



## A SENSITIVITY ANALYSIS OF A HOSPITAL IN CASE OF FIRE

THE IMPACT OF THE PERCENTAGE OF PEOPLE WITH REDUCED MOBILITY AND THE STAFF TO OCCUPANT'S RATIO

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Anass RAHOUTI <sup>1</sup>, **Prof Sélim DATOUSSAÏD** <sup>1</sup>, Dr Ruggiero LOVREGGIO <sup>2</sup>

<sup>1</sup> : Civil Engineering and Structural Mechanics Department, Faculty of Engineering, University of Mons, Belgium

<sup>2</sup> : Civil and Environmental Engineering Department, Faculty of Engineering, University of Auckland, New Zealand

[Anass.RAHOUTI@umons.ac.be](mailto:Anass.RAHOUTI@umons.ac.be)

# OVERVIEW

## Introduction & Objectives

## Material & Methods

Fire Risk Assessment Method for Engineering  
Agent-Based Model (Pathfinder)

## Case study : Hospital “Clinique Sainte Elisabeth”, Namur, Belgium

Hypothetical fire scenario and floor layout  
Occupants characteristics  
Evacuation strategy  
Evacuation procedure

## Testing

## Results

Comparison, analysis & discussion

# INTRODUCTION

- Statistics 2013: Belgian fire and rescue services attended over 22,733 fires including **236** in care homes and **79** in hospitals
- Health care facilities present a set of **challenges** from the perspective of fire safety:
  - Presence of a large number of vulnerable people → **ASSISTANCE** to evacuate
  - Preparation time needed for some patients (non-ambulant)
  - Low staff to occupant's ratio at night
- Real experiments are **prohibited** in such environment
- Simulation tools such as **Agent-based models** (e.g. Pathfinder) can be used

# OBJECTIVES

- Simulate prescript **assisted evacuation** using **existing evacuation models** such as **Pathfinder**
- Evaluate the impact of **different percentages and types of patients** on the evacuation process
- Study the effect of **staff to patient's ratio** on the evacuation process

# MATERIAL & METHODS

- FRAME method
- PyroSim
- Pathfinder



Mixture of Risk Assessment and Agent-based modeling techniques



**Critical floor (s)**

# MATERIAL & METHODS

- **FRAME** method



- PyroSim

- Pathfinder



- **Fire Risk Assessment Method for Engineering**
  - Developed by De Smet
  - Tool to help a fire protection engineer to define a sufficient level and cost effective fire safety concept for new or existing buildings
  - Risk for property and the content
  - Risk for the activities
  - Risk for **the occupants**
- } **< 1 (well protected)**
- Industry, airports, cultural heritage buildings and **health care facilities**

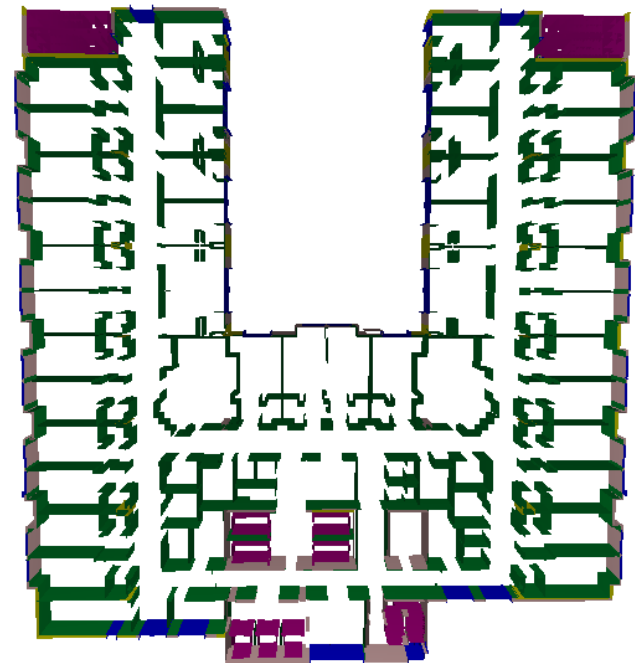
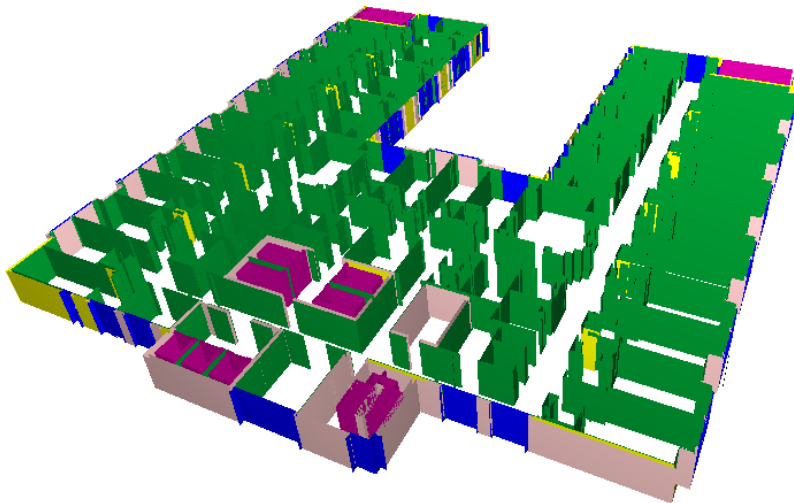
# MATERIAL & METHODS

