# The Simulation of Assisted Evacuation in Hospitals

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# Introduction

- Fire evacuation is hospitals requires a well-defined strategy and an effective execution that involves the assistance of patients that are not able to evacuate.
- Computer evacuation models have been developed for self-evacuation instead of assisted evacuation.
- All patients have a preparation time that may depends on the illness or treatment (i.e. disconnect from equipment, movement from bed to wheelchair, stretcher, or the common pre-evacuation activities such as get dressed or gathering belongings)
- Health care personnel will assist the patients and in many cases they will transport them during the evacuation.

**This work:**

- The capabilities of STEPS and Pathfinder to simulate an assisted evacuation is explored.
- A model strategy is proposed to adapt those models and it is applied to a hospital floor plant.

# Occupants characteristics

Type of occupants* in hospitals

- Health care personnel
- Patients

- Type A – Ambulant patients with reduced mobility
- Type B – Non- ambulant patients- wheelchair
- Type C – Non- ambulant patients- stretcher, blanket or others (may include the connection to any medical equipment).

*other occupants are not considered in this study

## Key parameters in an assisted evacuation

- Pre-Evacuation time ($t_{pe_S}$)- time elapsed until each health care personnel member starts the movement to evacuate the patients.
- Preparation time ($t_p$) – Time required for preparing the patients for Evacuation
- Uninpeded walking speed ($W_S$) - walking speed of each health care personnel moving towards a patients or returning to the next patient
- Transportation speed ($W_p$) – walking speed while transporting the patients

# Proposed inputs for key parameters

## Response and preparation time for patients

| Typology | Distribution law | Mean [s] | Sigma [s] | Range [s] |
|---|---|---|---|---|
| **Health care personnel** | Log-normal | 71 | 60 | |
| **Type 1** | Normal | 60 | 20 | 30-90 |
| **Type 2** | Normal | 110 | 36 | 100-120 |
| **Type 3** | Normal | 360 | 40 | 180-900 |

## Unimpeded and transportation velocities for health care facilities

| Parameter | Distribution law | Mean [m/s] | Sigma [m/s] | Range [m/s] |
|---|---|---|---|---|
| **Unimpeded speed for health care personnel members** | Normal | 1.35 | 0.25 | 0.65 - 2.05 |
| **Speed for ambulant patients with reduced mobility** | Uniform | 1.12 | 0.28 | 0.84 -1.40 |
| **Transportation speed for wheelchair** | Normal | 0.63 | 0.04 | |
| **Transportation Speed for stretcher** | Normal | 0.40 | 0.04 | |

# Levels of “triage” systems: Get as many patients out as possible

1. Inmediate danger
2. Type A – Ambulant patients
3. Type B – patients requiring some transport (wheelchair)
4. Type C – patients requiring transport (stretcher/blanket)
5. Patients who are difficult to evacuate ( i.e. ICU, bariatrics)

# Model strategy for assisted evacuation

1. Personnel gathered in an initial point receiving the information (Evacuation priority)
2. Two personnel member (emergency group EG) will assist each patient. Each EG is represented as ONE agent in the model.
3. Each agent has his/her $t_{pe_S}$ and $W_S$
4. Each agent (EG) wait in the room a time equivalent to the preparation time.
5. After the preparation time $t_p$ , the agent will start the Evacuation movement with a walking speed similar to the transportation speed.
6. Once the agent has reached the safe place, the agent will move towards the next patient ($W_S$ ).
7. Steps 2 to 6 to be repeated until each agent has complete his defined evacuation priority.

