AGENT BASED MODELING OF META-COMMUNICATION WITH ASSISTED PEOPLE DURING EMERGENCY EGRESS

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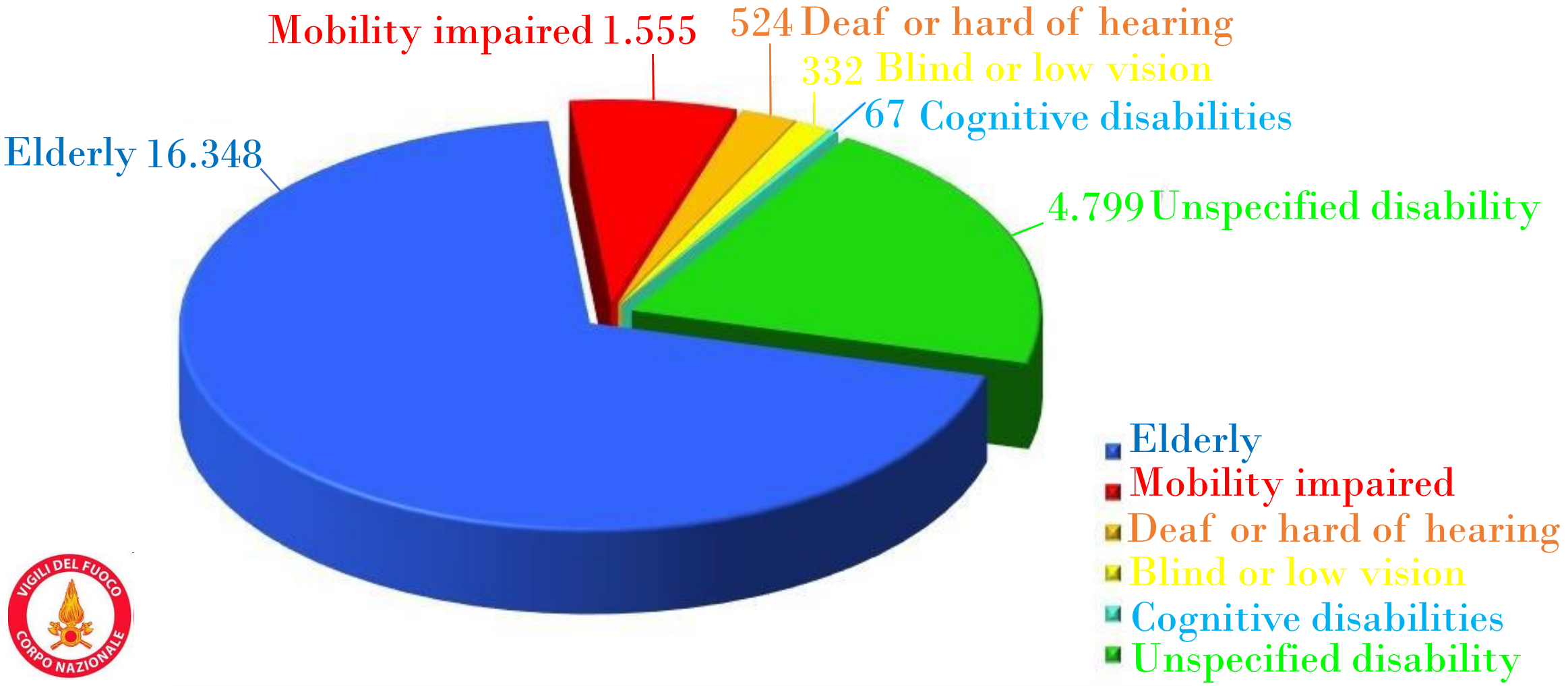
Outline

1. **Introduction**
2. **Evacuation capabilities framework integrating persons with special needs**
3. **Case study: assisted horizontal evacuation of a hospital ward**
4. **PathFinder MonteCarlo simulation results**
5. **Conclusion and future research topics**

1 Persons with special needs assisted by fire brigades in Italy

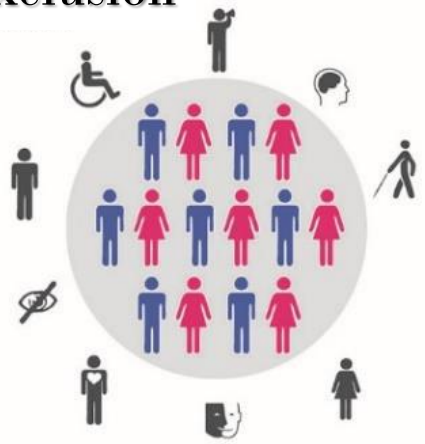


Total number of people with special needs assisted by ff's in 2016 in Italy: 23.625 (65 #/day)

Total number of persons assisted by ff's in 2016 in Italy: 74.122 (203 #/day)

The path toward Inclusion in fire codes

Exclusion



Segregation

Integration

Inclusion

Detection

Notification

Mobility devices

Way-finding

Disabilities classification

Table 1: Disabilities classification derived from NFPA DARAC Guide (2016).

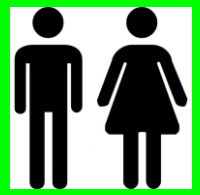
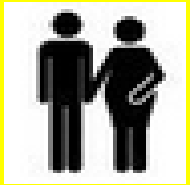
General category		Examples of mobility devices required
Mobility	*Ambulatory mobility*	Canes, crutches, walkers
	Wheelchair users	Power-driven or manually operated wheelchair
	Respiratory	Depending on the case
Blind or Low vision		Canes, service animals.
Deaf or Hard of hearing		
Speech disabilities		
Cognitive disabilities		Depending on the case
Temporary disabilities		Depending on the case

NFPA DARAC

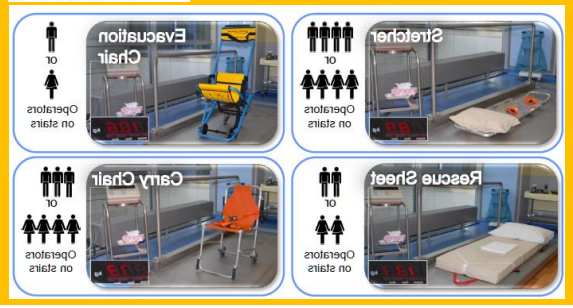
Establish a link with the assisted: meta-communication

2

Occupants evacuation capabilities framework

MOBILITY AND WAY FINDING CAPABILITIES	MOBILITY DEVICES	STAFF/EMERGENCY RESPONSE ASSISTANCE	REMARKS AND EXAMPLES
1. Autonomous 			• Staff/Emergency response teams • Walking patients (priority classif. level 4) • Visitors, occupants Full way finding capability and ability to independently walk on even and uneven surfaces and negotiate stairs
2. Autonomous *with mobility devices*	Canes, crutches, walkers, rollators, wheelchairs		• Temporary or permanent disabilities Full way finding capability. *Type a)*: move/walk independently through an horizontal accessible route *Type b)*: with the use of a mobility device may also be able to negotiate stairs without supervision
3. Autonomous *requiring assistance in way finding* 		1 or 2 staff operators for each autonomous walking occupant	• Blind or Low vision persons • Cognitive disabilities • Children • Deaf or Hard of hearing (only to be notified) • Walking patients (priority classif. level 3) Able to walk on even and uneven surfaces and negotiate stairs only with the assistance of another person

Occupants evacuation capabilities framework

MOBILITY AND WAY FINDING CAPABILITIES	MOBILITY DEVICE	STAFF/EMERGENCY RESPONSE ASSISTANCE	REMARKS AND EXAMPLES
4. Not autonomous - *Major mobility devices required* Hunt (2016) 	**Wheelchair stretcher, rescue sheet, emergency stair travel device**	**1 to 4 operators for each assisted person**	• **Not autonomous patients (priority classif. level 2)** ***Type a)*: transferrable only on a wheelchair, a stretcher or a rescue sheet through an accessible route (for relocation on the same floor)** ***Type b)*: transferrable on stairs with emergency travel devices or by means of a firefighter lift (i.e. complying with EN 81-72:2015, clause 5.2.4) accessible for a wheelchair or stretcher (i.e. types 3 to 5 according to EN 81-70:2018)**
5. Not autonomous – *Transferrable only with beds or incubators*	**Bed, incubator**	**1 or 2 operators for each assisted person**	• **Critical patients (priority classification level 1)** ***Type a)*: transferrable only on a bed or incubator through an accessible route (for relocation on the same floor)** ***Type b)*: transferrable on stairs only by means of a firefighter lift (i.e. complying with EN 81-72:2015, clause 5.2.4) with adequate accessibility (i.e. type 5 according to EN 81-70:2018)**

