Technische Universität Braunschweig

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EVACUATION ANALYSIS IN NURSERY SCHOOLS – CHALLENGES OF PARAMETERIZING THE BEHAVIOR OF CHILDREN

Jan Lyzwa, M. Sc.

Institute of Building Materials, Concrete Construction and Fire Safety (iBMB)

Technische Universität Braunschweig, Germany

FEMTC 18 | Gaithersburg, MD, USA | October 1-3, 2018

Introduction

- Ensuring life safety is a priority aspect of structural, technical and organizational fire protection measures
- **No uniform rules and guidelines** for fire protection exist in nursery schools in Germany
- Different levels of safety between individual buildings
- No statutory evacuation exercises
- Currently, fire protection in nursery schools is mainly ensured with structural and increasingly with technical measures

Effects of missing uniform rules and guidelines

- Fire protection measures might be **ineffective**
  - In worst case even have a **negative impact** on the children's safety
  - E. g. alarm systems can induce anxiety in the children
- **Are measures suitable for children?**
- Can organizational measures **compensate** missing structural or technical fire protection measures?
- Performance-based life safety concepts with regard to organizational fire protection measures and evacuation simulation models are regarded as an inadequate option

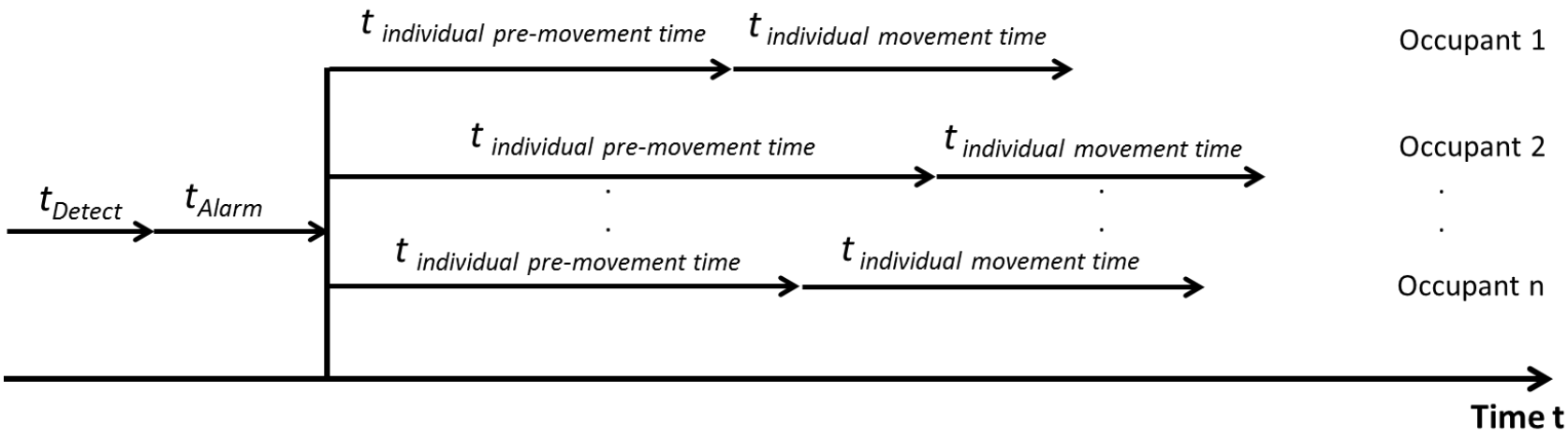
Objectives

- Examination of the evacuation organization and behavioral patterns in nursery schools
- Collection of empirical data from evacuation exercises in different nursery schools
- Main focus and measurement of the pre-movement time
- Development of an evacuation model with FDS+Evac, which depicts the special situation in nursery schools
- Comparison of exercise and simulation results
- Formulation of optimization potential regarding fire safety in nursery schools in Germany