# Application of STEPS for assisted Evacuation in hospitals

**Occupants behaviour**

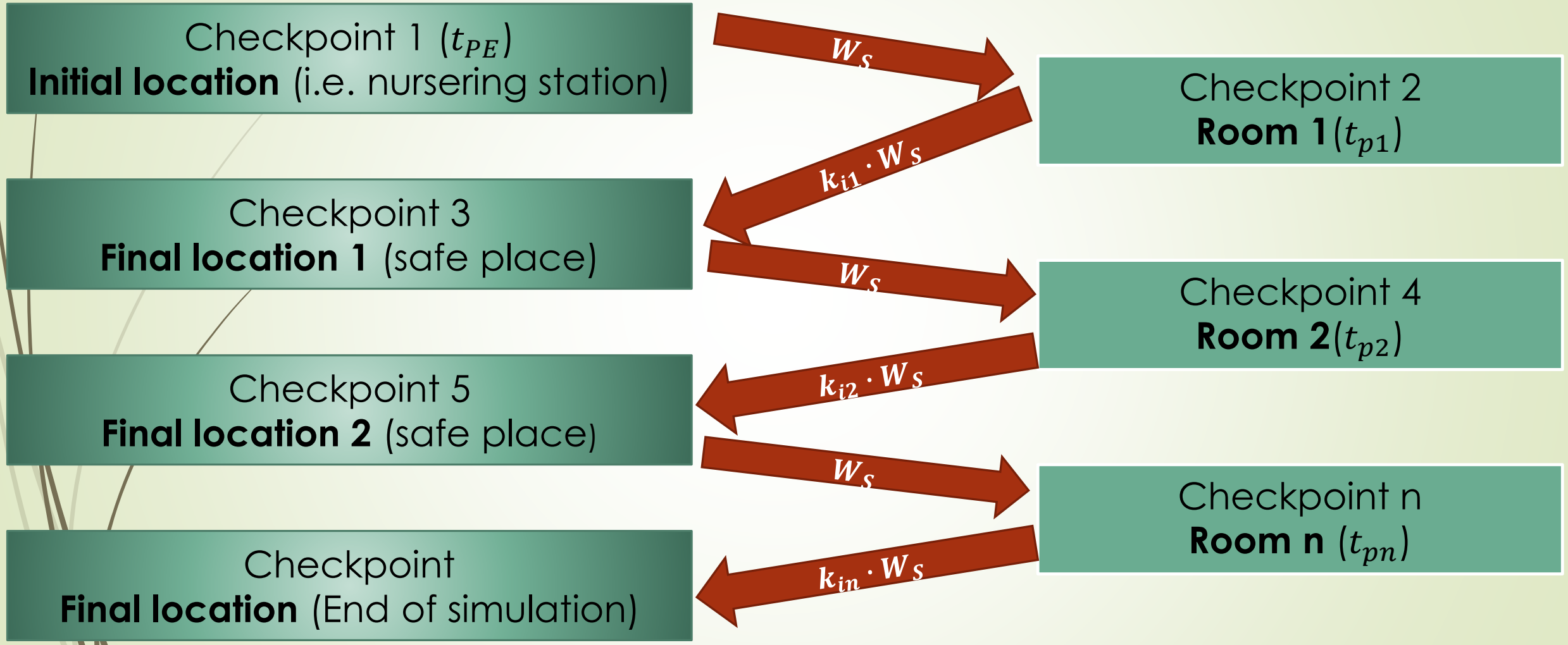
- Pre-evacuation time → $t_{pe_S}$
- Preparation time → $Delay\ point$

