Knowledge FOr Resilient soCiEty

Potential Joint Course

Evacuation calculation and modeling

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Evacuation calculation and modeling

Course content/structure

1. *Evacuation – basic concepts and definitions*

- There are many reasons, which may cause emergency people movement in a building.

- In most of emergencies, fire is more complicated for emergency movement than others because of the rapid change to untenable conditions (dynamic);

- In case of fire, the occupants' safety depends on their timely evacuation to a place of safety.

- The aim of timely evacuation is to minimize the required evacuation time to ensure that it is less than the available evacuation time.

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2. *Evacuation decision making and human behavior in fire*

- risk perception in fire evacuation behavior

- decision of occupants to evacuate during the early stages of an building fire emergency.

- theories of human behavior in fire

Factors effecting human behavior in fire

Occupant characteristics	Building characteristics	Fire characteristics	Occupant characteristics	Building characteristics	Fire characteristics
Profile • Gender • Age • Ability • Limitation	**Occupancy** Residential (lowrise, midrise, highrise) Office Factory Hospital Hotel Cinema College and University Shopping Centre	**Visual cues** Flame Smoke (color, thickness) Deflection of wall, ceiling, floor	**Condition at the time of event** • Alone vs. with others • Active vs. passive • Alert • Under drug/alcohol/medication	**Activities in the building** • Working • Sleeping • Eating • Shopping • Watching a show, a play, a film, etc	**Audible cues** • Cracking • Broken glass • Object falling
Knowledge and experience • Familiarity with the building • Past fire experience • Fire safety training • Other emergency training	**Architecture** • Number of floors • Floor area • Location of exits • Location of stairwells • Complexity of space/finding way • Building shape • Visual access	**Olfactory cues** • Smell of burning • Acrid smell	**Personality** • Influenced by others • Leadership • Negative toward authority • Anxious	**Fire safety features** • Fire alarm signal (type, audibility, location, number of nuisance alarms) • Voice communication system • Fire safety plan • Trained staff • Refuge area	**Other cues** • Heat

Proulx G. Occupant behavior and evacuation. In: Proceeding of the 9# International Fire Protection Symposium, Munich, 2001. p. 219–232.

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3. *Egress strategies*

- (1) total evacuation,
- (2) phased evacuation,
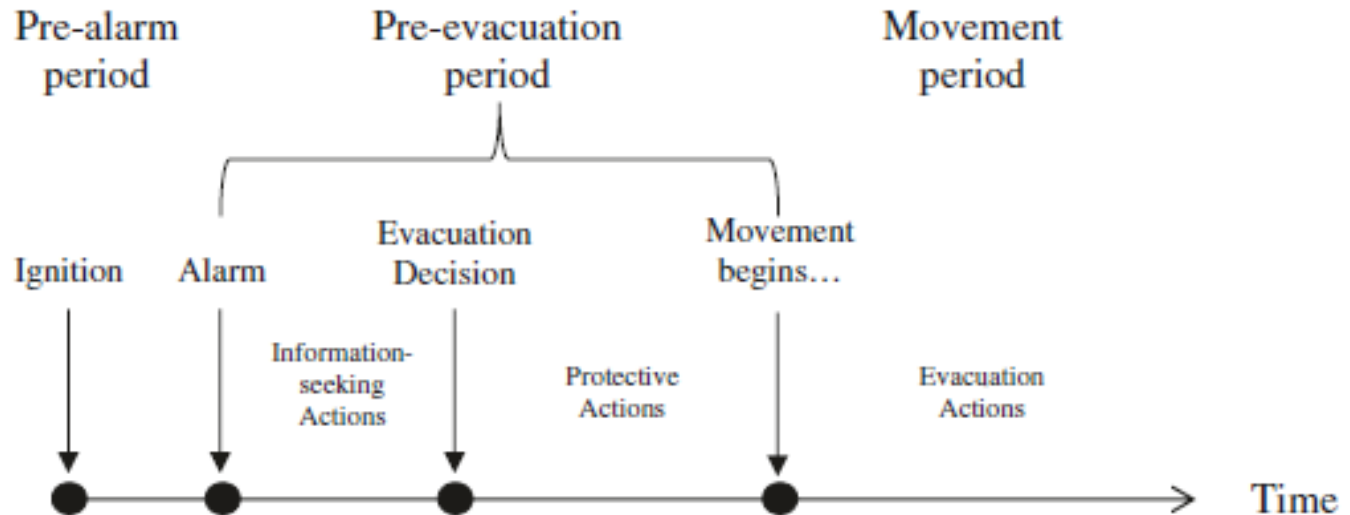- (3) defend-in-place and
- (4) delayed evacuation.