Basic *autonomous* occupant profiles

Autonomous occupant profile	Unhindered walking speed (m/s) (on level terrain, straight-line movement)					Social grouping	Remarks
	Distribution law						
	Type	μ	σ	Min	Max		
Active staff	Normal Alonso and Ronchi (2016)	1.35	0.25	μ -2.8σ	μ +2.8σ	Individual or assistance team member	Familiar & Trained
Emergency response	Assumed equal to Active staff					Individual or assistance team member	Familiar & Trained
Visitor to in-patient (or generic autonomous occupant)	Normal Fruin (1987), Boyle (1999)	1.20	0.20	μ -3.0σ	μ +3.0σ	Individual or groups, eventually linked to one in-patient	Uncertain familiarity & Not Trained
Worker (not in charge of egress assistance)	Assumed equal to Visitor to in-patients					Individual or with co-workers	Familiar & Trained
Autonomous in-patient	Normal Boyle (1999)	0.95	0.32	μ -2.2σ	μ +2.2σ	Individual or linked to Visitors	Uncertain familiarity & Not Trained

Basic *autonomous* mobility impaired occupant profiles

Autonomous mobility impaired occupant profile		Unhindered walking speed (m/s) (on level terrain, straight-line movement)					Social grouping	Remarks
		Distribution law						
		Type	μ	σ	Min	Max		
Mobility device	Crutches	Normal Boyle (1999)	0.94	0.30	μ -1.0σ	μ +1.4σ	Individual or linked to visitors	Uncertain familiarity & Not Trained
	Walking stick	Normal Boyle (1999)	0.81	0.38	μ -1.4σ	μ +2.0σ	Individual or linked to visitors	Uncertain familiarity & Not Trained
	Rollator or walking frames	Normal Boyle (1999)	0.57	0.29	μ -1.6σ	μ +1.6σ	Individual or linked to visitors	Uncertain familiarity & Not Trained
	Electric wheelchair	Constant Boyle (1999)	0.89				Individual or linked to visitors	Uncertain familiarity & Not Trained
	Manual wheelchair	Normal Boyle (1999)	0.69	0.35	μ -1.6σ	μ +1.9σ	Individual or linked to visitors	Uncertain familiarity & Not Trained

Basic *assisted* occupant profiles

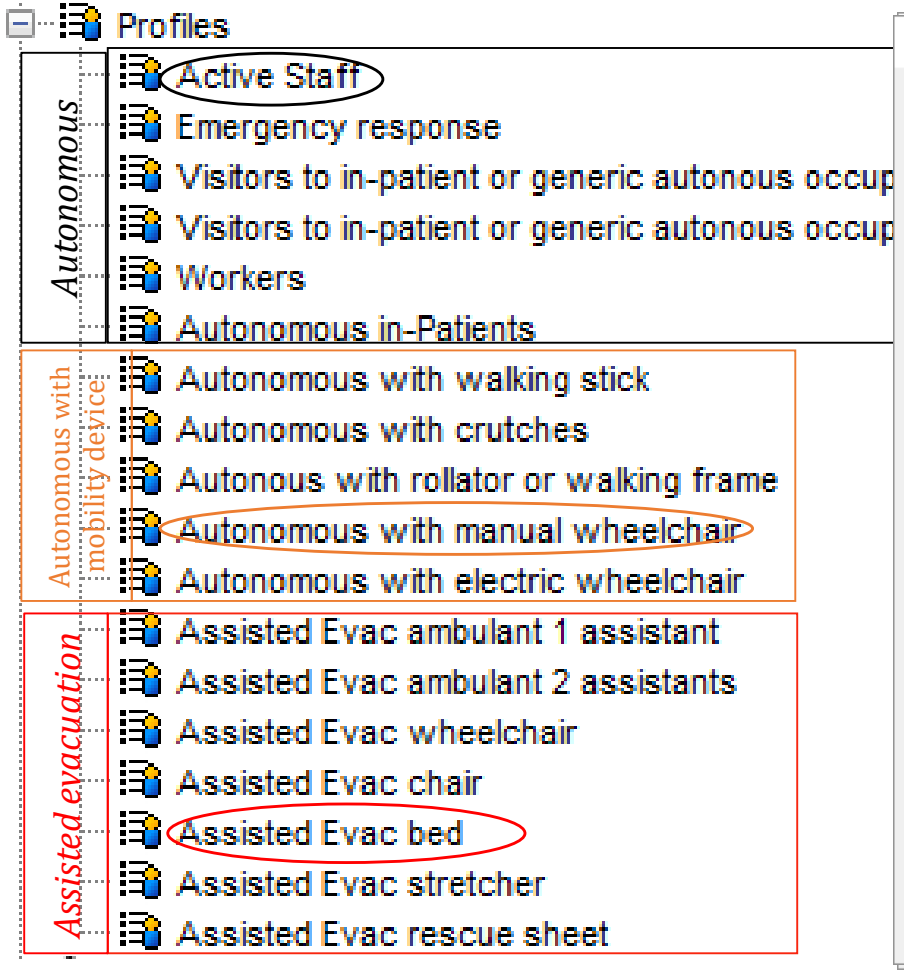
Assisted occupant profile	Assisted travel speed (m/s) (on level terrain, straight-line movement)					Active staff/ Emergency resp. assignment
	Distribution law					
	Type	μ	σ	Min	Max	
Assisted ambulant	Normal Boyle (1999)	0.71	0.34	μ -1.7σ	μ +1.8σ	1 operator [1]
Assisted transported on a wheelchair [2]	Normal Alonso (2014,2016)	0.63	0.04	μ -3.0σ	μ +3.0σ	1 operator [1]
Assisted transported on a carry or evac chair	Uniform Hunt (2012, 2015)			1.34	1.75	1 operator [1]
Assisted transported on a bed [2]	Normal Alonso (2014,2016)	0.40	0.04	μ -3.0σ	μ +3.0σ	2 operators
Assisted transported on a hand-held rescue sheet	Uniform Hunt (2012, 2015)			0.52	1.23	2 operators
Assisted transported on a hand-held stretcher	Uniform Hunt (2012, 2015)			0.91	1.23	4 operators [2]