- FRAME method
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FRAME



Pathfinder



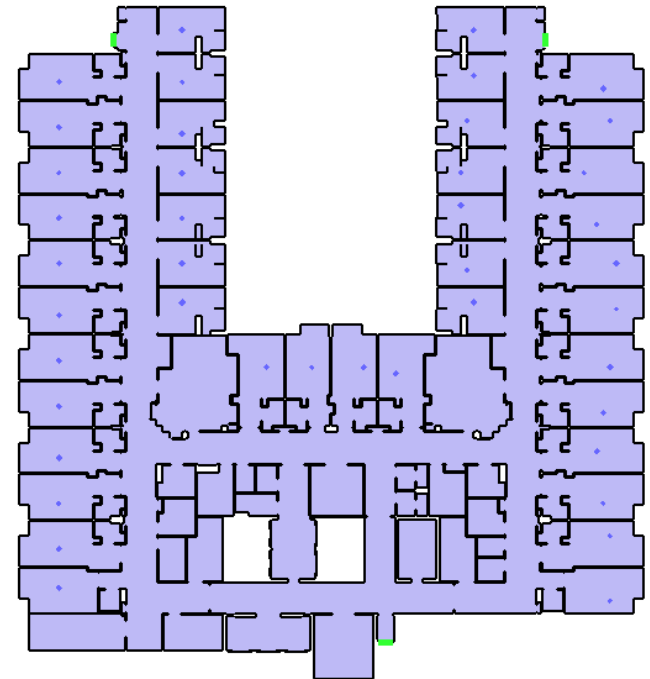
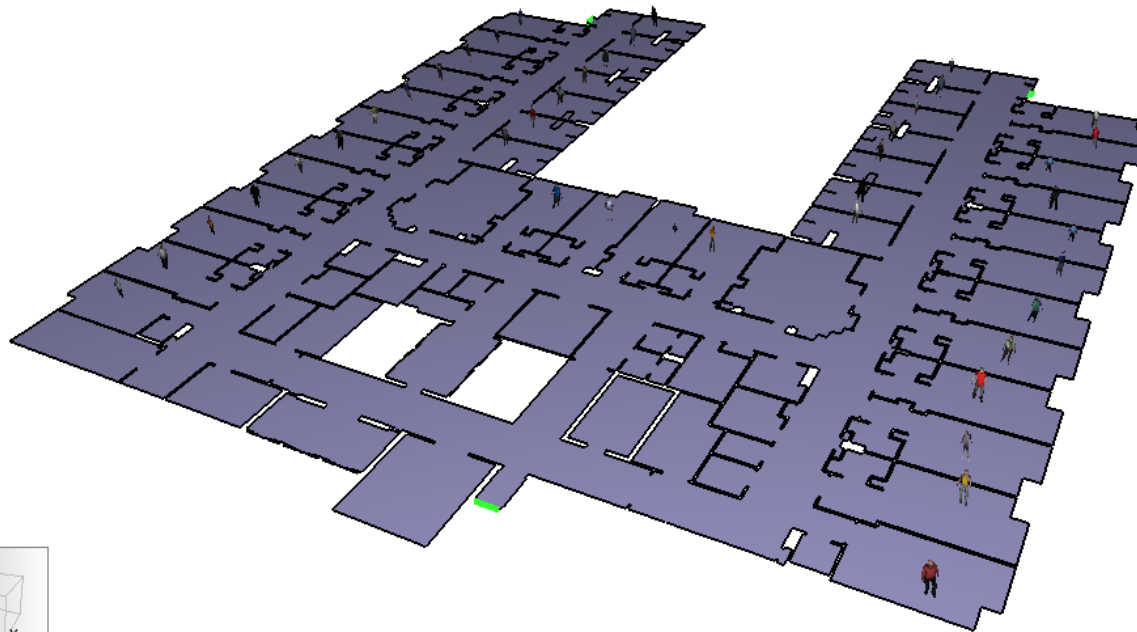
# MATERIAL & METHODS