The possible application of different strategies is mainly dependent upon the characteristics of the building in general, the population involved and the staff/rescue operators.

2013. Ronchi E, Nilsson D (2013) Fire evacuation in high-rise buildings: a review of human behaviour and modelling research. Fire Sci Rev 2(1):7, doi:10.1186/2193-0414-2-7

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4. Evacuation stages

Timeline of building fire evacuation.

2010. Kuligowski E, Peacock R, Hoskins B (2010) A Review of building evacuation models NIST, Fire Research Division. Technical Note 1680 Washington, US
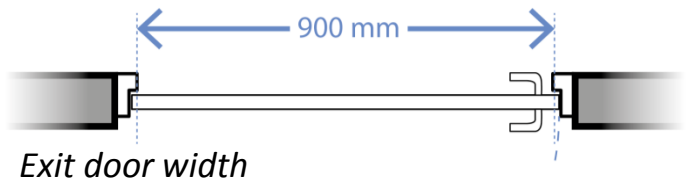
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5. Evacuation corridors
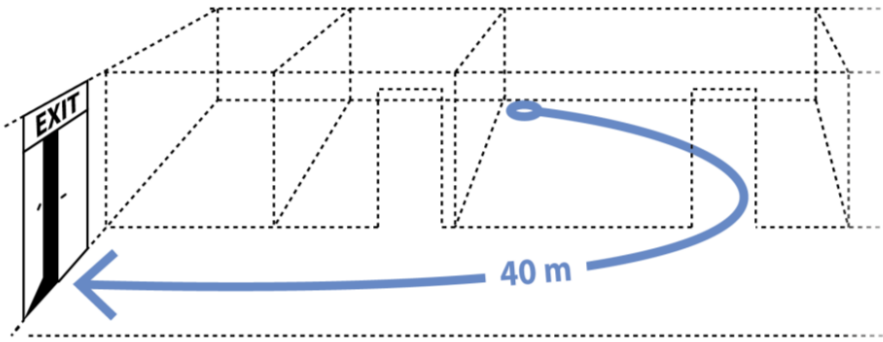
Maximum travel distance

40 m

900 mm

Exit door width

Signage visibility

❌ ✔️

Exits opening direction

❌ ✔️
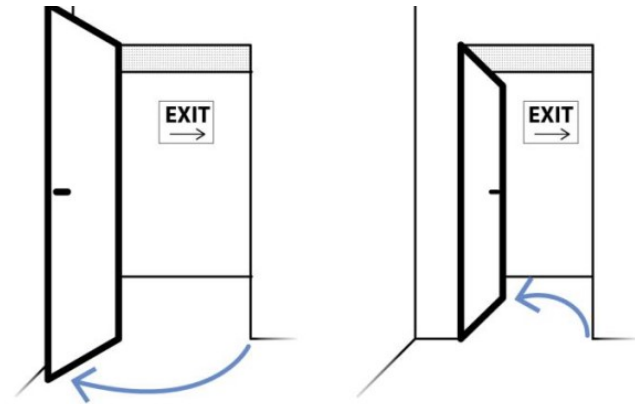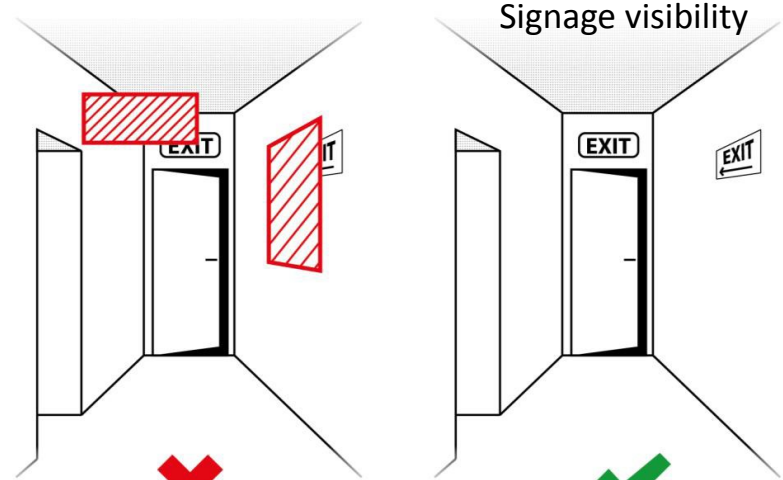
Smoke and fire separation zones