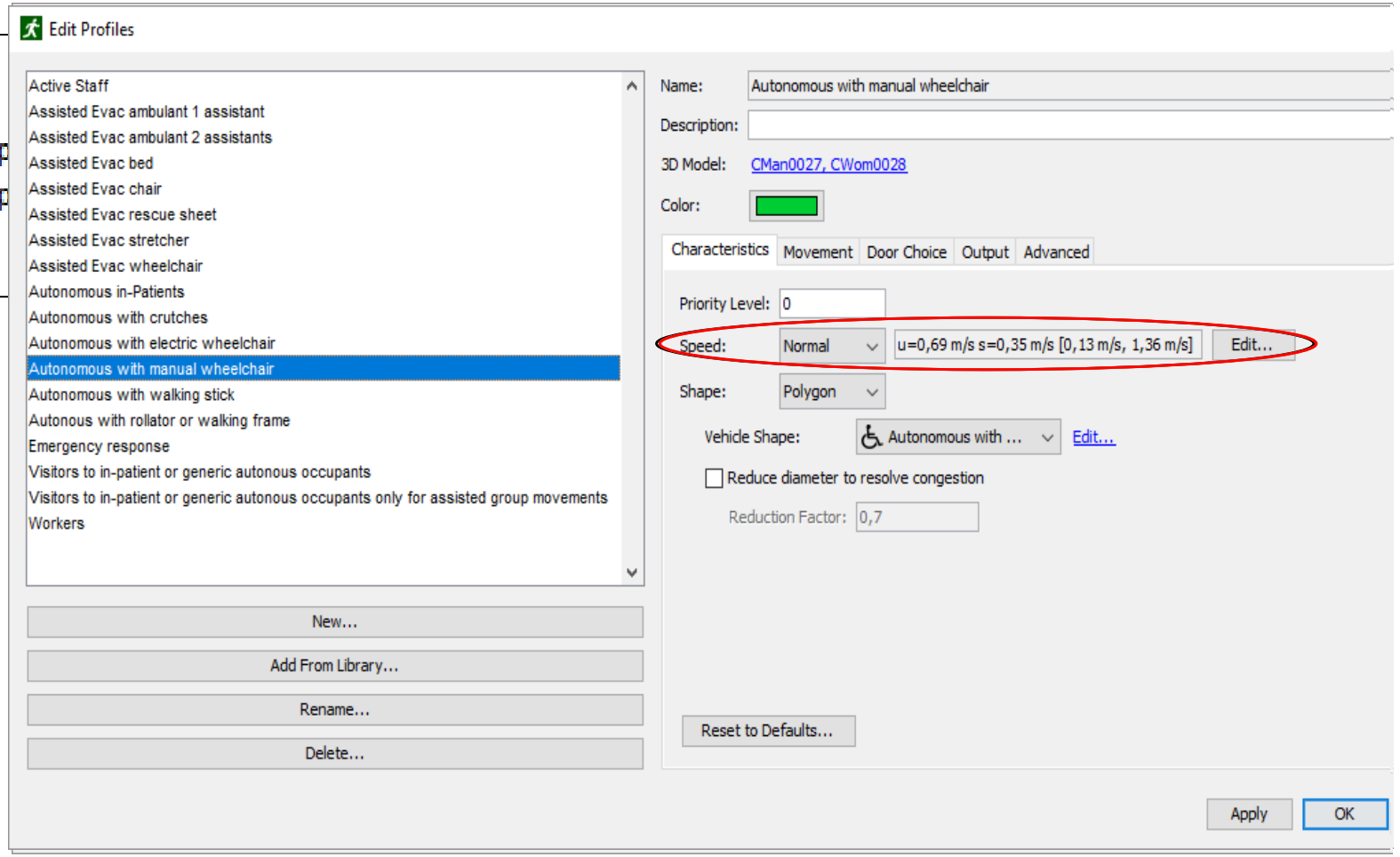
[1] An additional operator may be needed to prepare the patient for transportation or assist along the travel path

[2] Could be reduced to two operators only to execute the task to prepare the patient for transportation

Basic occupant profiles

Case study: staged horizontal evacuation from a hospital ward





No age or gender differentiation

Modeling issue in *assisted* ambulant evacuation using PathFinder

Edit Vehicle Shapes

- Assisted Evac ambulant by 1 operator
- Assisted Evac ambulant by 2 operators
- Assisted Evac bed
- Assisted Evac chair
- Assisted Evac rescue sheet
- Assisted Evac rollator/walking frame
- Assisted Evac stretcher
- Assisted Evac wheelchair
- Autonomous Visitor/generic occupant only for assisted grouped movement
- Autonomous with rollator/walking frame
- Autonomous with wheelchair

New... Rename... Delete...

Name: Assisted Evac ambulant by 1 operator
Description: Body shape - 1 assisting operator
Height: 1,8 m
3d Model: <shape>
Occupant Animation: Default
Occupant Offset: X: 0,0 m Y: 0,0 m Z: 0,0 m

Points:

	X	Y
1	0,0932 m	0,225 m
2	-0,0932 m	0,225 m
3	-0,225 m	0,0932 m
4	-0,225 m	-0,0932 m
5	-0,0932 m	-0,225 m
6	0,0932 m	-0,225 m
7	0,225 m	-0,0932 m

Insert Row | Remove Row | Move Up | Move Down

Pivot:

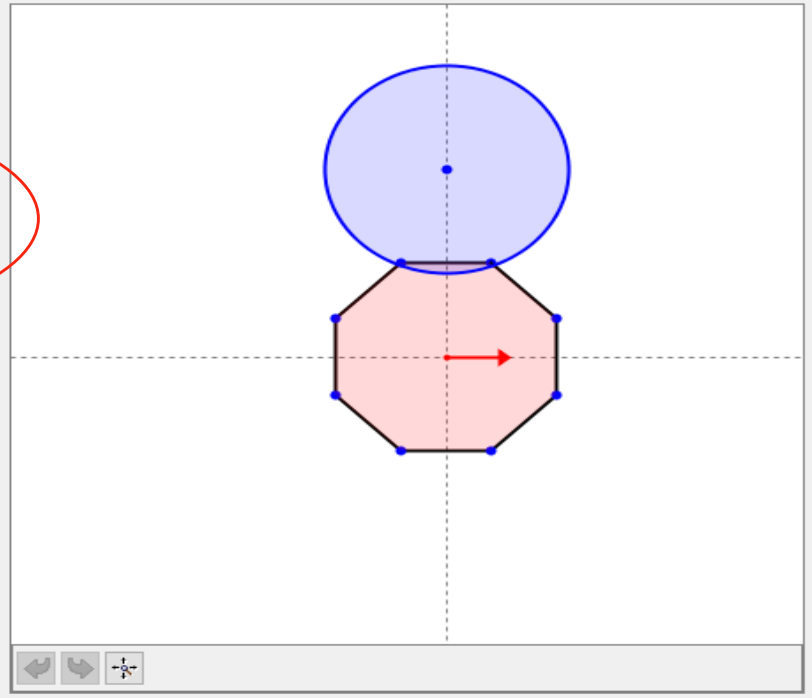
X	Y
0,0 m	0,0 m

Positions of attached occupants:

	X	Y
1	0,0 m	0,45 m
*		

Remove Row

Shape Area: 0,167758 m²
Corresponding occupant count: 1



Apply OK Cancel

Basic movement groups

Case study: staged horizontal egress in health care occupancies

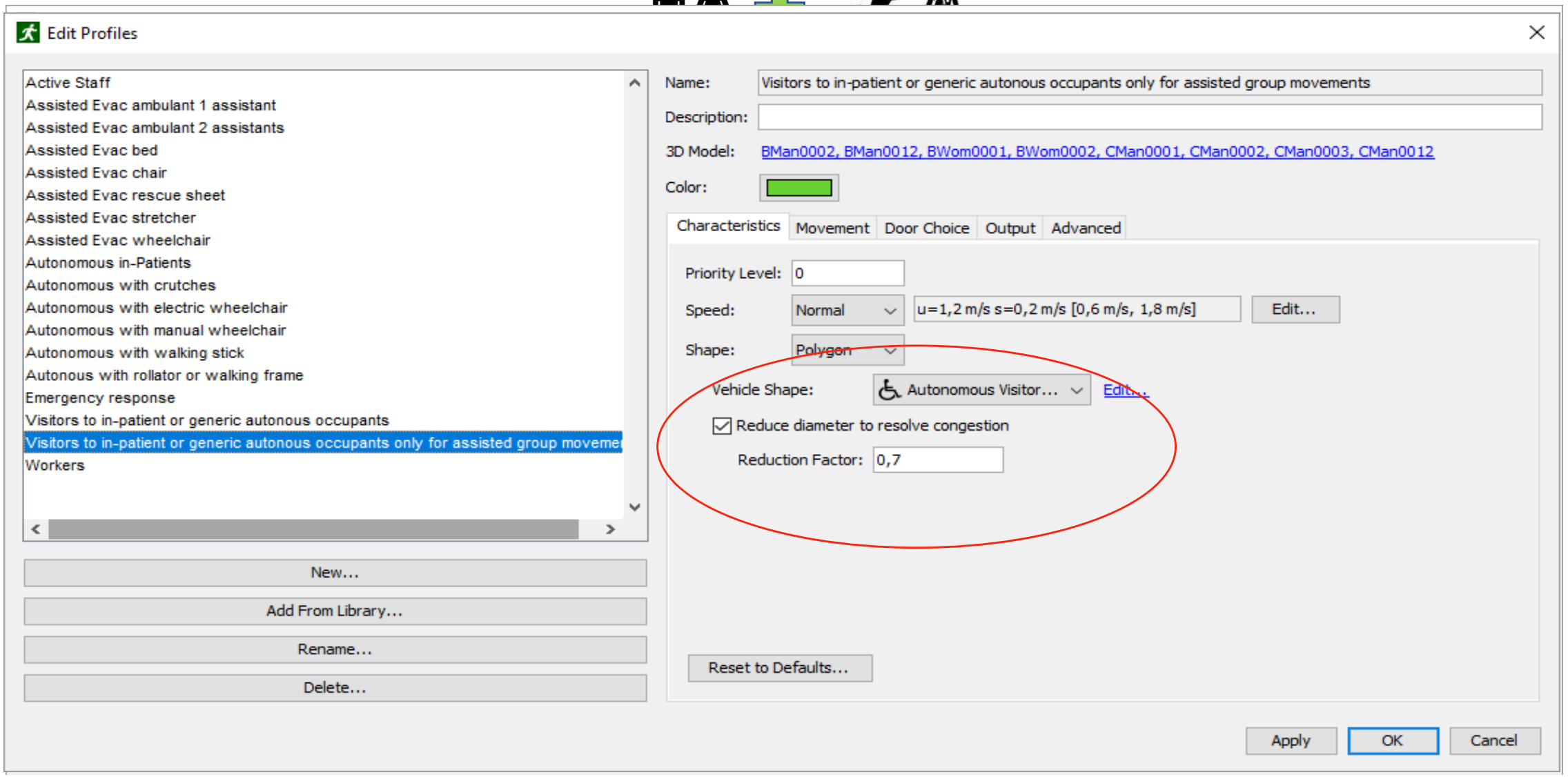
Movement groups for occupants having *autonomous* evacuation capabilities
2 or more Visitors to in-patients (or generic *autonomous* occupants)
2 or more Workers (not in charge of egress assistance)
1 *Autonomous* in-patient and 1 or more Visitors to in-patient
1 *Autonomous* but mobility impaired (5 categories) and 1 or more generic *autonomous* occupants