- FRAME method
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FRAME



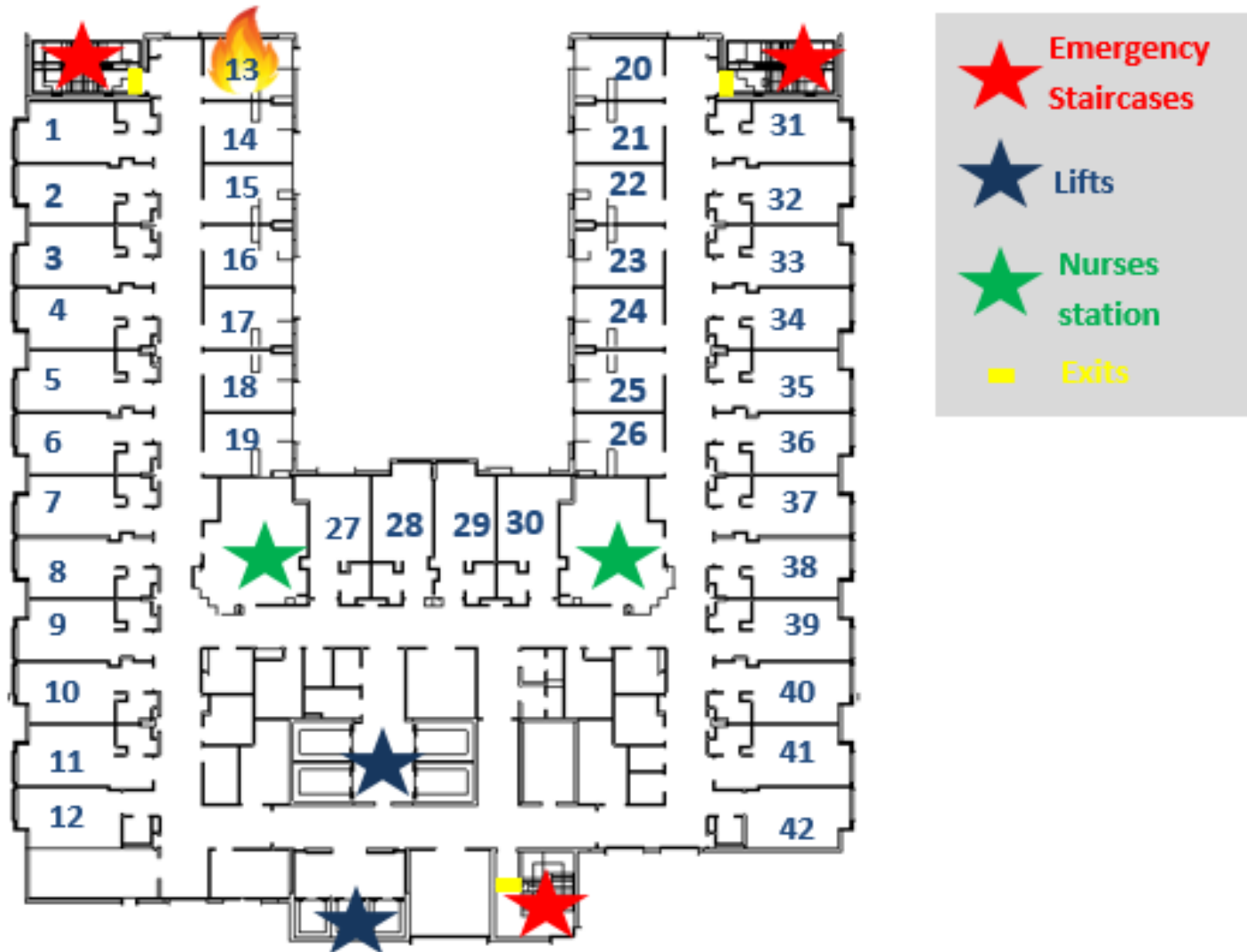
 **Pathfinder**





# CASE STUDY

## Hypothetical fire scenario and floor layout



# CASE STUDY

## Occupants characteristics

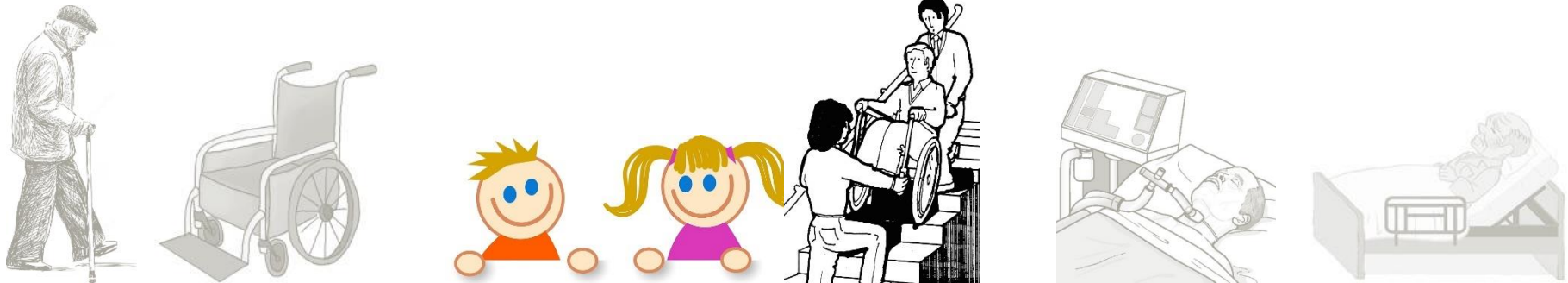
- In health care facilities, the occupants will be a mixture of visitors, staff and **patients**
- Patients will be **independent**, dependent or highly-dependent



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Profile of independent patients			
	Mean	$\sigma$	Range
Pre-evacuation time [s]	50.8	-	30 – 66
Horizontal walking speed [m/s]	1.00	0.42	0.10 – 1.77

			Mean	$\sigma$	Range
Dependent patients	Evacuation Chair	Preparation time [s]	32.7	5.3	-
		Transportation walking speed [m/s]	1.46	0.09	-
	Stretcher	Preparation time [s]	77.7	19.2	-
		Transportation walking speed [m/s]	1.04	0.09	-
Highly dependent patients		Preparation time [s]	-	-	180 – 900
		Transportation walking speed [m/s]	0.40	0.04	-

- **Emergency groups** are composed of **2 attendants** (staff members)

# CASE STUDY

## Evacuation strategy and procedure

- **Evacuation strategy** : horizontal evacuation only (most of hospitals focus on horizontal evacuation in the first stage of an emergency)
  
- **Evacuation procedure** : the objective is to evacuate as many patients as possible
  - 1) Patients in immediate danger
  - 2) Independent patients
  - 3) Dependent patients
  - 4) Highly-dependent patients

# TESTING

**Scenario 1:** all the patients are ambulant (**basis scenario**)

**Scenario 2:** mix of ambulant and non-ambulant patients with different percentage of dependent and highly-dependent patients (6 attendants are present)

Sub-scenario	Number of independent patients	Number of dependent patients	Number of highly dependent patients
2.1	28	14	0
2.2	28	7	7

**Scenario 3:** mix of ambulant and non-ambulant patients with a fixed percentage of ambulant and non-ambulant patients but different staff to patients' ratios