0-1,000m^2	1 zone
1,000m^2 – 2,000m^2	2 zones
2,000m^2 – 3,000m^2	3 zones
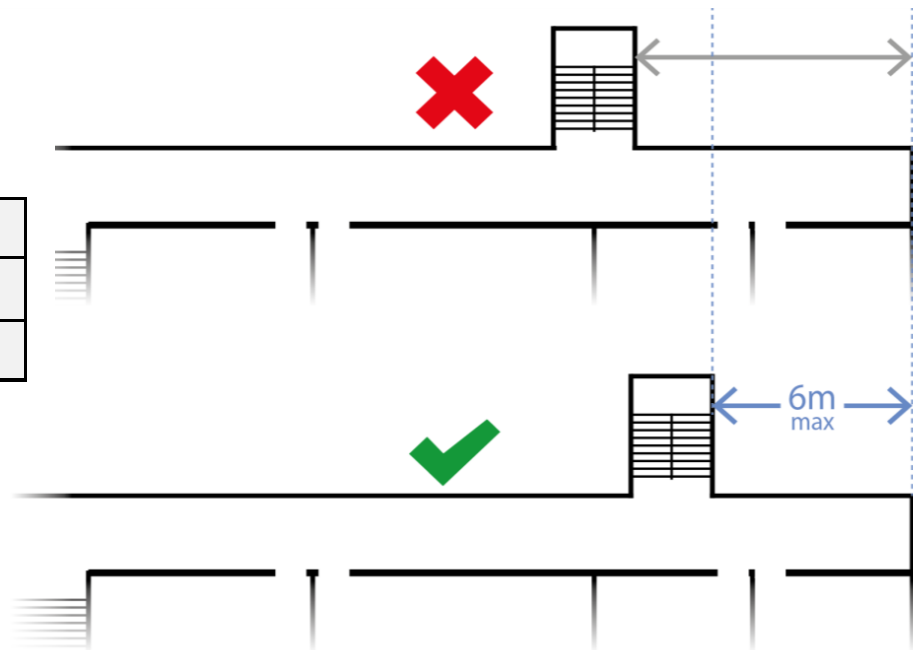
Dead end corridors
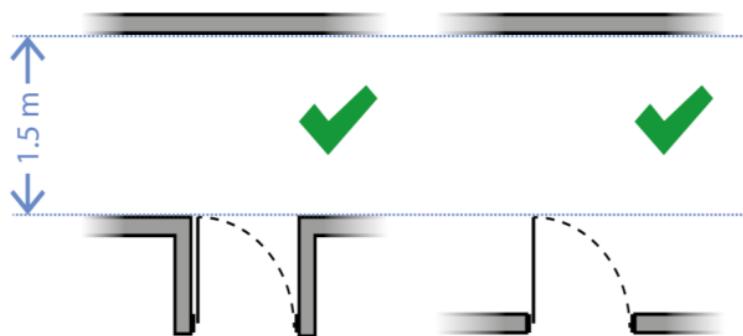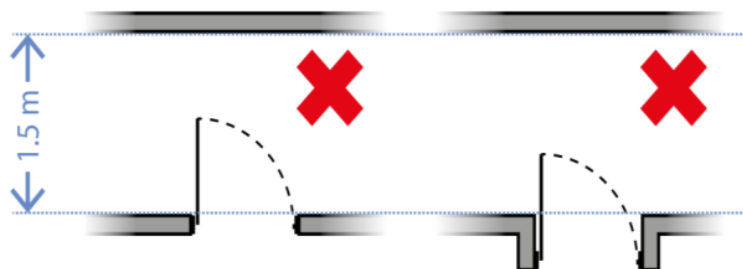
Minimum corridor width
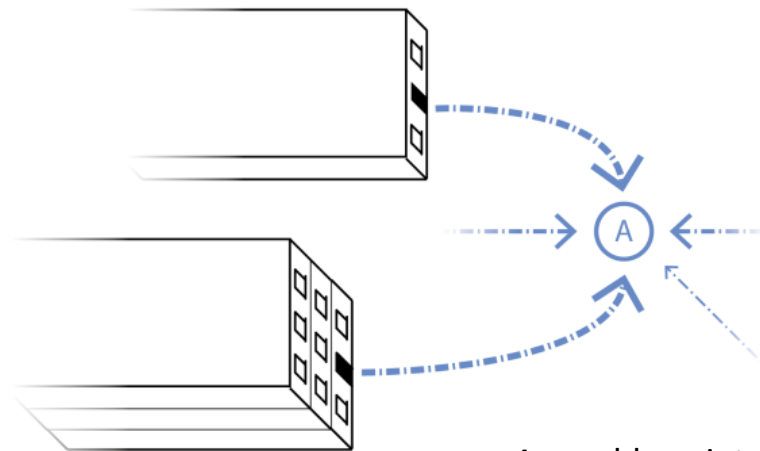
Assembly points

