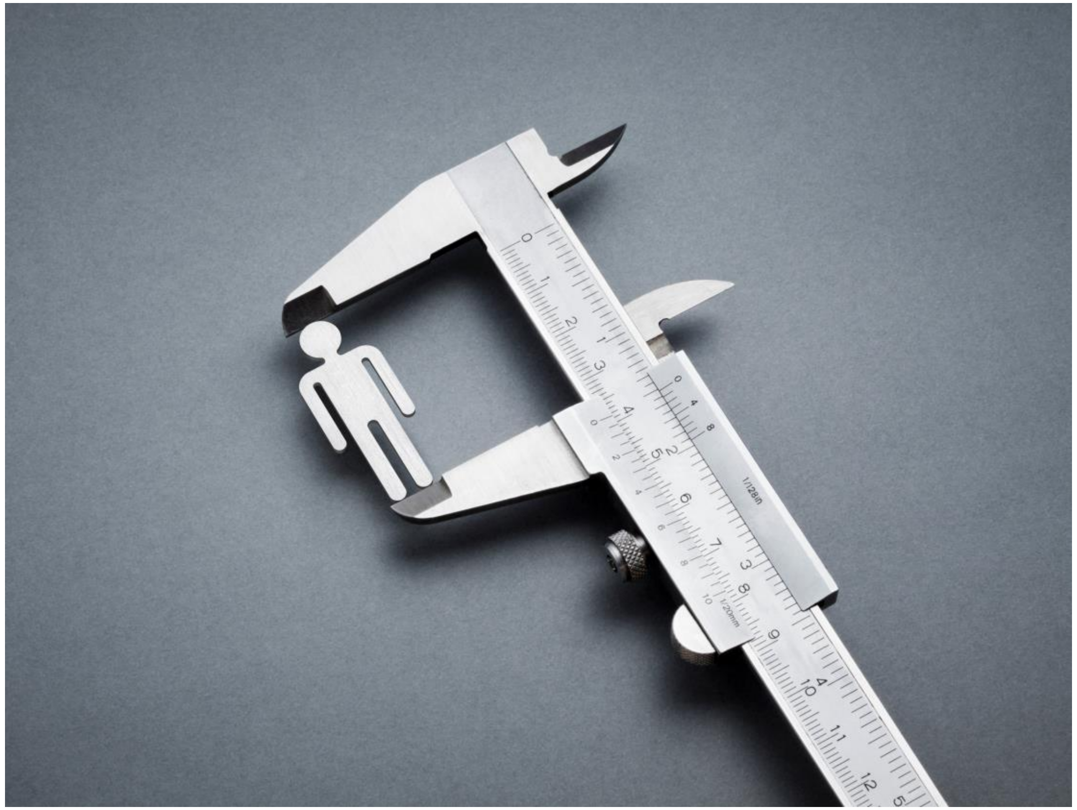
Conclusion

AN EGRESS MODEL WITHOUT COLLECTED AND CALIBRATED DATA IS **WRONG**…

- An engineer not using calibrated population data for a computational egress model can obtain **results that potentially negatively impact safety.**
- Defining geographic location and calibrating user groups are essential to accurately represent a building's or site's occupant population in an egress model.

Takeaways

"PATHFINDER IS INTENDED ONLY TO SUPPLEMENT THE INFORMED JUDGMENT OF THE QUALIFIED USER."



Thank you,

Raeshawn Kennedy, PE

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