Stochastic analysis of egress simulations

Quentin JULLIEN

Centre Scientifique et Technique du Bâtiment - France

CSTB
le futur en construction

quentin.jullien@cstb.fr

Content

1. Content
2. Context
3. Statistical analysis method principles
4. Hypothesis of the model
5. Reference study case
6. Analysis of the statistical influence of the parameters
7. Results synthesis
8. Method assets
9. Conclusion

Context

The use of egress simulation models in performance-based analysis relies on the confidence in the input data and the output data.

But, data strongly depend on a large number of parameters.

These parameters model human behavior and are scattered.

$\rightarrow$ The results are prone to be scattered.

This study proposes a analysis method to deal with it.

Aim of the study

Realization of a method to analyze the stochastic aspects of an egress simulation model.

- The method is based on **statistical estimations of the distribution quantiles of the output parameters.** The key result is Required Safe Egress Time (RSET).

Benefits of the method:

- Provide **quantitative informations** on the RSET.
- **Justify the number of simulations** to obtain a relevant output precision level.

Statistical analysis method principles

The **egress phenomena is scattered in itself**: evacuating a building can occur in a lot of different ways.

The method tries to deal with the whole range of possibilities.

A stochastic approach is used for that, generating distribution function for each outputs.

The random aspects are processed by the mean of the **confidence interval concept**.

Statistical analysis method: calculation

Example:

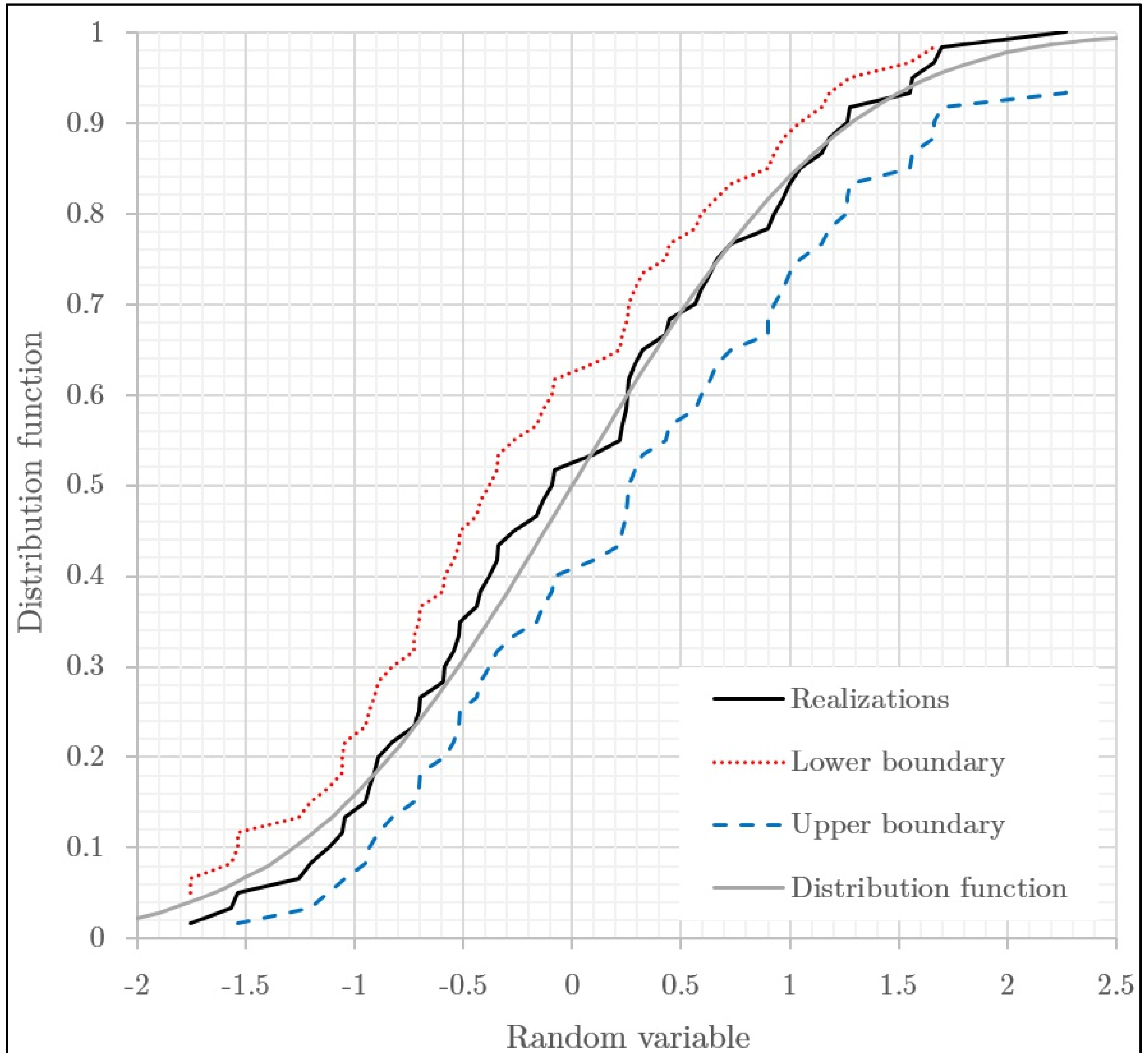
- A sample of n realizations of a random variable that follows a normal law distribution.
- A confidence interval *Ip* for each quantile α.
- A level of confidence p: here 90%.