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6. Evacuation walking speeds

Walking speed is an important parameter used in evacuation models and varies with many factors, such as:

- walking types
- walking conditions,
- occupant types
- and place types.

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Walking speed according to influencing factors.

Influencing factors		Speed (m/s)	Range (m/s)	References
Walking type	Free move		1.2–1.8	[17]
	Exit move		0.8–1.5	
Walking conditions for corridors, doorway on ship	Low	1.4		[6]
	Optimum	0.70		
	Moderate	0.39		
	crush	0.10		
Place type	Public place		0.51–1.27	[19]
	High-rise apartment	1.05	0.57–1.20	
		0.95	0.56–1.12	
Occupant type[a]	Children	1.08		[18]
	Female elderly	1.04		
	Male elderly	1.05		
	Elderly	1.04		
	Female adult	1.24		
	Male adult	1.30		

Walking speed for disabled occupants.

Factors		Speed (m/s)	Range (m/s)	References
Wheelchair	Man	1.06		[11]
	Woman	1.06		
High-rise building	Electric wheelchair	0.89		[20]
	Manual wheelchair	0.69		
	Crutches	0.94		
	Walking stick	0.81		
	No disability	1.24		
Disabled subjects	All disabled subjects	1.00	0.10–1.77	[21]
	With locomotion	0.80	0.10–1.68	
	No aid	0.95	0.24–1.68	
	Crutches	0.94	0.63–1.35	
	Cane	0.81	0.26–1.60	
	Walker/Rollator	0.57	0.10–1.02	
	Without locomotion disability	1.25	0.82–1.77	
	Unassisted wheelchair	0.89	0.85–0.83	
	Assisted ambulant	0.78	0.21–1.40	
	Assisted wheelchair	1.30	0.84–1.98	

Travel speeds on stairs in terms of stair characteristics.

Stair characteristics		Speed (m/s)	Remarks	References
Stair dimensions	0.20; 0.25[a]	0.85		
	0.18; 0.25	0.95		[22]
	0.17; 0.30	1.00		
	0.17; 0.33	1.05		

	gradient	Up-stair	Down-stair	
Slope gradient	20°		0.9	
	25°		0.8	
	30°		0.7	[23]
	35°		0.6	

Travel speeds on stair according to occupant.