**Occupants movement**

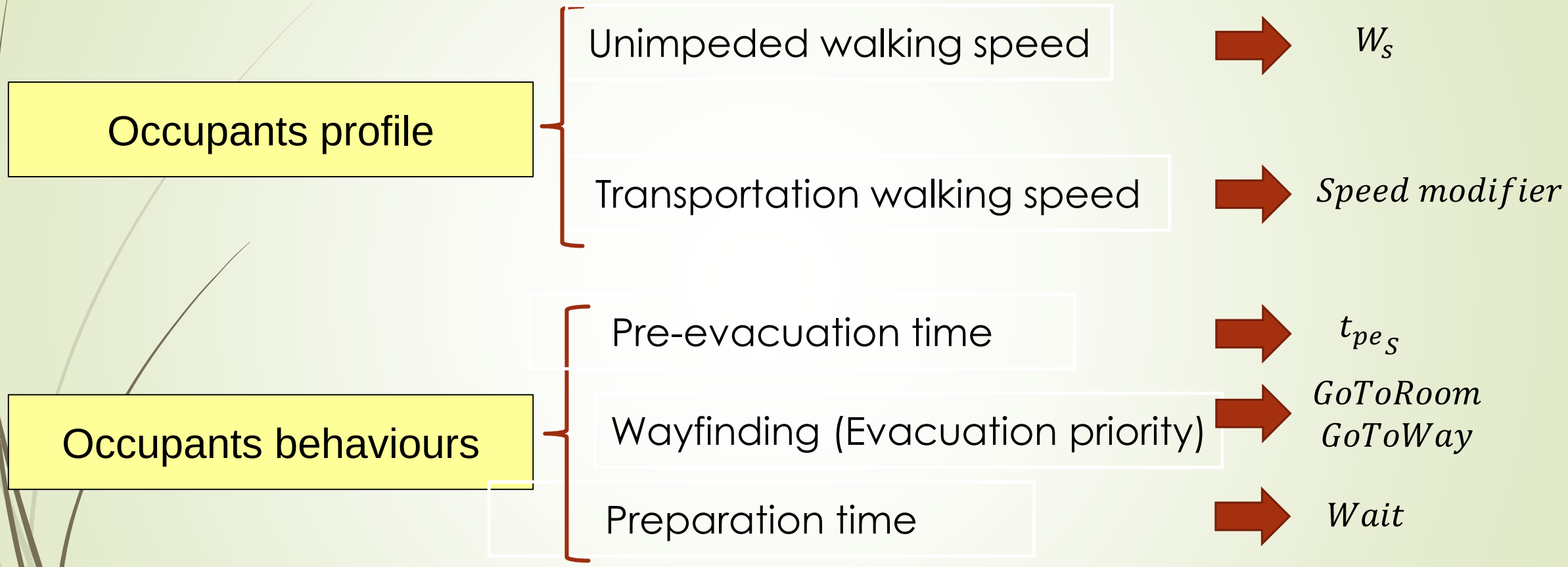
- Wayfinding (Evacuation priority) → $Checkpoints$
- Unimpeded walking speed → $W_s$
- Transportation walking speed → $Evacuation\ route + Decreasing\ coefficient$

| Type of patients | Coefficient |
|---|---|
| Type 1 | 0.83 |
| Type 2 | 0.47 |
| Type 3 | 0.30 |