For the assisted profiles, it is stipulated that only one agent of that type can be put in relationship with one or more *autonomous* profiles

Movement groups for *assisted* occupants [1]
1 Assisted ambulant and 1 or more Visitors to in-patients (or generic *autonomous* occupants)
1 Assisted transported on a wheelchair or evac chair and 1 or more Visitors to in-patients
1 Assisted transported with hand-held rescue sheet and 1 or more Visitors to in-patients
1 Assisted transported with hand-held stretcher and 1 or more Visitors to in-patients
1 Assisted transported on a bed and 1 or more Visitors to in-patients

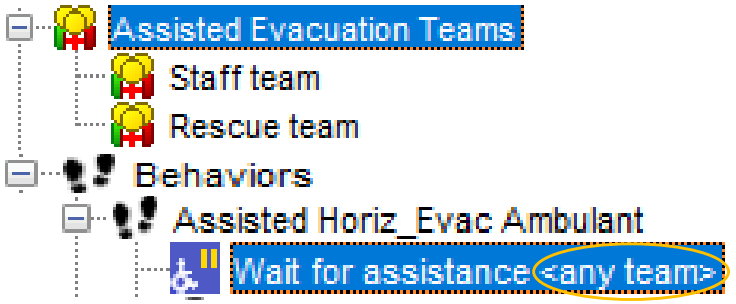
[1] Each group will include by default also the prescribed number and skilled assisting operators

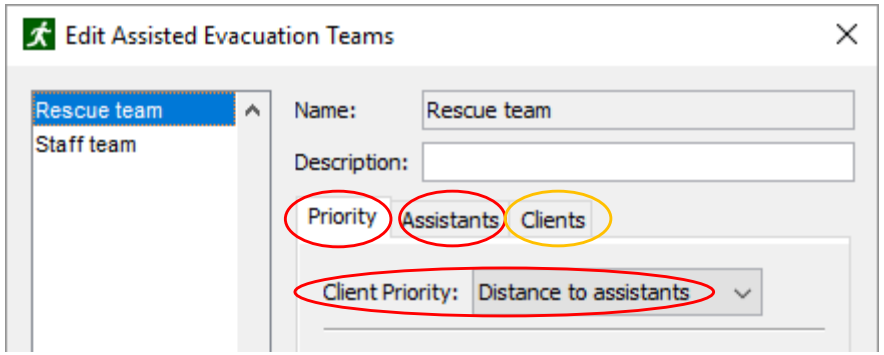
Modeling issue in PathFinder group movements linking an *autonomous* profile with an assisted occupant



Basic set of evacuation team profiles

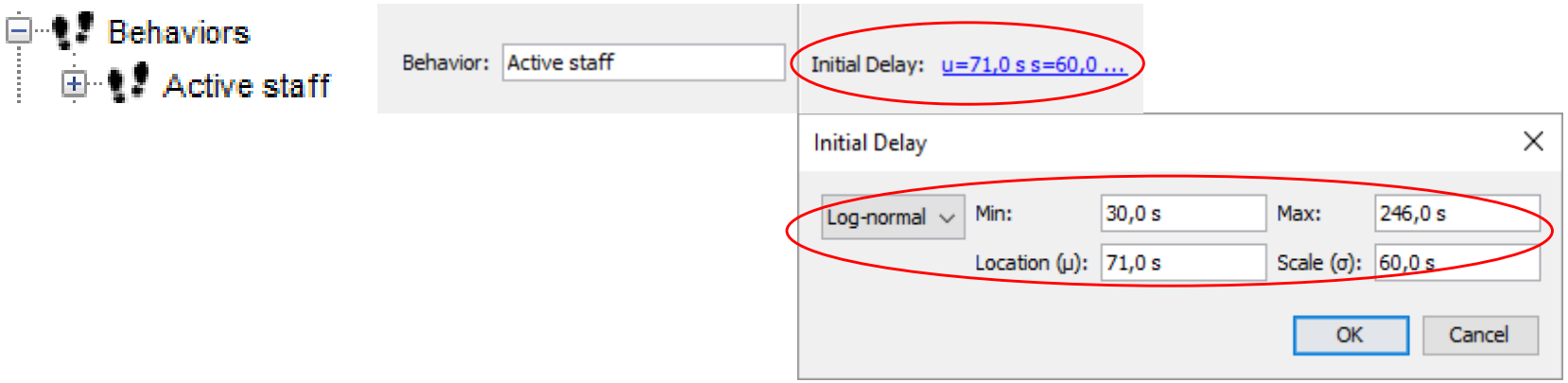
Evacuation team profiles	*Members profiles*	Assisted profiles	**Remarks**
Active staff team	*Active staff*	Restricted to selected occupant profiles	Cannot use elevators in emergency May have restrictions on travel path choice
Emergency response team	*Emergency response*	All assisted profiles	No restriction in travel path choice Able to use selected elevators in emergency





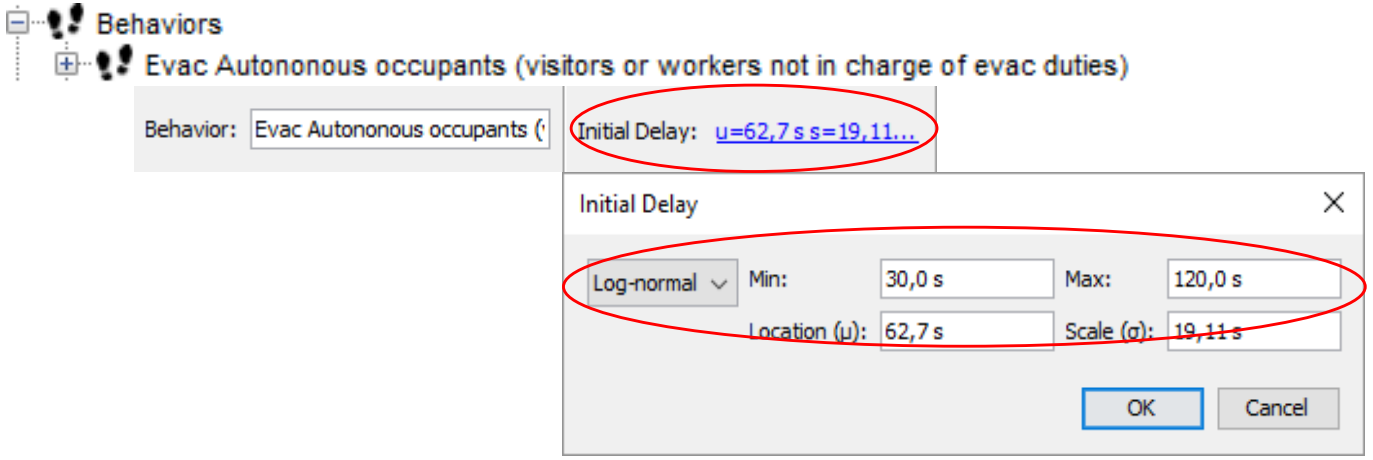
Pre-evacuation times (response times for assisting operators)