$$Ip = \left[\tilde{F}^{-1}\left(\alpha - c\sqrt{\frac{\alpha(1-\alpha)}{n}}\right); \tilde{F}^{-1}\left(\alpha + c\sqrt{\frac{\alpha(1-\alpha)}{n}}\right)\right]$$

c equals to 1.645 for p=90%.

Calculating the empirical distribution function

→ Random realizations ranked in ascending order constitute the empirical distribution function.



Observations

- A random variable can have no theoretical maximum.
- Even if there is a maximum value, the finite size of the samples prevent from calculating this maximum value.

$\rightarrow$ Only percentiles are available.

- Available percentiles increases with the growth of the sample size.
- Confidence interval width decreases with the growth of the sample size.

$\rightarrow$ So, the required number of simulations is set by:

- the desired precision,
- the order of the desired quantile.

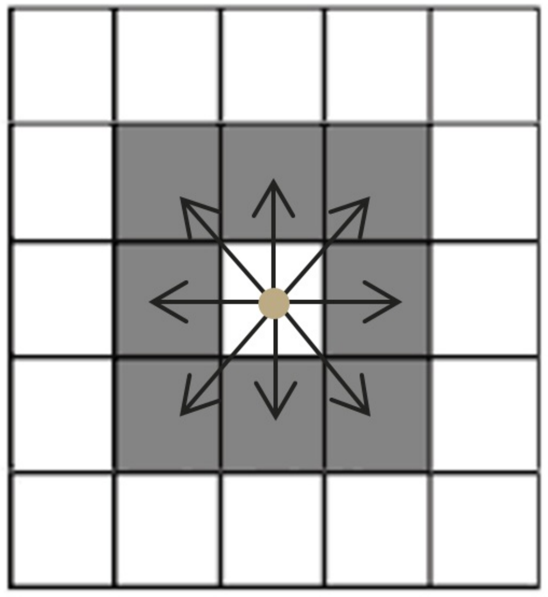
Hypothesis of the model

The numerical tool used in this study is BuildingExodus.

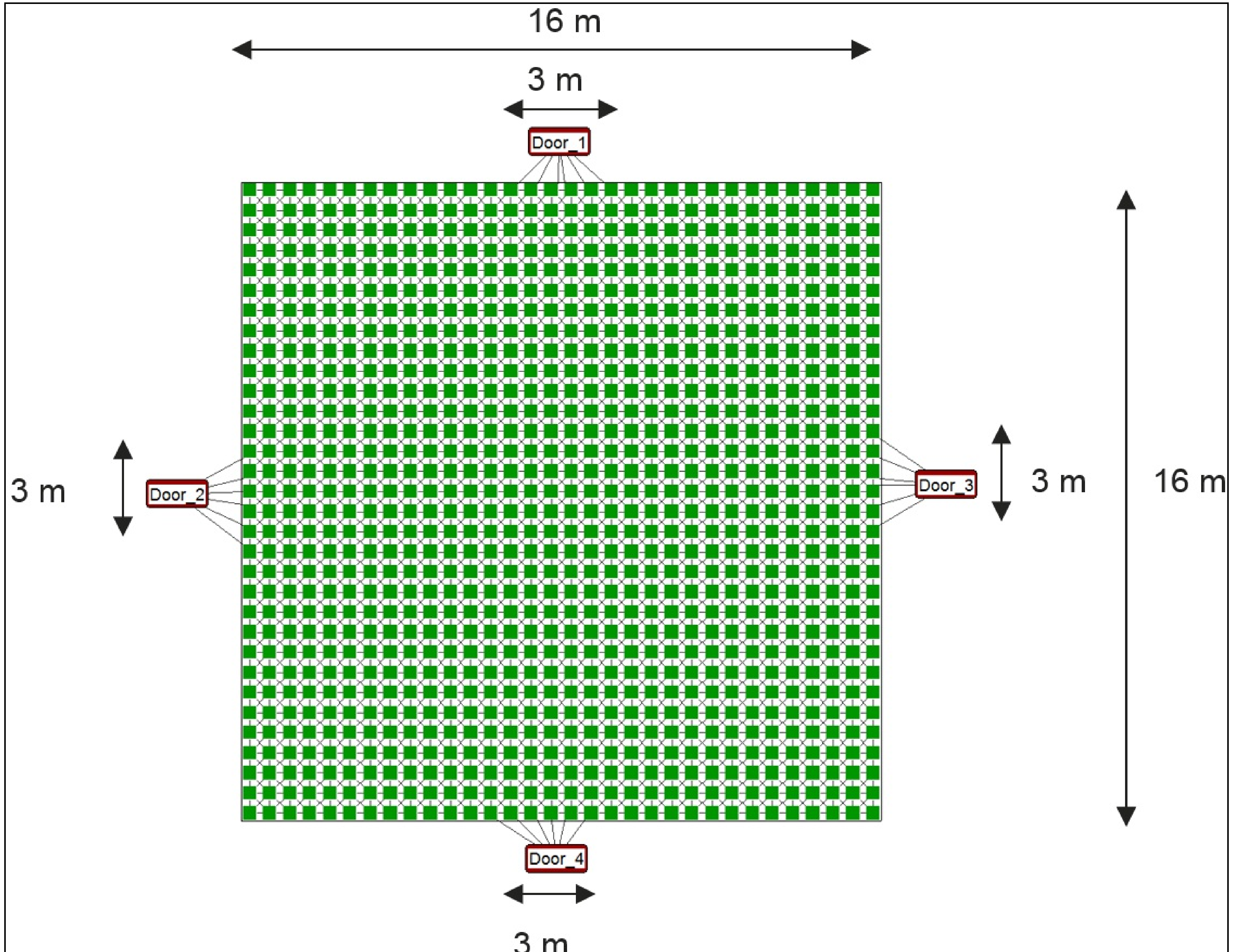
But, statistical processing can be performed with any simulator.