Sub-scenario	Number of attendants	Emergency groups
3.1	8	4
3.2	12	6

# RESULTS

## FRAME Method

- Calculation of the potential risk carried on each floor of the building but only for the characteristic premises
- R** is the calculated risk for the property and content
- R1** is the calculated risk for the occupants
- R2** is the calculated risk for the activities
- For a well protected compartment, R, R1 and R2 **shall be < 1**

Floor Number	Compartment	CALCULATION of the POTENTIAL RISKS			CALCULATION of the ACCEPTANCE LEVELS			CALCULATION of the PROTECTION LEVELS			RISK for		
		Property & content	Occupants	Activities	Property & content	Occupants	Activities	Property & content	Occupants	Activities	Property & content	Occupants	Activities
		P	P1	P2	A	A1	A2	D	D1	D2	R	R1	R2
R+7	Technical Room	1,59	3,51	1,01	1,39	1,29	1,35	1,53	2,53	0,96	0,74	1,07	0,78
	Technical Room + Small Room	0,42	3,19	0,27	1,50	1,40	1,45	2,02	3,39	1,29	0,14	0,67	0,14
R+6	Double Bedroom	0,34	2,85	0,26	1,47	1,37	1,45	1,64	2,16	1,05	0,14	0,96	0,17
	Single Bedroom	0,34	2,87	0,26	1,48	1,38	1,45	1,64	2,16	1,05	0,14	0,96	0,17
	Waste Room	0,17	2,79	0,11	1,50	1,40	1,45	1,82	2,39	1,16	0,06	0,83	0,06
R+5	Middle care	0,33	2,59	0,25	1,47	1,37	1,45	1,64	2,16	1,05	0,14	0,87	0,17
R+4	Medical Office	0,29	2,42	0,17	1,60	1,50	1,55	1,82	2,39	1,16	0,10	0,67	0,10
R+3	Dirt Laboratory	0,29	2,42	0,17	1,60	1,50	1,55	1,82	2,39	1,16	0,10	0,67	0,10
	Clean Laboratory	0,37	2,29	0,23	1,60	1,50	1,55	1,82	2,39	1,16	0,13	0,64	0,13
R+2	Head nurse room	0,68	4,78	0,43	1,50	1,40	1,45	1,92	3,72	1,23	0,24	0,92	0,24
	Operating Room	0,30	1,56	0,19	1,60	1,50	1,55	1,82	3,54	1,16	0,10	0,29	0,11
R+1	Dirty Laundry Unit	0,25	2,33	0,15	1,50	1,40	1,45	1,82	2,39	1,16	0,09	0,70	0,09
	Clean Laundry Unit	0,14	1,65	0,09	1,50	1,40	1,45	1,82	3,54	1,16	0,05	0,33	0,05
R0	Radiologie-Osseaux4	0,18	1,07	0,11	1,30	1,30	1,25	2,02	3,23	1,29	0,07	0,26	0,07
R-1	Pharmacy + Cold Storage	0,23	2,00	0,17	1,60	1,50	1,55	1,92	2,52	1,23	0,07	0,53	0,09
	Pharmacy + Archives	0,30	2,84	0,19	1,50	1,40	1,45	1,92	2,52	1,23	0,10	0,81	0,11
Legend			Slight risk				Medium risk				High risk		