Autonomous occupant profile	Pre-evacuation times (s)					Remarks
	Distribution law					
	Type	μ	σ	Min	Max	
Active Staff	Log-normal Alonso (2014, 2016) for health care staff (same mean value in Gwynne et al. (2002, 2003))	71	60	30 Gwynne et al. (2002, 2003)	246 Gwynne et al. (2002, 2003)	Familiar & Trained
Emergency response	Log-normal ISO/TR 16738 (2009) data range for awake&familiar profiles in level M1 occupancies	43	6.44	30	60	Familiar & Trained



Pre-evacuation times (autonomous occupant profiles)

Autonomous occupant profile	Pre-evacuation times (s)					Remarks
	Distribution law					
	Type	μ	σ	Min	Max	
Other autonomous profiles (Workers, Visitors to in-patients or generic occupants, Autonomous in-patients, Autonomous but mobility impaired)	Log-normal ISO/TR 16738 (2009) data range for awake&unfamiliar profiles in level M1 occupancies	62.7	19.11	30	120	Uncertain familiarity & Not Trained & Not grouped with an assisted occupant



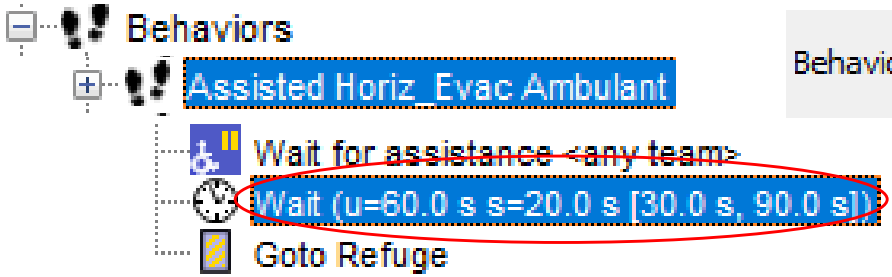
Preparation times for assisted occupant profiles

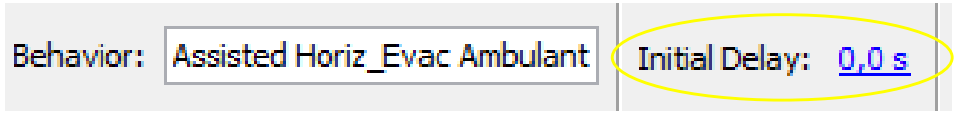
Assisted occupant profile	Preparation time (s)				
	Distribution law				
	Type	μ	σ	Min	Max
Assisted ambulant	Normal Alonso (2014, 2016)	60	20	μ -1.5σ	μ +1.5σ
Assisted transported on a wheelchair	Normal Alonso (2014, 2016)	110	36	μ -0.3σ [2]	μ +0.3σ [2]
Assisted transported on a bed	Assumed equal to assisted on a wheelchair				
Assisted transported on a carry or evac chair	Normal Hunt (2012, 2015) [1]	41.5	7.9	μ -1.2σ	μ +1.3σ
Assisted transported with hand-held rescue sheet	Normal Hunt (2012, 2015) [1]	65.2	14.1	μ -1.4σ	μ +1.5σ
Assisted transported with hand-held stretcher	Normal Hunt (2012, 2015) [1]	77.7	19.2	μ -0.9σ	μ +2.2σ

[1] Based on Hunt (2012, 2015) overall data for carry chair for an assisting team of two health care operators
[2] Based on Hunt (2012, 2015) overall data, for an assisting team of two health care operators

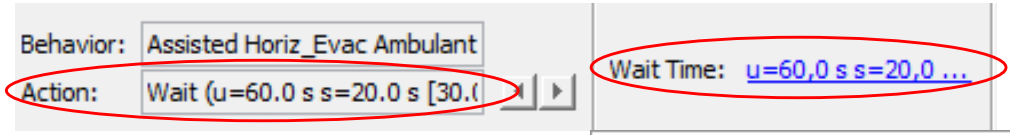
Preparation times for assisted occupant profiles - Example

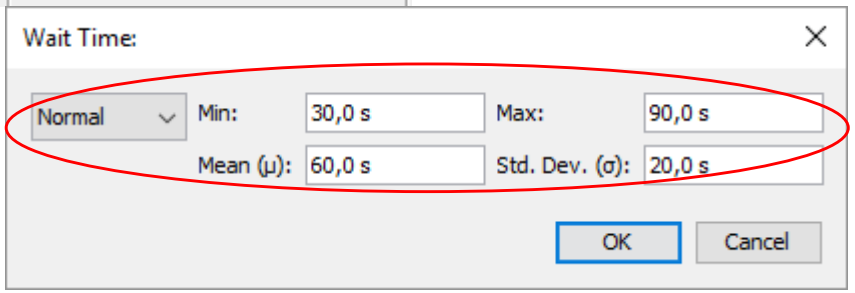
Assisted occupant profile	Preparation time (s)				
	Distribution law				
	Type	μ	σ	Min	Max
Assisted ambulant	Normal Alonso (2014, 2016)	60	20	μ -1.5σ (30)	μ +1.5σ (90)



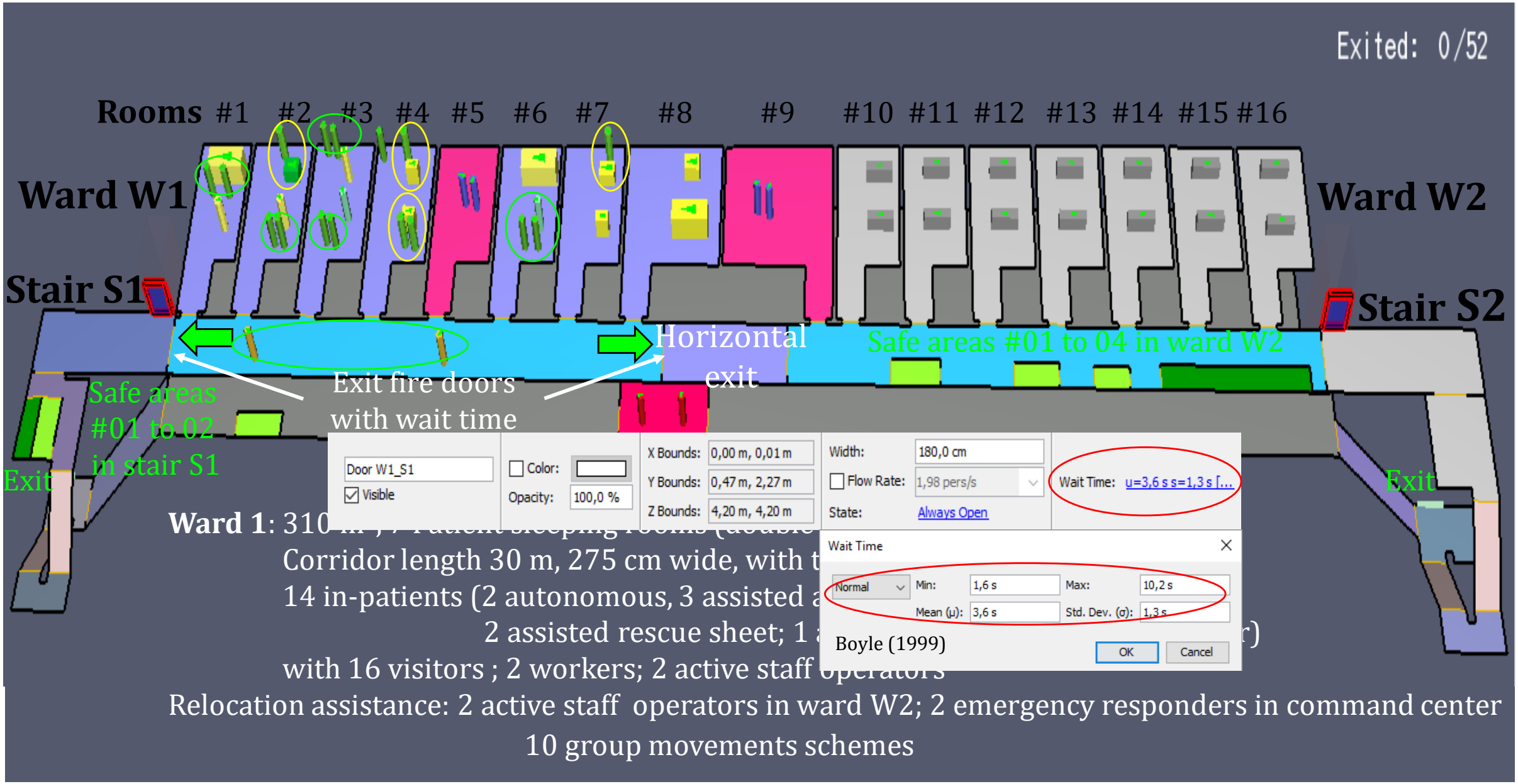


[1] Preparation time starts only *after* an assisting team has taken on duty the client (and all team components are in place)