Reminder:

- BuildingExodus is based on a discretization of space in node of 50 cm x 50 cm.
- The connection model is the one of Moore.


The Moore neighbourhood

Test case geometry



Behavioral hypothesis

Occupants:

- same leaderships,
- same patience,
- valid,
- speed of 1.2 m/s,
- response time (RT) of 15 s or variable between 0 and 30 s,
- act independently of each other.

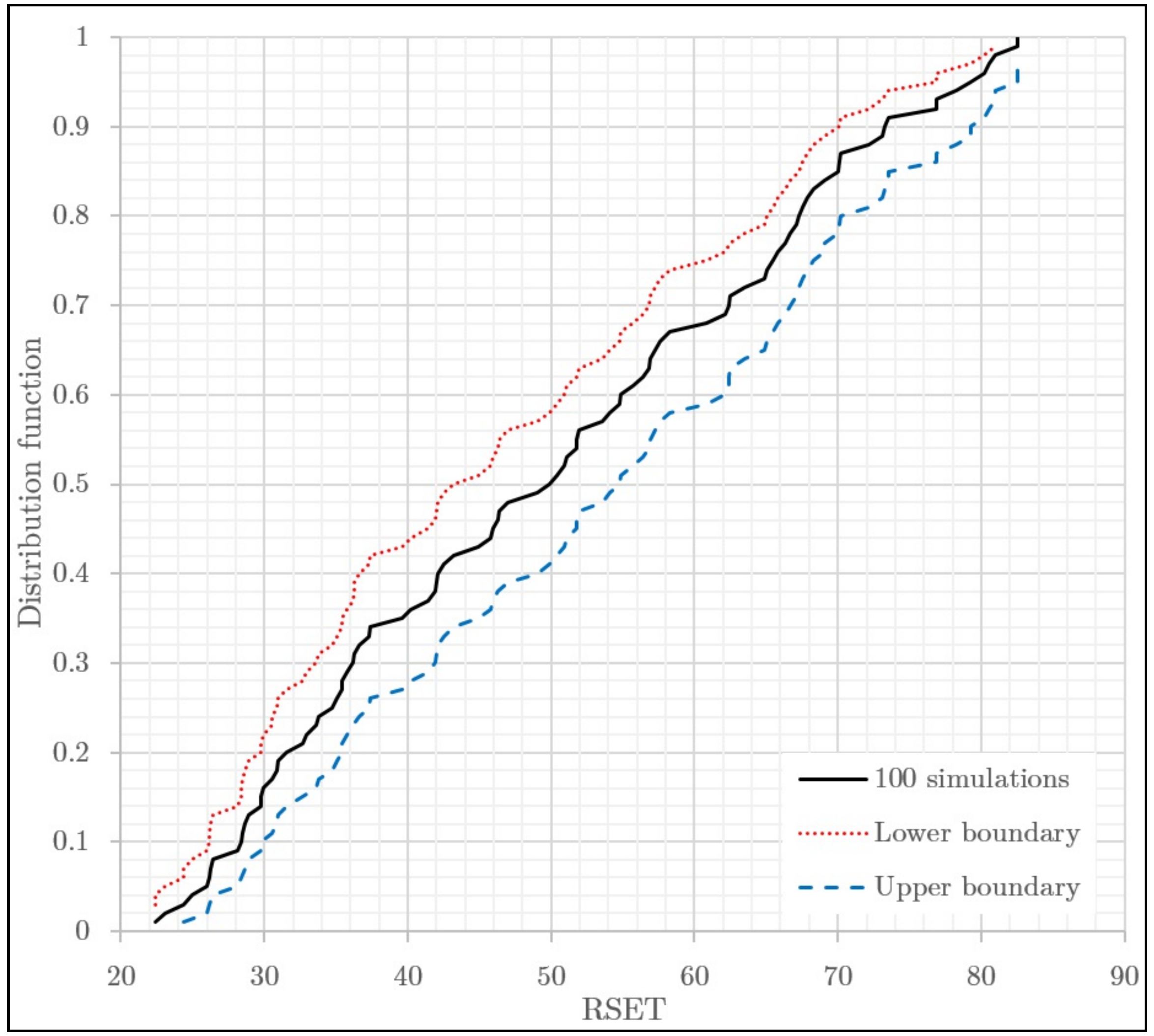
The identical leaderships imply a conflict resolution time included between 0.8 s and 1.5 s. The fixed value of 1.15 s will be use too.