# RESULTS


## FRAME Method

RISK for		
Property & content	Occupants	Activities
R	R1	R2
0,74	1,07	0,78
0,14	0,67	0,14
0,14	0,96	0,17
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0,06	0,83	0,06
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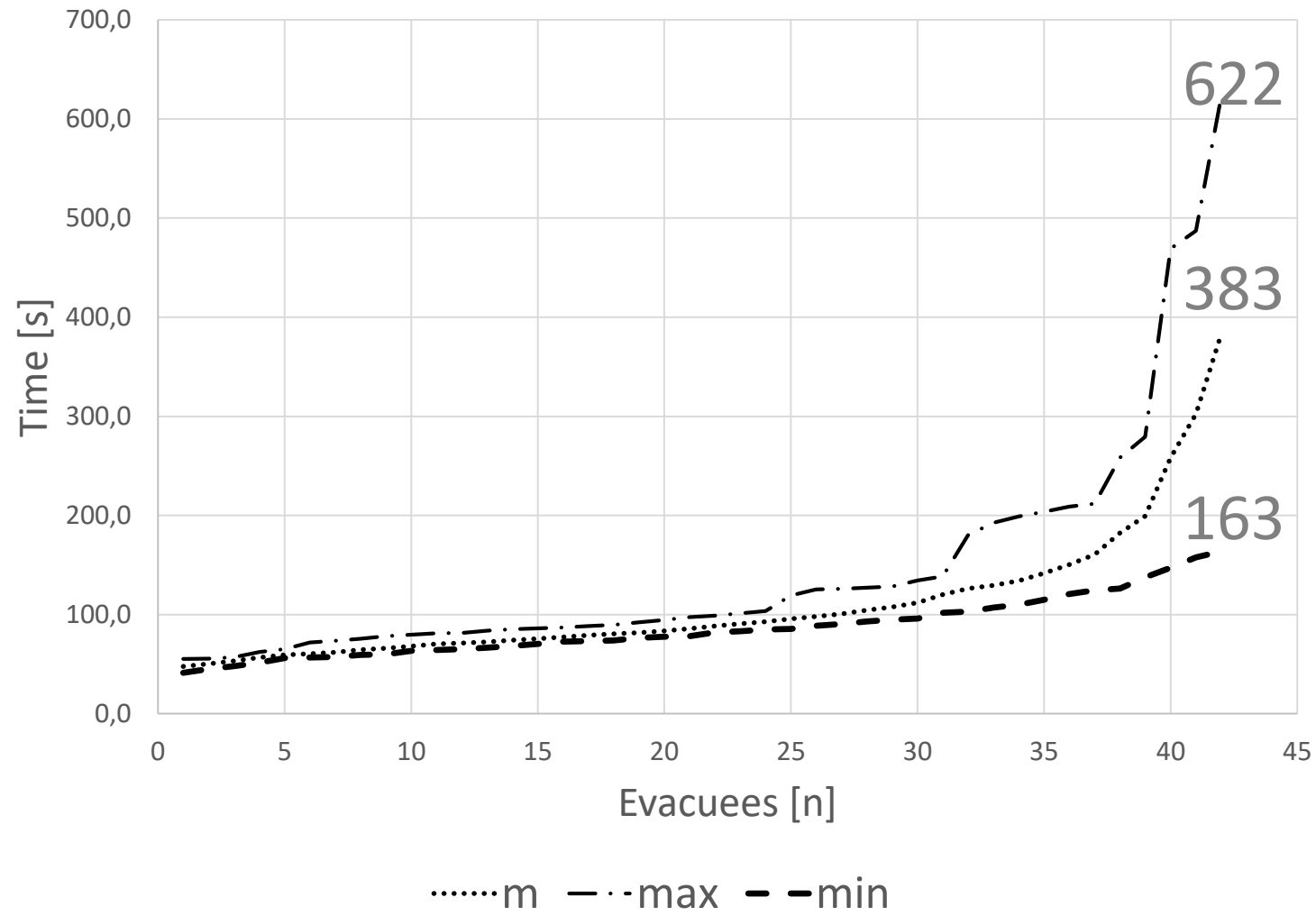
# RESULTS

## FRAME Method

- In general, the building is well protected against fire excluding the technical premise of the 7<sup>th</sup> floor in which the  **$R1 > 1$**
- Follows strictly the Belgian Prescriptive Codes (AR 6 November 1997)
- The risk for the occupants is greater than 1 due to the presence of the ventilation and heating machinery
- 7<sup>th</sup> floor : difficult access for firefighters but not accessible to the public (only the staff)
- The following critical premises are the sleeping rooms of the 6<sup>th</sup> floor
- Floor selecting for modelling  **6<sup>th</sup> floor**