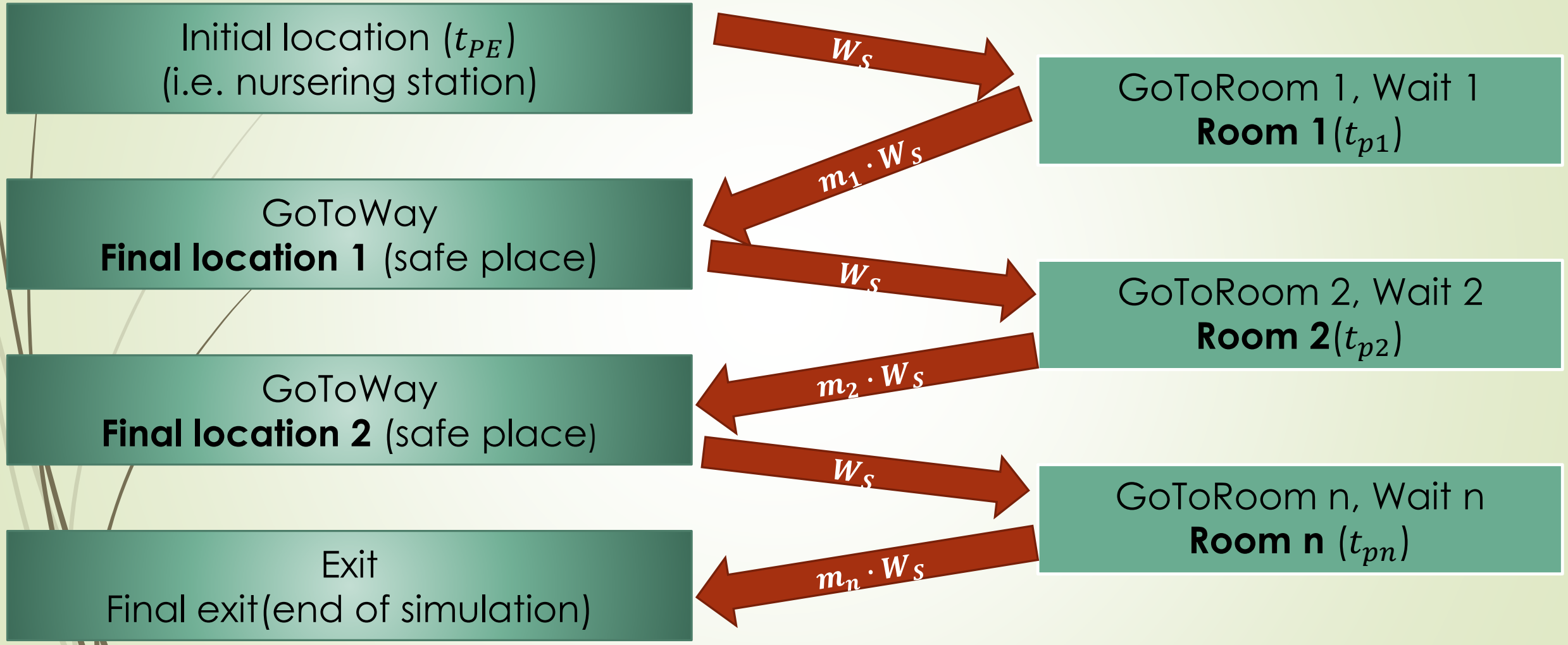
# Calibration method for STEPS model



# Application of Pathfinder for assisted Evacuation in hospitals

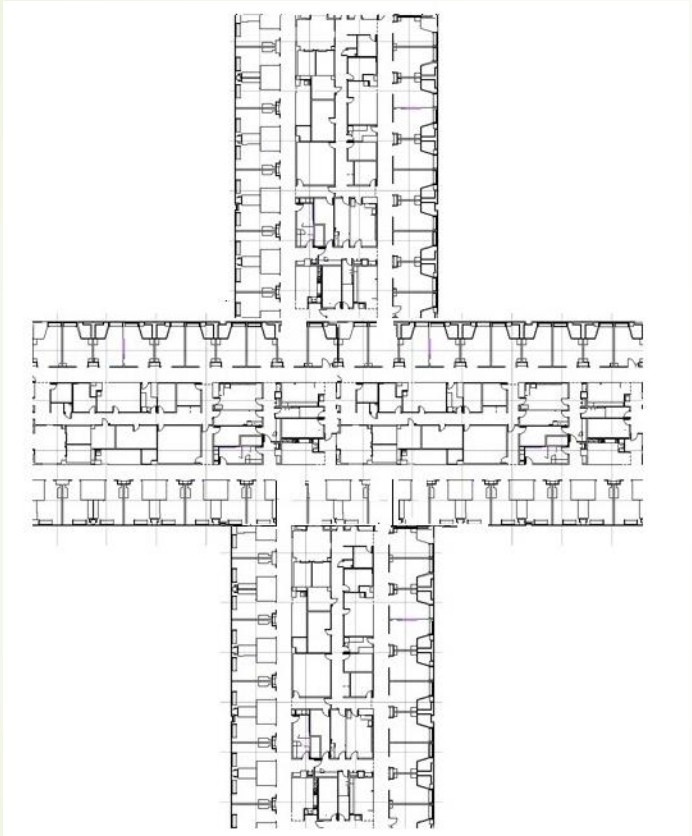


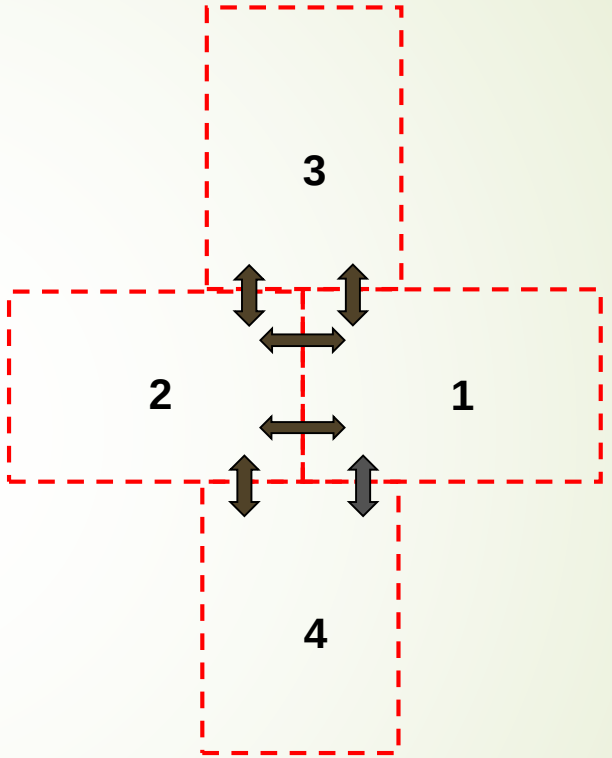
# Calibration method for Pathfinder model