The draws are realized with an uniform law.

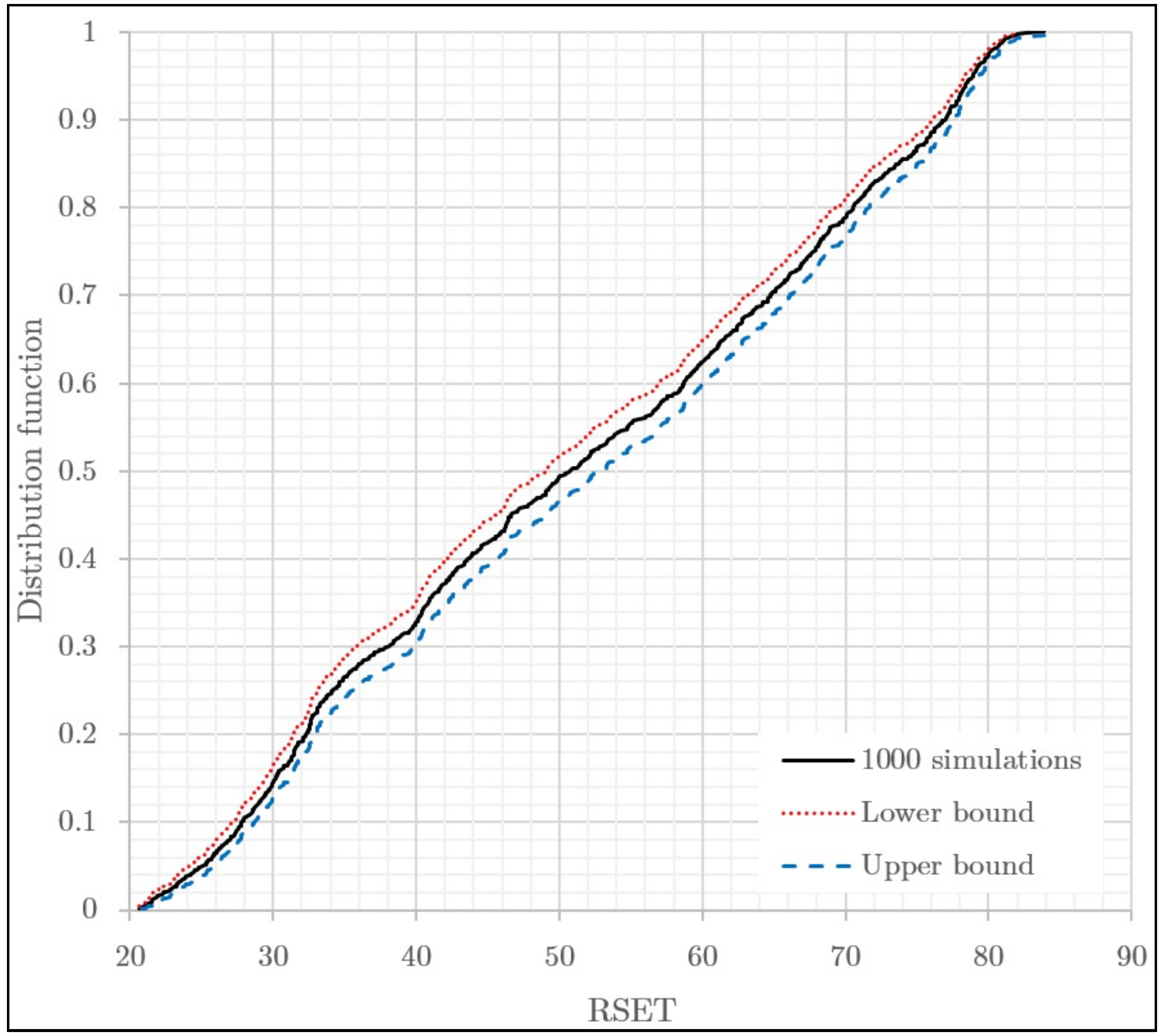
Reference study case

Occupants are randomly located in the room and drawn between 1 and 1,000.