Influencing factors		Speed (m/s)		References
		Up-stairs	Down-stair	
Occupant density (persons/m^{-2})	One by one		1.0	[22]
	2.5		0.88	
	2.4		0.82	
	2.2		0.91	
	1.5	0.57		
	1.5	0.76		
	2.0	0.72		
	One by one	0.8		
Conditions for traveling on ships	Low	0.80	1.00	[6]
	Optimum	0.40	0.50	
	Moderate	0.22	0.28	
	Crush	0.10	0.13	
Occupant age	Male <30	0.67	1.01	[24]
	30–50	0.63	0.86	
	>50	0.51	0.67	
	Female <30	0.635	0.755	
	30–50	0.59	0.655	
	>50	0.485	0.595	
Occupant type[a]	Children	0.29	0.31	[18]
	Female elderly	0.27	0.26	
	Male elderly	0.29	0.29	
	Elderly	0.28	0.28	
	Female adult	0.30	0.36	
	Male adult	0.32	0.42	
	Adult	0.31	0.38	

[a] The travel speeds on stairs according to occupant type are average data. All of these data were take when pedestrian density was less than 0.72 person/m².

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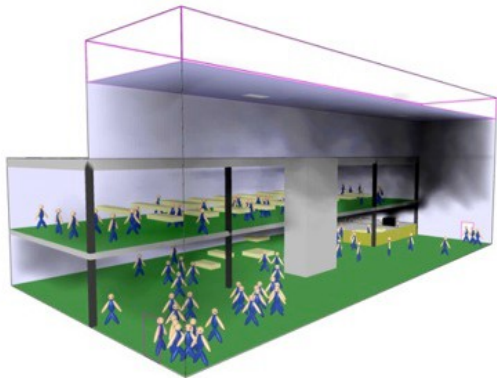
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7. *Calculation of evacuation*

- REQUIRED SAFE EGRESS TIME (RSET)

- AVAILABLE SAFE EGRESS TIME(ASET)

- TOTAL EVACUATION TIME (TET)

- PRE-MOVEMENT TIME.

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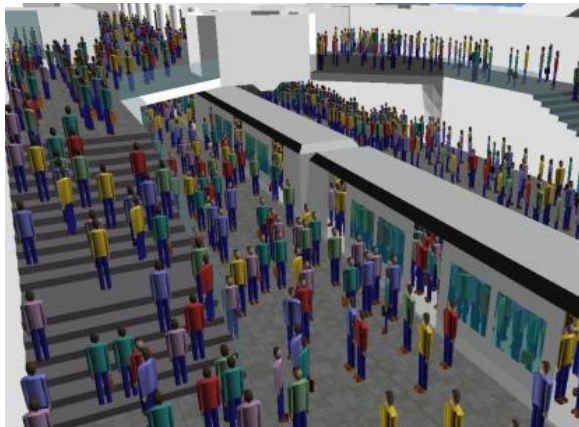
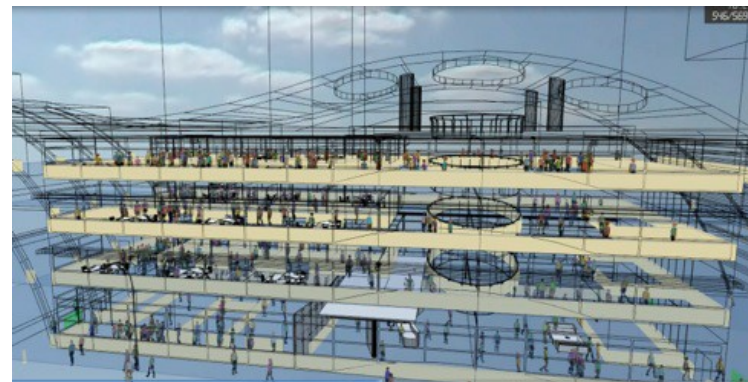### *8. Computer modelling of evacuation*