3 Case study: Progressive horizontal evacuation of a hospital ward



Ward 1: 310 [illegible]; 7 patient sleeping rooms (double

Corridor length 30 m, 275 cm wide, with t

14 in-patients (2 autonomous, 3 assisted a

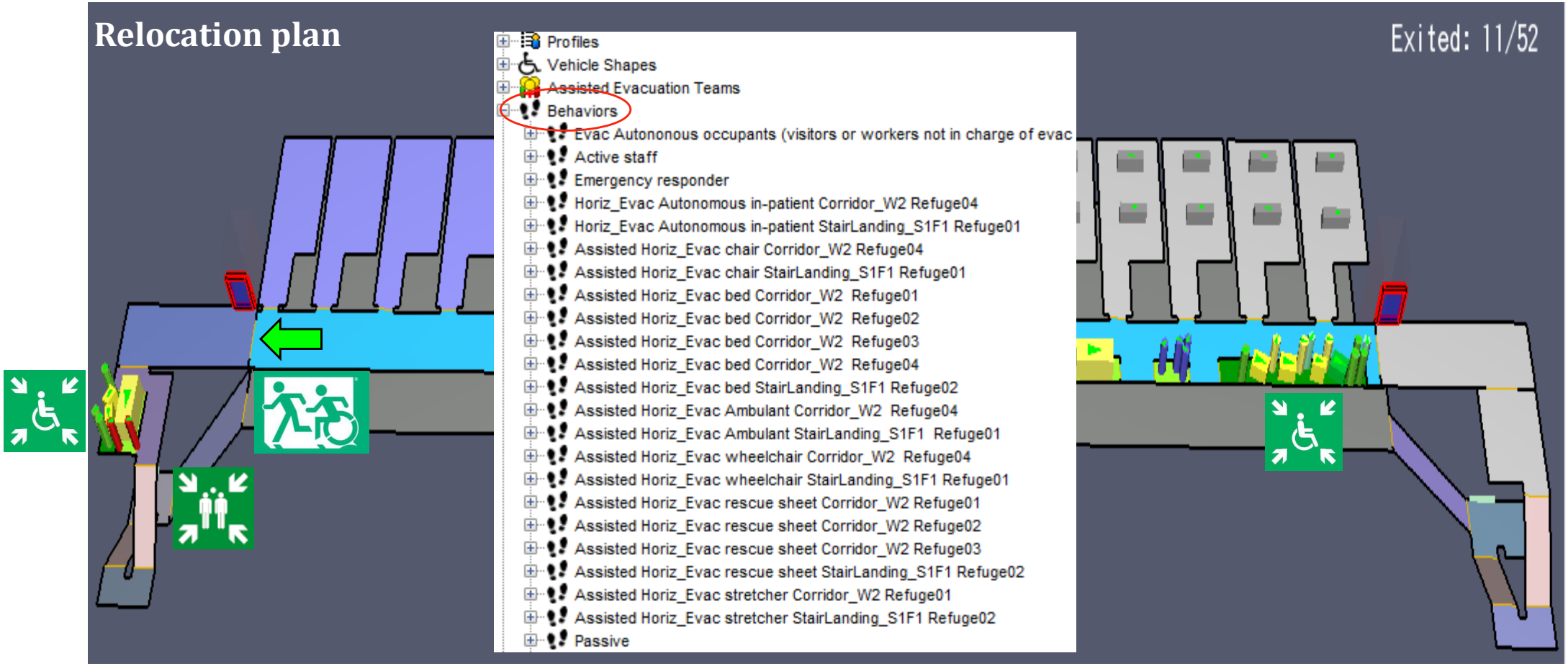
2 assisted rescue sheet; 1 a r)

with 16 visitors ; 2 workers; 2 active staff operators

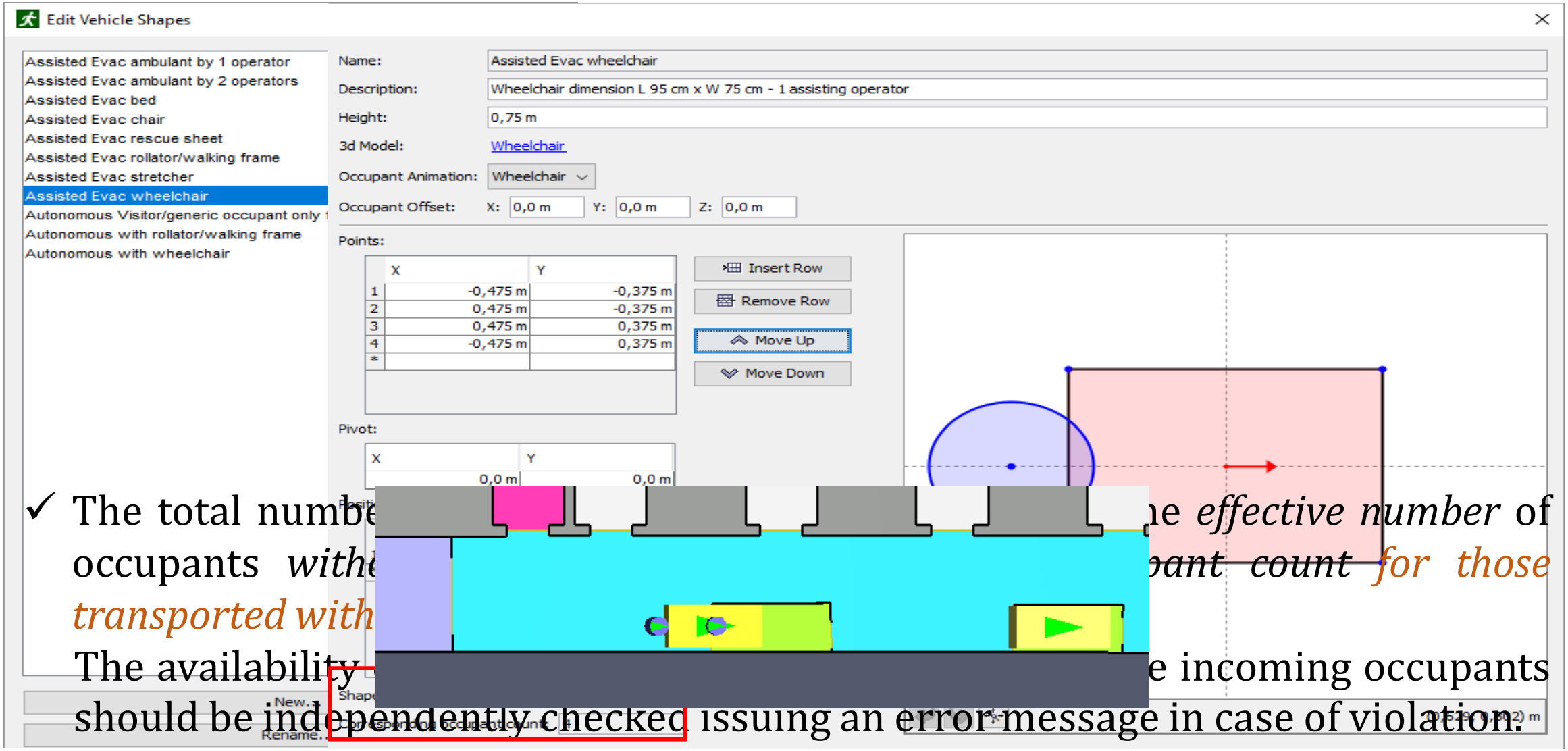
Relocation assistance: 2 active staff operators in ward W2; 2 emergency responders in command center

10 group movements schemes

Case study: Progressive horizontal evacuation of a hospital ward



Modeling issue in *Refuge areas* using PathFinder (1/2)



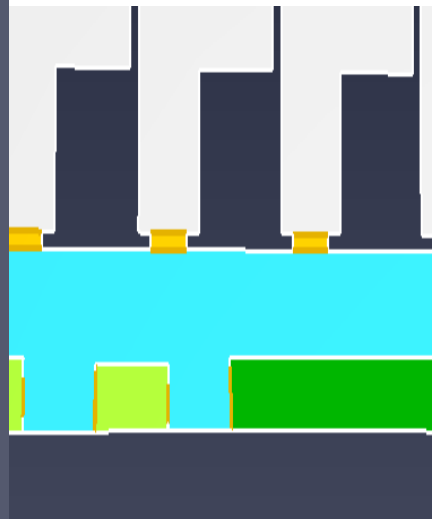
✓ The total numbe…ne *effective number* of occupants *withe*…*pant count for those transported with*…

The availability …e incoming occupants should be independently checked issuing an error message in case of violation.