100 simulations



1,000 simulations



Analysis

It is impossible to statistically determine a RSET maximum.

- Extreme percentiles have a confidence interval with infinite bounds.

  In any case, a **RSET max is bound to a catastrophic scenario**.

  $\rightarrow$ It seems preferable to retain a high order percentile.

- This study used the 95^{th} percentile.

- The value of this parameter is essential to an egress study conclusions and has to be discussed.

Analysis (2)

The confidence interval decreases with the increase of the number of simulations. ✔

There are at least 3 separate evacuation patterns according to the number of occupants.

- Three parameters sets are based on this three patterns and used in this study to get rid of the occupant density influence.These patterns are used in this study to see the influence of others parameters more independently of the density of people.

  → The method provides additional elements to understand evacuation behaviors even in this simplistic case.

Analysis of the statistical influence of the parameters

Parameters tested: conflict resolution time, position of the occupants and response time (RT).

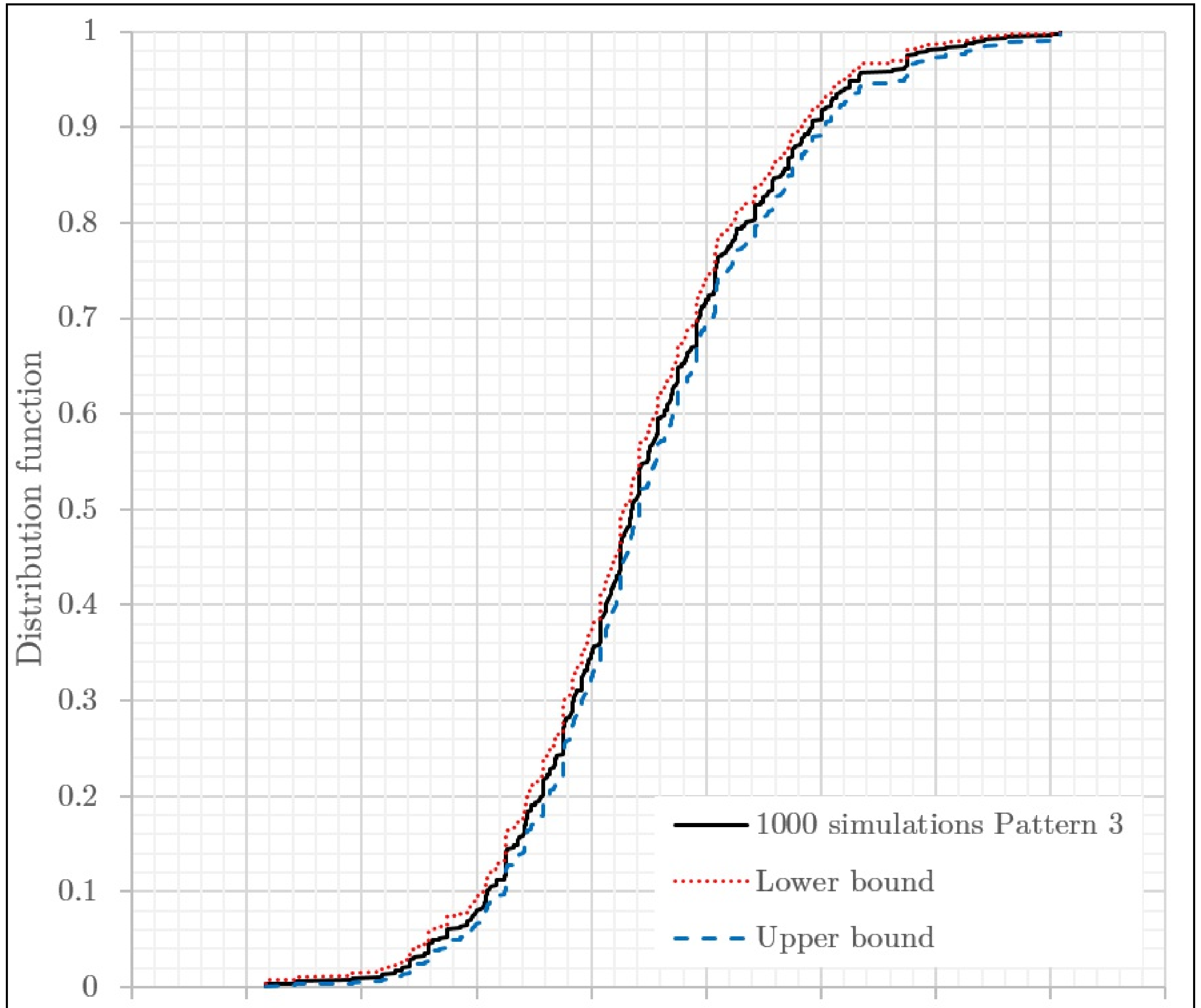
1,000 simulations for each patterns.