## Hypothetical hospital floor plant for sleeping area[1]

STEPS model






4 smoke compartaments of 1781m$^2$ (mantaining the 61 m as máximum travel distance)

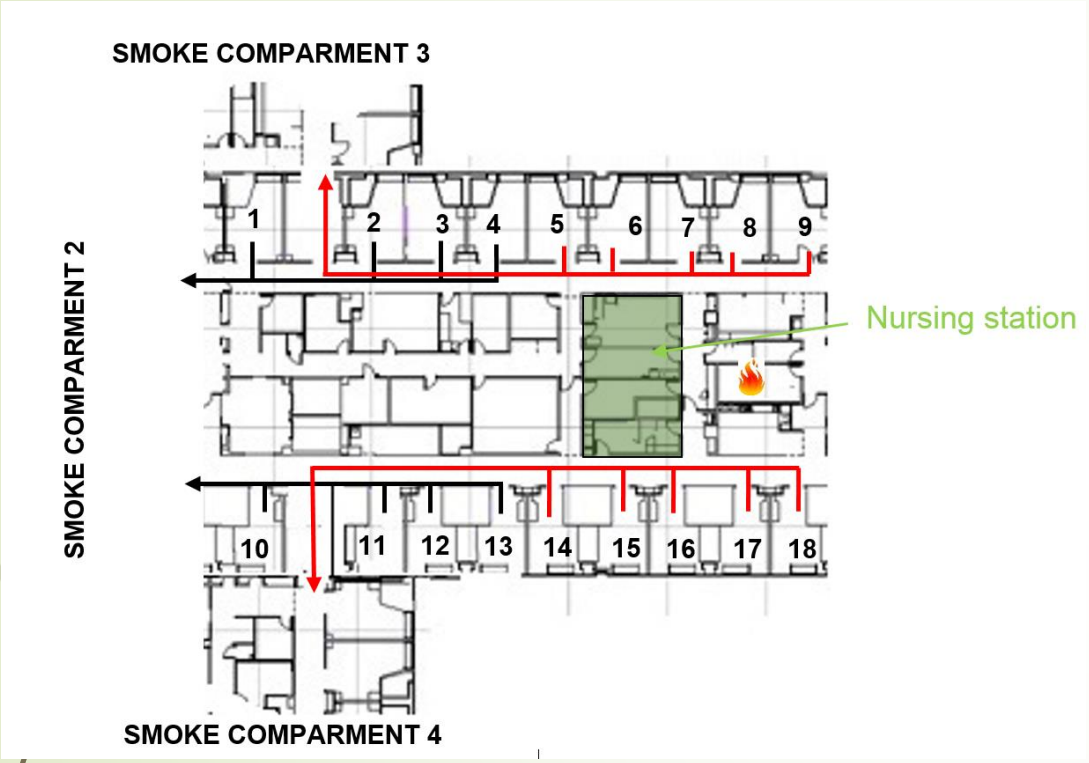
18 rooms in each smoke compartament

22 patients

[1]V. Alonso, "Egress Modelling in health Care Occupancies," National Fire Protection Association, Fire Protection Research Foundation report, 2014.