Modeling issue in *Refuge areas* using PathFinder (2/2)

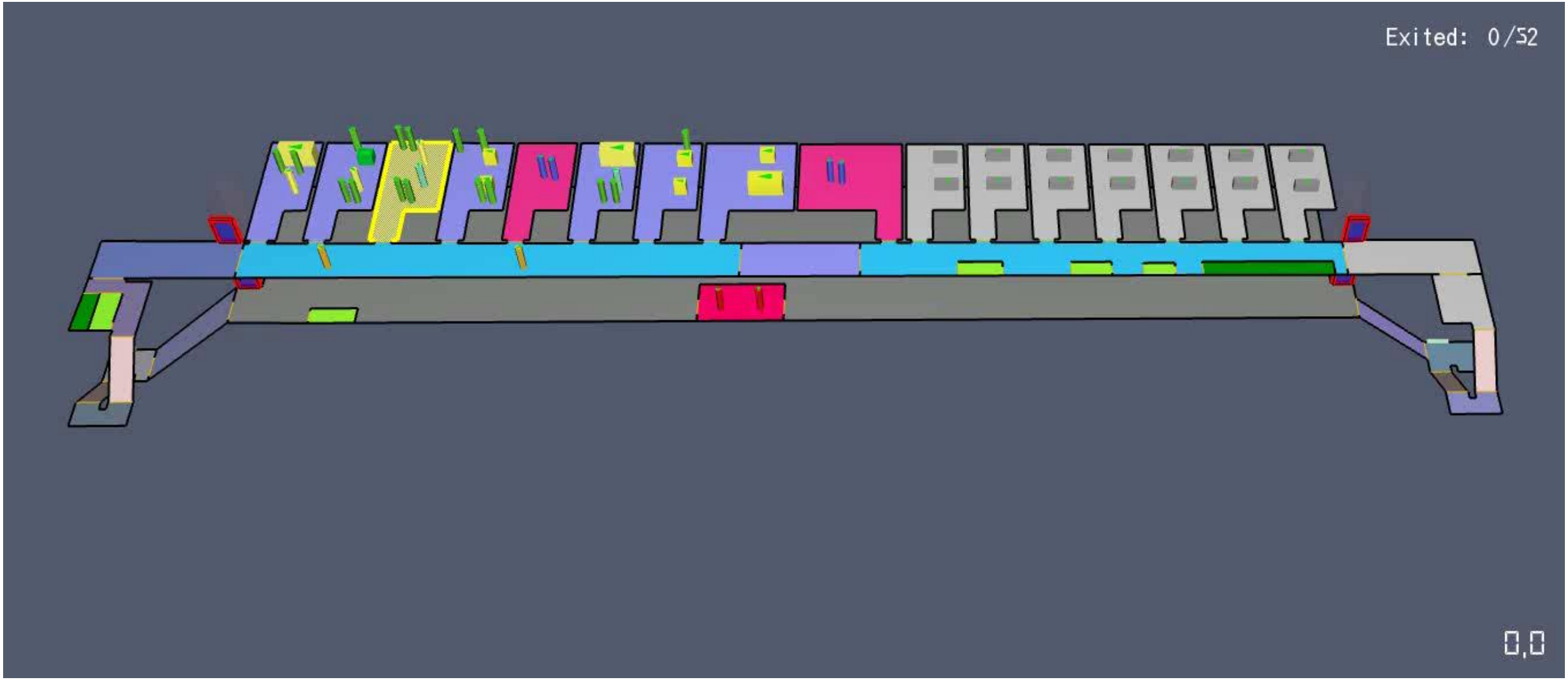
- *Recalling that assisted occupants do not have autonomous movement capability, they remain in the refuge in the position where they are left by the assisting team and can unduly impede the entering of other occupants following them or limit the space availability if not correctly oriented.*

- ✓ If mobility i… area, "parking" zones shou…

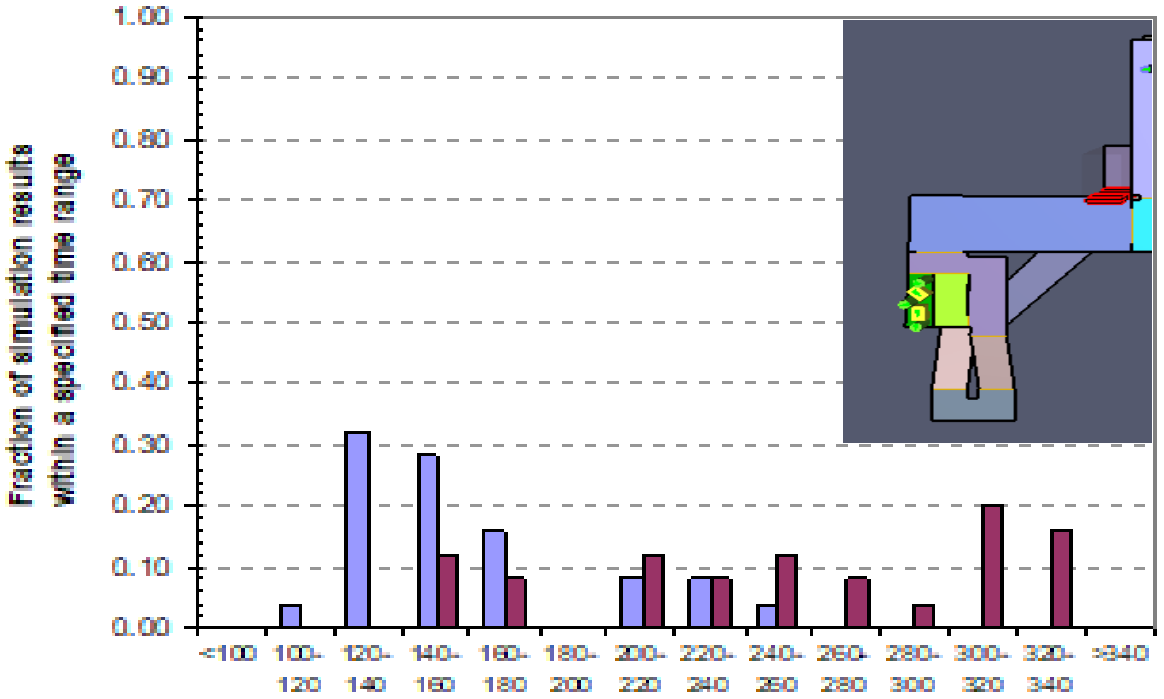


Relocating ar…
may be defin…
defining a spa…
the mobility s…
Two virtual d…
refuge access…
through the …
assistants can…
without remaining unduly entrapped.