Test case	Conflict resolution time (s)	Position of the occupants	RT (s)
1	[0.8 ; 1.5]	Fixed	15
2	1.15	Fixed	15
3	[0.8 ; 1.5]	Random	15
4	[0.8 ; 1.5]	Random	[0 ; 30]

Test case 1

The empirical distribution function is not uniform.

→ linked to the variability of the conflict resolution time and to the history effect.



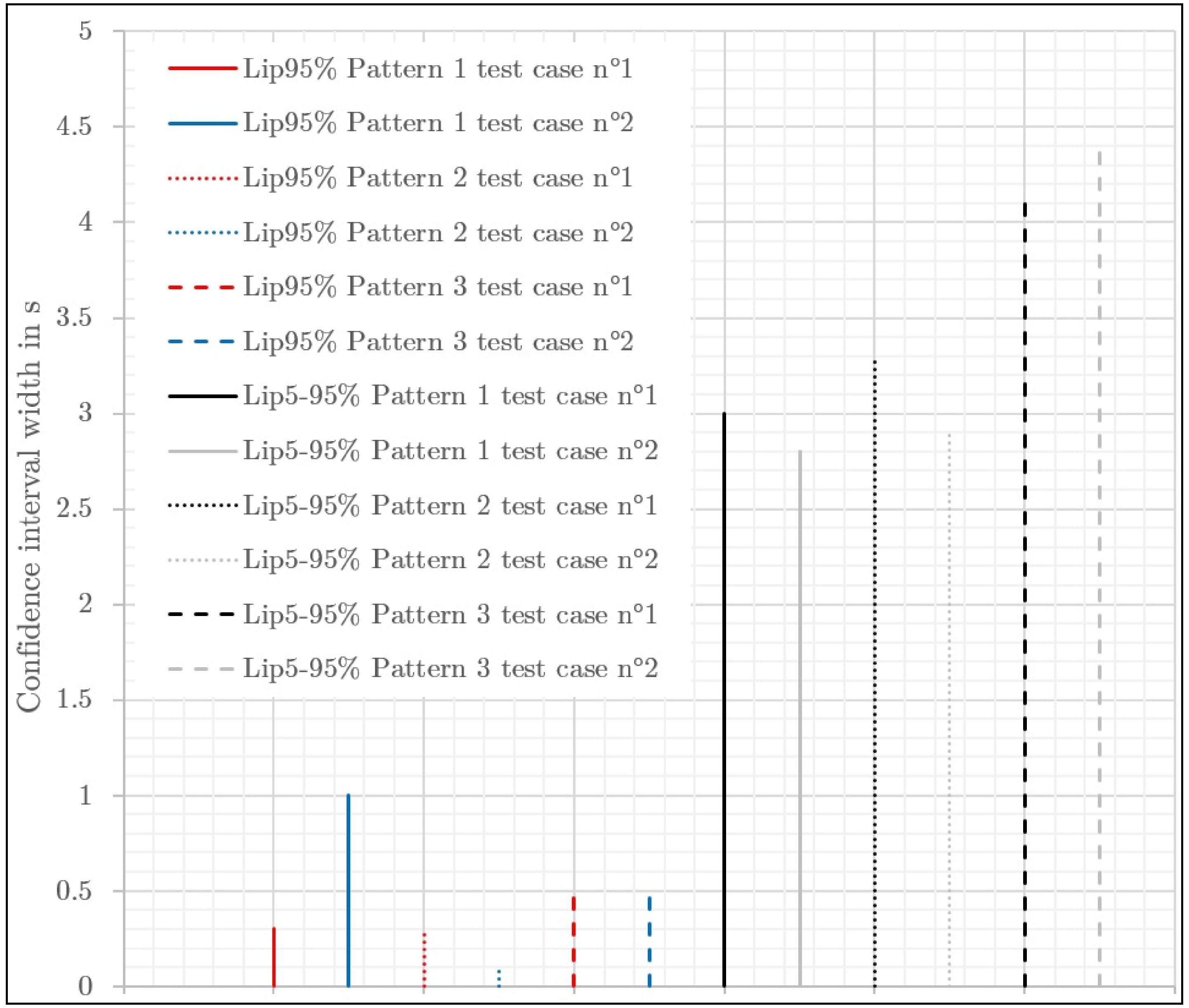
Notations

Notations used to make quantitative comparisons:

- $I_{p95\%}$ the confidence interval of the 95th percentile.
- $L_{Ip95\%}$ the width of the confidence interval of the 95th percentile.
- $I_{p5\%-95\%}$ the interval between the lower bound of the 5th percentile and the upper bound of the 95th percentile.
- $L_{Ip5\%-95\%}$ the width of the last one.
- $L_{Ip5\%-95\%/q50\%}$ the ratio between the last interval and the 50th percentile.