FDS + Evac (OpenSource)
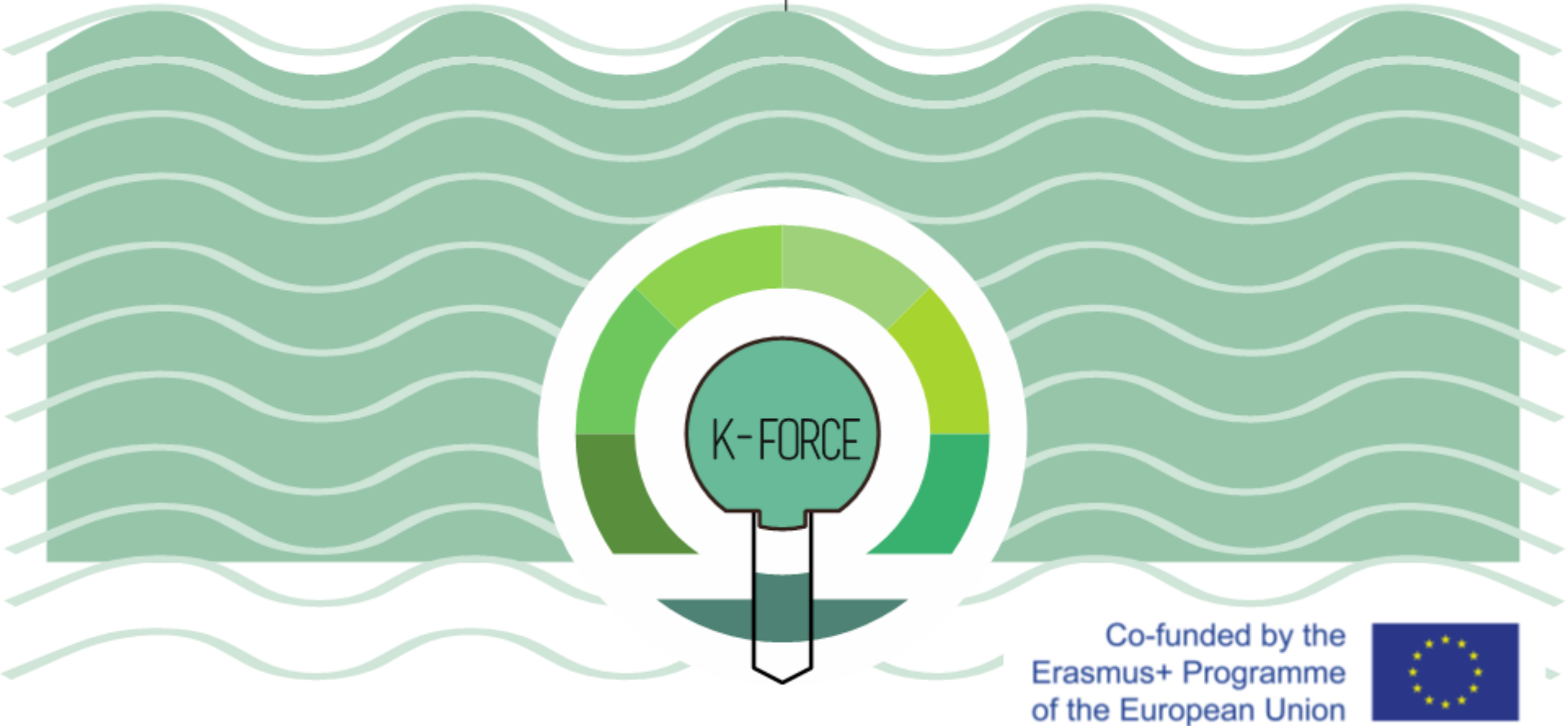

BuildingEXODUS (FSEG)

PathFinder (Thunderhead)

STEPS (MottMac)

Simulex (IES)

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9. *Evacuation drills*
10. *Evacuation plans*

Thank you for your attention!

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