4 Case study: Progressive horizontal evacuation of a hospital ward

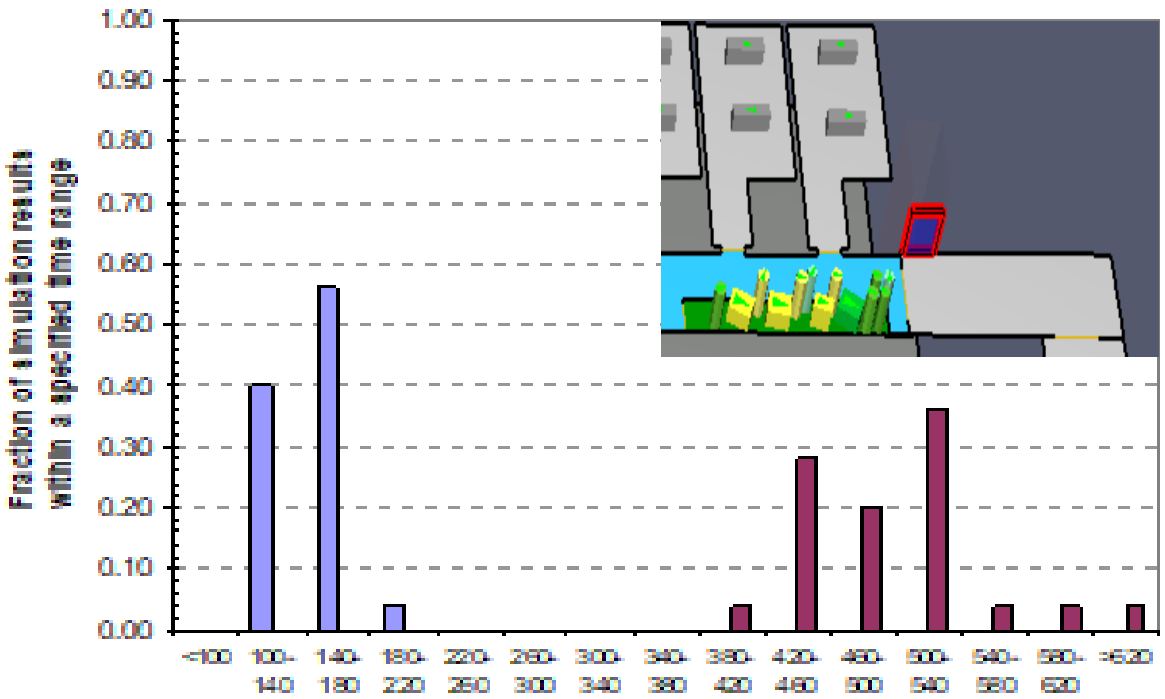


Case study: Progressive horizontal evacuation of a hospital ward



Time 1st and last (5th) occupant to reach safe area #01 on stair S1 (s)

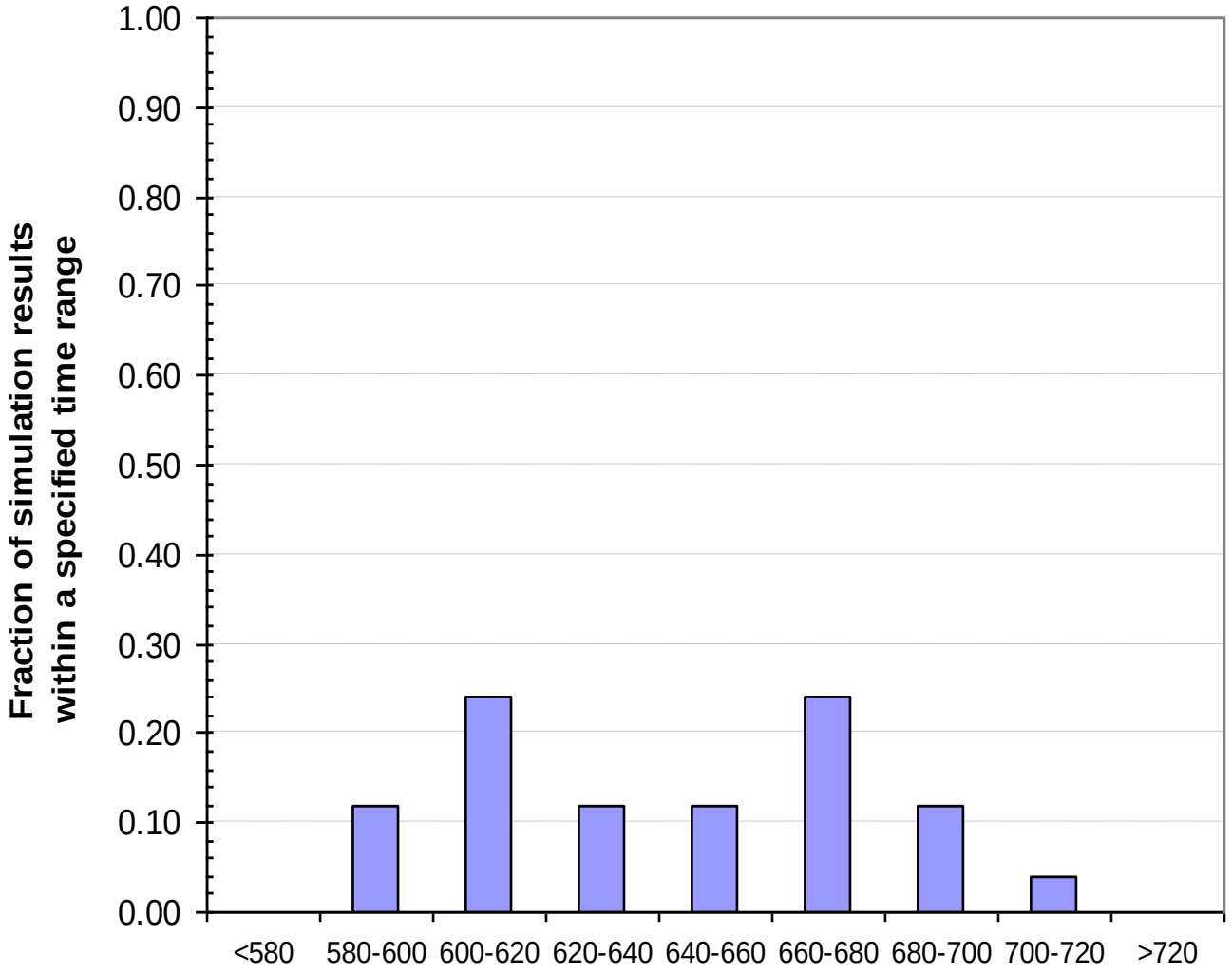
Time (s)	First in	Last in (5)
Mean	159	253
Std. deviation	37	62
Minimum	117	141
Maximum	247	339



Time 1st and last (13th) occupant to reach safe area #04 on corridor in ward W2 (s)

Time (s)	First in	Last in (13)
Mean	147	494
Std. deviation	20	59
Minimum	109	402
Maximum	182	659

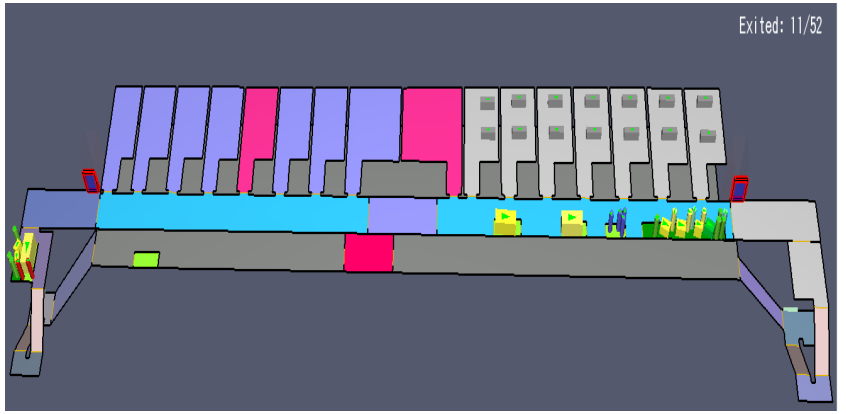
Case study: Progressive horizontal evacuation of a hospital ward



Time required to relocate the in-patients

Statistic	RSET (s)
Mean	643
Std. deviation	35
Minimum	581
Maximum	709

Based on 25 simulations



5

Conclusion and future research work

- There is a need to include assisted evacuation not only when dealing with health care occupancies.
- Assisted evacuation simulation can be a valuable tool helping to identify in advance critical issues relating to the adequacy of the staff and of the procedures adopted in emergency planning.
- The model should be calibrated with site specific data.
- Implementation in the NetLogo platform has the potential to extend our actual modeling capabilities concerning :
  - ✓ space occupancy when mobility devices are considered
  - ✓ way finding adapting to environmental conditions
  - ✓ behavioural rules
  - ✓ occupants fatigue

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Thank you

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