Test case 2

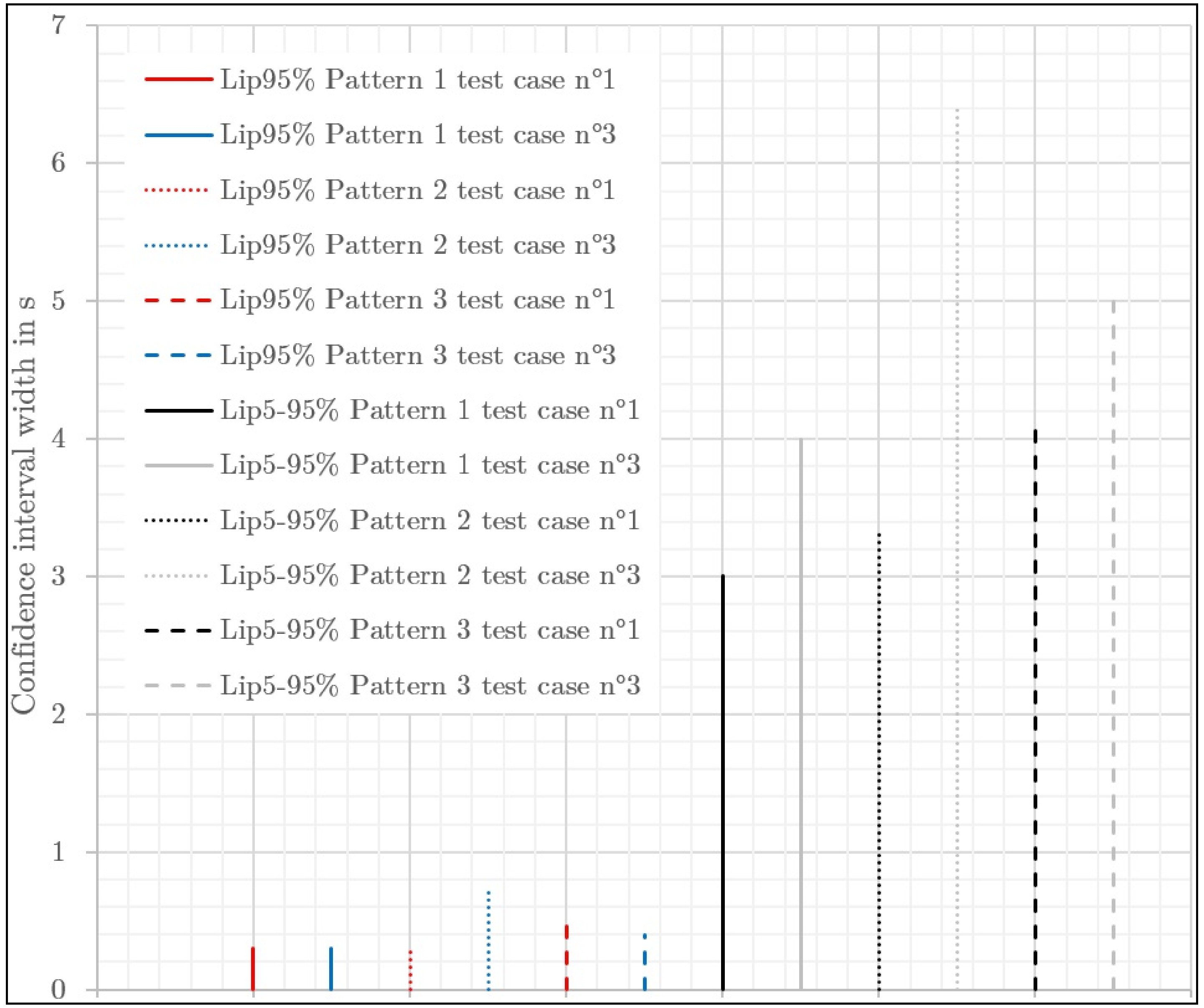
Reminder: Conflict resolution time, position, RT fixed.



→ Most of the variability comes from the history effect.