# Model case study – Evacuation scenario

## Evacuation to other smoke compartment




## Ramdon location of patients in rooms


- Scenario 1 – 6 emergency groups (12 health care personnel)
- Scenario 2 – 4 emergency groups (8 health care personnel)
- Scenario 3 – 3 emergency groups (6 health care personnel)

# Model case study – Evacuation strategy

Evacuation priority based on the “triage” system:

| | | Rooms | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Scenario 1** | EG 1 | 9 | 2 (T1) | 5 | 2 (T3) | | | | |
| | EG 2 | 8 | 7 | 4 | | | | | |
| | EG 3 | 6 (T1) | 6 (T3) | 3 | 1 | | | | |
| | EG 4 | 18 | 14 (T2) | 16 ($T3_1$) | 11 | | | | |
| | EG 5 | 17 | 15 | 13 | 10 | | | | |
| | EG 6 | 14 (T1) | 16 ($T3_2$) | | | | | | |
| **Scenario 2** | | | | | | | | | |
| | EG 1 | 9 | 2 (T1) | 7 | 5 | 3 | 1 | | |
| | EG 2 | 8 | 6 (T1) | 6 (T3) | 4 | 2 (T3) | | | |
| | EG 3 | 18 | 14 (T1) | 14 (T2) | 16 ($T3_1$) | 12 | 10 | | |
| | EG 4 | 17 | 15 | 16 ($T3_2$) | 13 | 11 | | | |
| **Scenario 3** | | | | | | | | | |
| | EG 1 | 9 | 17 | 2 (T1) | 7 | 6 (T3) | 4 | 2 (T3) | 1 |
| | EG 2 | 18 | 6 (T1) | 15 | 16 ($T3_1$) | 5 | 12 | 11 | |
| | EG 3 | 8 | 14 (T1) | 14 (T2) | 16 ($T3_2$) | 13 | 3 | 10 | |

# Model case study – Analysis and Results

100 simulations for each simulation

| Scenario | Mean evacuation time (min) | Standard deviation (min) | 90th percentile of the evacuation time (min) | 95th percentile of the evacuation time (min) |
|---|---|---|---|---|
| 1 | **30:13** | 02:25 | 33:24 | 34:32 |
| 2 | **43:08** | 02:16 | 46:13 | 47:01 |
| 3 | **59:34** | 04:09 | 65:04 | 66:23 |

**Scenario 1/ Scenario 2 –** More than 12 minutes

**Scenario 1/ Scenario 3 –** More than 29 minutes

# Discussion

- Two types of occupants are identified in hospital evacuation: Health care personnel and patient.
- The evacuation procedure in hospitals follows a predefined evacuation priority (usually triage).
- Key parameters are identified in an assisted evacuation: $t_{pe_S}$, $t_p$, $W_S$, $W_p$.
- Evacuation models are mainly developed for simulating self evacuation processes but their flexibility allow the user to calibrate them to represent  other scenarios such as assisted evacuation.
- Based on a defined model strategy, STEPS and Pathfinder are calibrated for the simulation of horizontal evacuation in hospitals

- The capabilities and limitations of STEPS and Pathfinder are:

| | STEPS | | | Pathfinder* | | |
|---|---|---|---|---|---|---|
| | Directly modelled? | Calibrated ? | Additional information | Directly modelled? | Calibrated? | Additional information |
| **Geometry** | YES | - | Limitations of fine network models | YES | - | |
| **Pre-evacuation time** | YES | - | | YES | - | |
| **Preparation time** | NO | YES | Delay points in rooms | NO | YES | Wait in rooms |
| **Unimpeded walking speed** | YES | - | | YES | - | |
| **Transportation speed** | NO | YES | Decreasing coefficient linked to a defined route | NO | YES | Using speed modifiers in certain areas |
| **Evacuation priority** | NO | YES | checkpoints | NO | YES | GoToRoom |

** New featuress for assisted evacuation will be relased in PathFinder 2016.2*

- The case study shows the possibilities of the calibration method for STEPS.

# Conclusions

- STEPS and Pathfinder models have sufficient flexibility to be calibrated and used in assisted evacuation in hospitals.
- Both models can simulate the pre-evacuation time and unimpeded walking speed of health care personnel and can be calibrated for representing the evacuation priority in case of fire.
- Model´s attributes *delay point* (STEPS) and *Wait* (Pathfinder) represent the preparation times of patients in each room, but Wait is a deterministic input.
- STEPS defines an evacuation route assigning a decreasing coefficient to a route to mimic the transportation time. Pathfinder allows the use of speed modifier to be applied in certain areas. Assumptions on the areas and routes to be considered.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