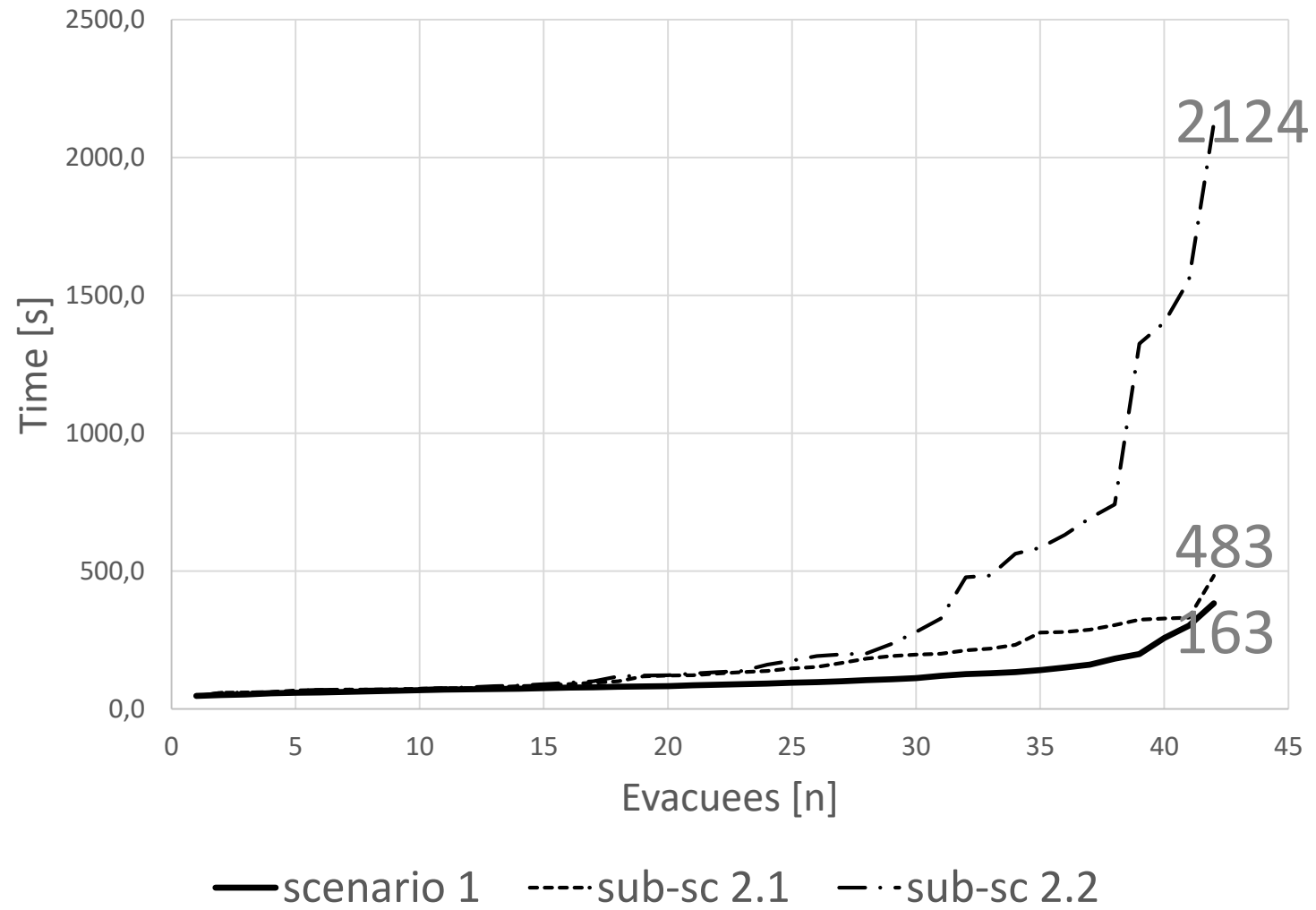
# RESULTS

## Scenario 1



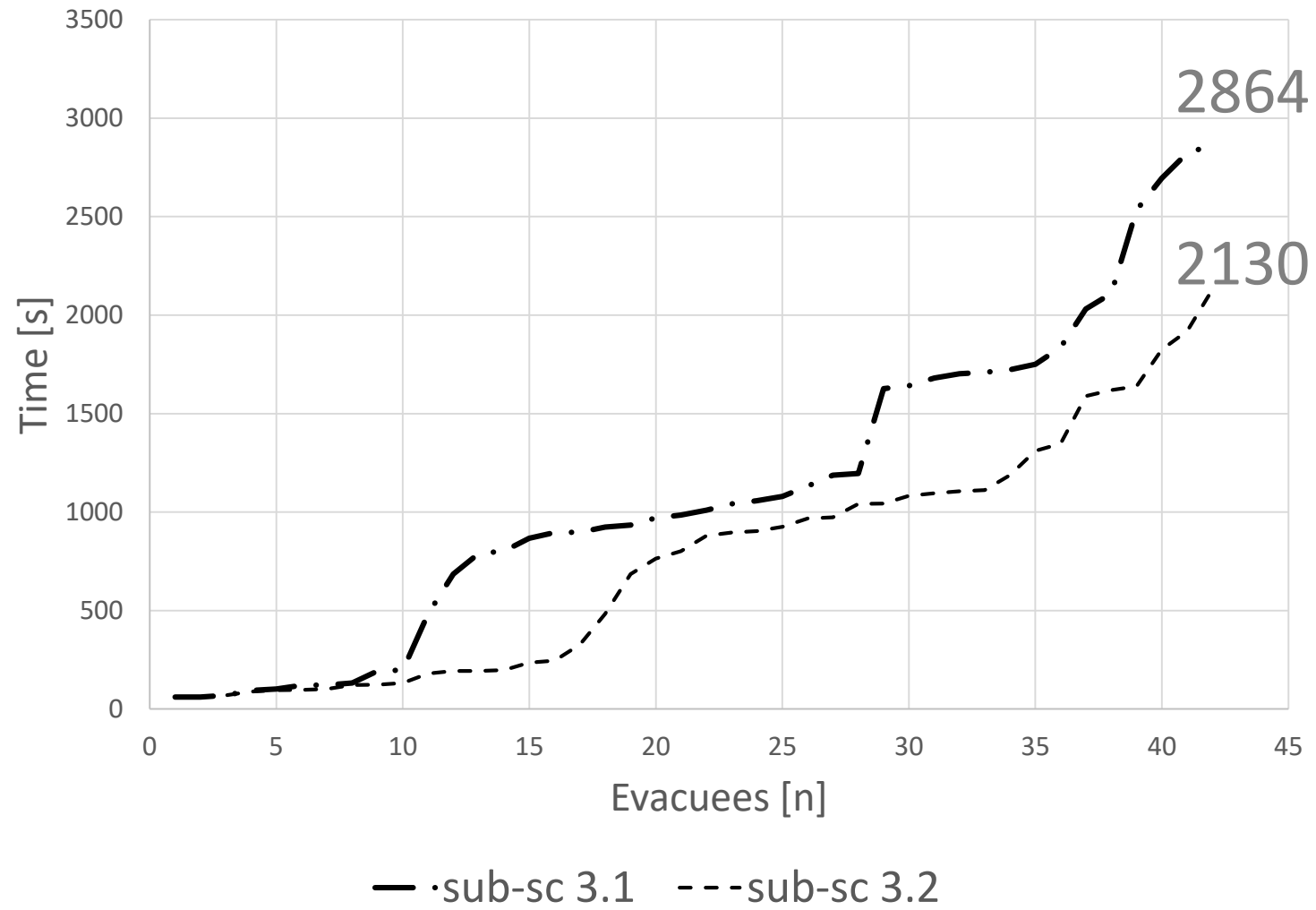
# RESULTS

## Scenario 1 & 2 (comparison)



# RESULTS

## Scenario 3



# CONCLUSIONS

- Pathfinder is able to simulate prescript assisted evacuation (implicitly embedded by using the special features such as delays, assigned travel itineraries, etc.). However, the transportation devices are not modelled (interactions agents-devices are missing)
- The results showed that :
  - 1) Conducting an assisted evacuation takes a higher time than an evacuation involving only ambulant patients;
  - 2) The number of non-ambulant patients should be designed as few as possible to limit the time needed to conduct a safe evacuation;
  - 3) The type of non-ambulant patients involved on the evacuation process influence the total evacuation time. Indeed, evacuating highly-dependent patients lead to a higher total evacuation time than evacuating dependent patients; and,
  - 4) The presence of a large number of attendants leads to faster evacuation

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# Thank you for your attention



Anass RAHOUTI <sup>1</sup>, **Prof Sélim DATOUSSAÏD** <sup>1</sup>, Dr Ruggiero LOVREGGIO <sup>2</sup>

<sup>1</sup> : Civil Engineering and Structural Mechanics Department, Faculty of Engineering, University of Mons, Belgium

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