Test case 3

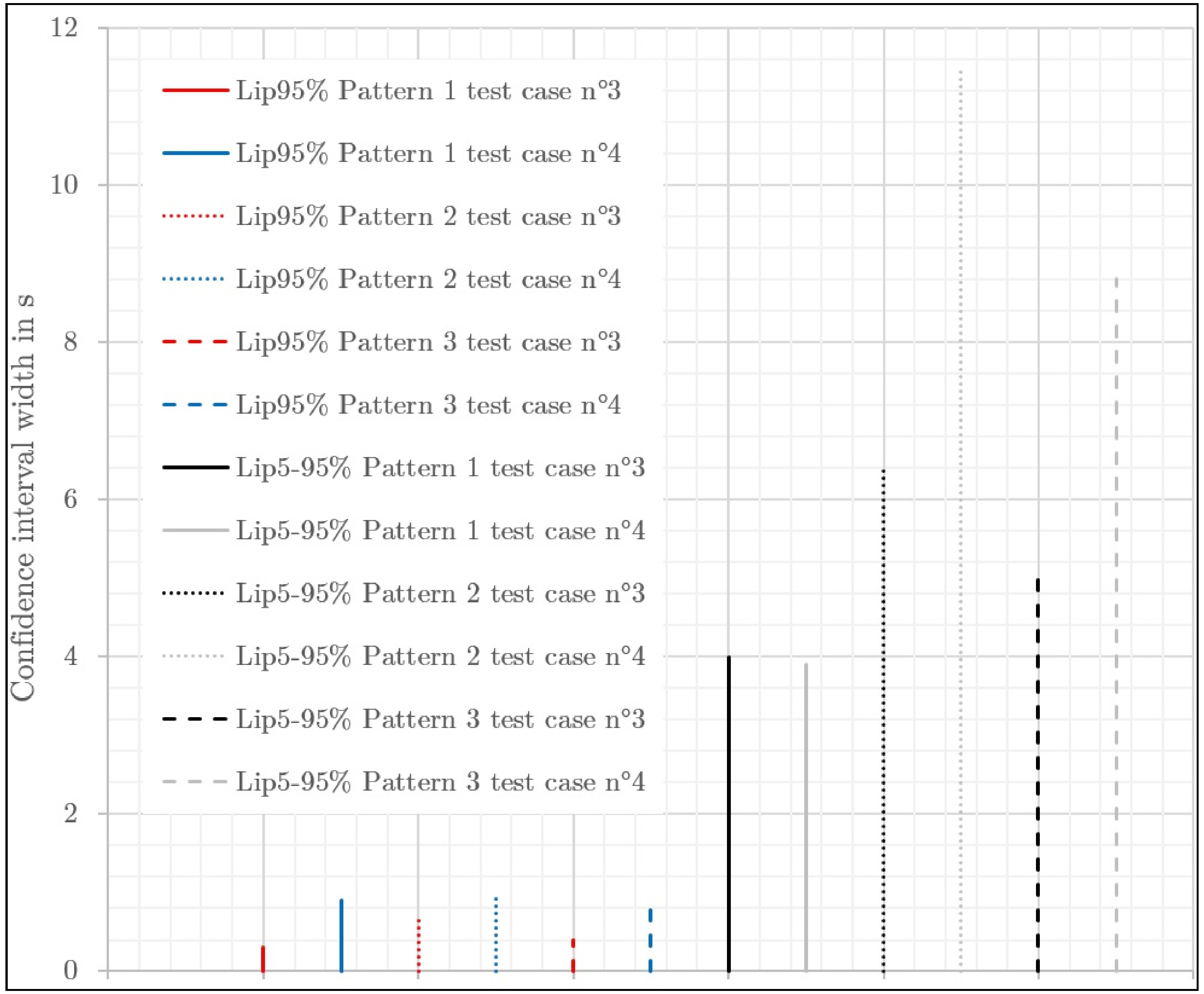
Reminder: Conflict resolution time and position vary, RT is fixed.



→ Position has more influence on low and average densities.

Test case 4

Reminder: Resolution conflict time, position and RT vary.



→ the variability of output parameters increases with the one of

Results synthesis

Studied parameters	Variation range of the input parameter	Qualitative influence
Occupant number	From 1 to 1,000 persons or 187, 610 and 927 persons	Very important
Occupant position	Fixed or random	Important
Conflict resolution time	From 0.8 s to 1.5 s or 1.15 s	Negligible
Response time	From 0 s to 30 s or 15 s	Important

Method assets

- Give a methodological justification to the RSET quantification.
- Assess the number of simulations to perform to get an appropriate confidence interval width.
- Estimate quantitatively the influence on the RSET of the input parameters dispersion.

Method assets

- Better understand some phenomena occuring during the evacuation.
- Show non-linear effects of input parameters on the RSET.
- Raise the question of what RSET is.

Conclusion

- Interpret the influence of variability of an input parameter to an output parameter ✔
- Quantify the number of simulations required to make to have a short confidence interval ✔

$\rightarrow$ There is still a lot of work.

- to make an engineering level tool,
- to find relevant input data.

Conclusion

Prospects:

- Test more realistic case.
- Test cross interactions thoroughly (experiment plans).
- Compare to some evacuation trials.
- Industrialize the method on tools dedicated to stochastic analysis.
- Compare different simulations tools.

Discuss of what is an acceptable failure probability.