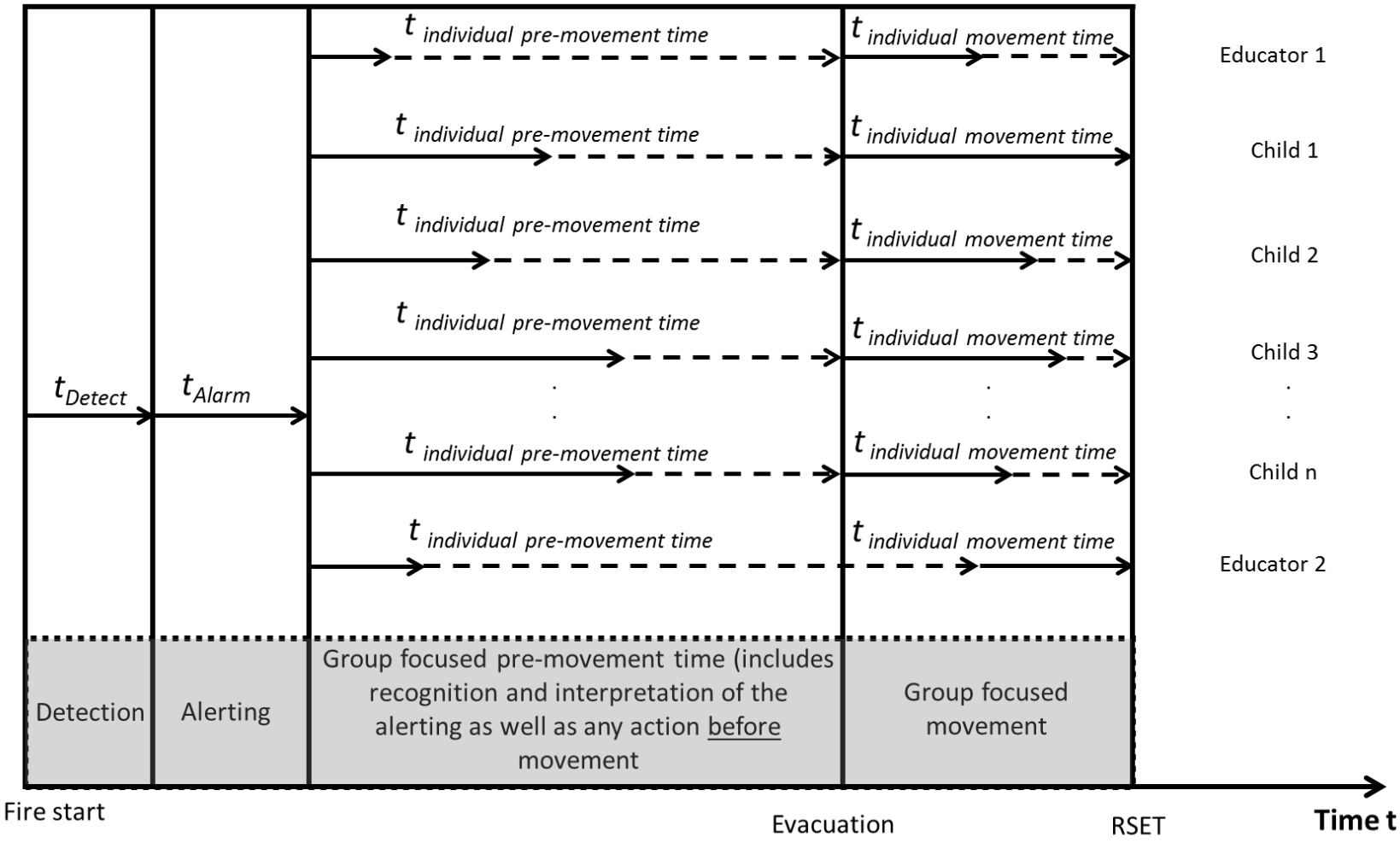
Composition of the evacuation time

- Ensure a performance-based life safety concept in case of fire:

  available safe egress time **ASET > RSET** required safe egress time



Evacuation organization in nursery schools



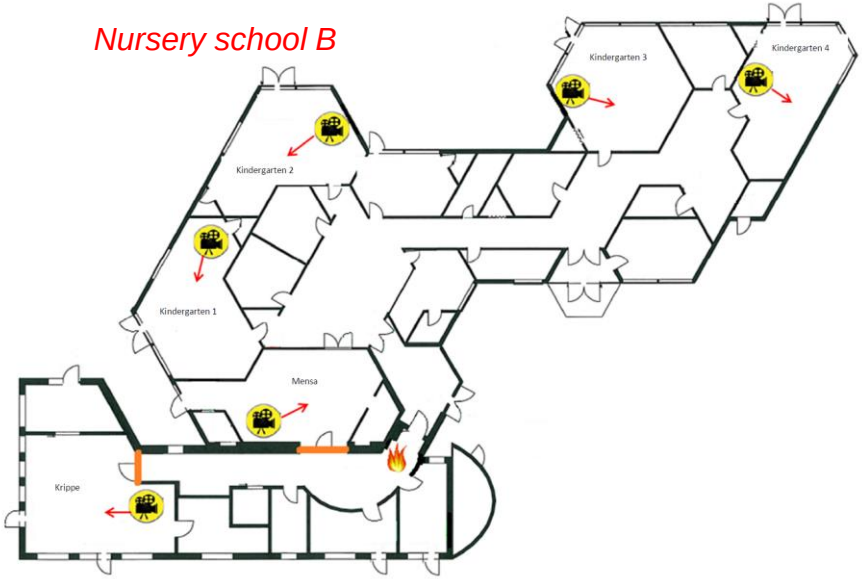
Evacuation exercises in nursery schools - Objectives and experimental setup

- Evacuation exercises serve building users to test dangerous or emergency situations
- Only through exercises, wrong behavior can be avoided in the future and an optimized evacuation can be conducted
- Different types of nursery schools were selected
- Differences result from inequalities between structural, technical and organizational fire protection measures of the nursery schools

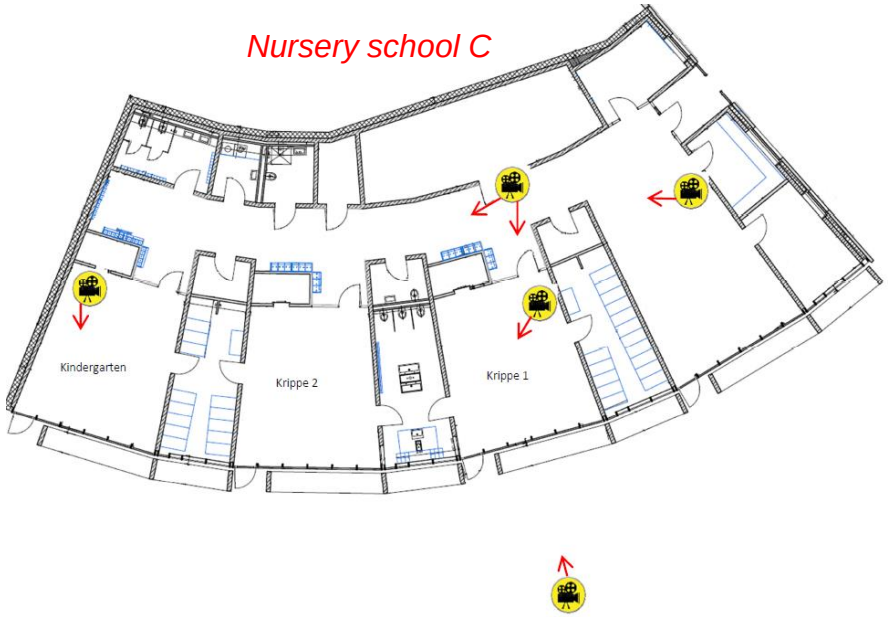
Evacuation exercises in nursery schools - Objectives and experimental setup

- Video cameras recorded the behavior of the children and educators after an alarm, in order to allow an assessment and measurement of the pre-movement times and walking speed
- Measurement of the evacuation duration of the entire respective nursery school
- Evacuation was finished when all users had reached the assembly areas outside the nursery school

Nursery school B



Nursery school C



Exercise Results - behavioral patterns after an alarm

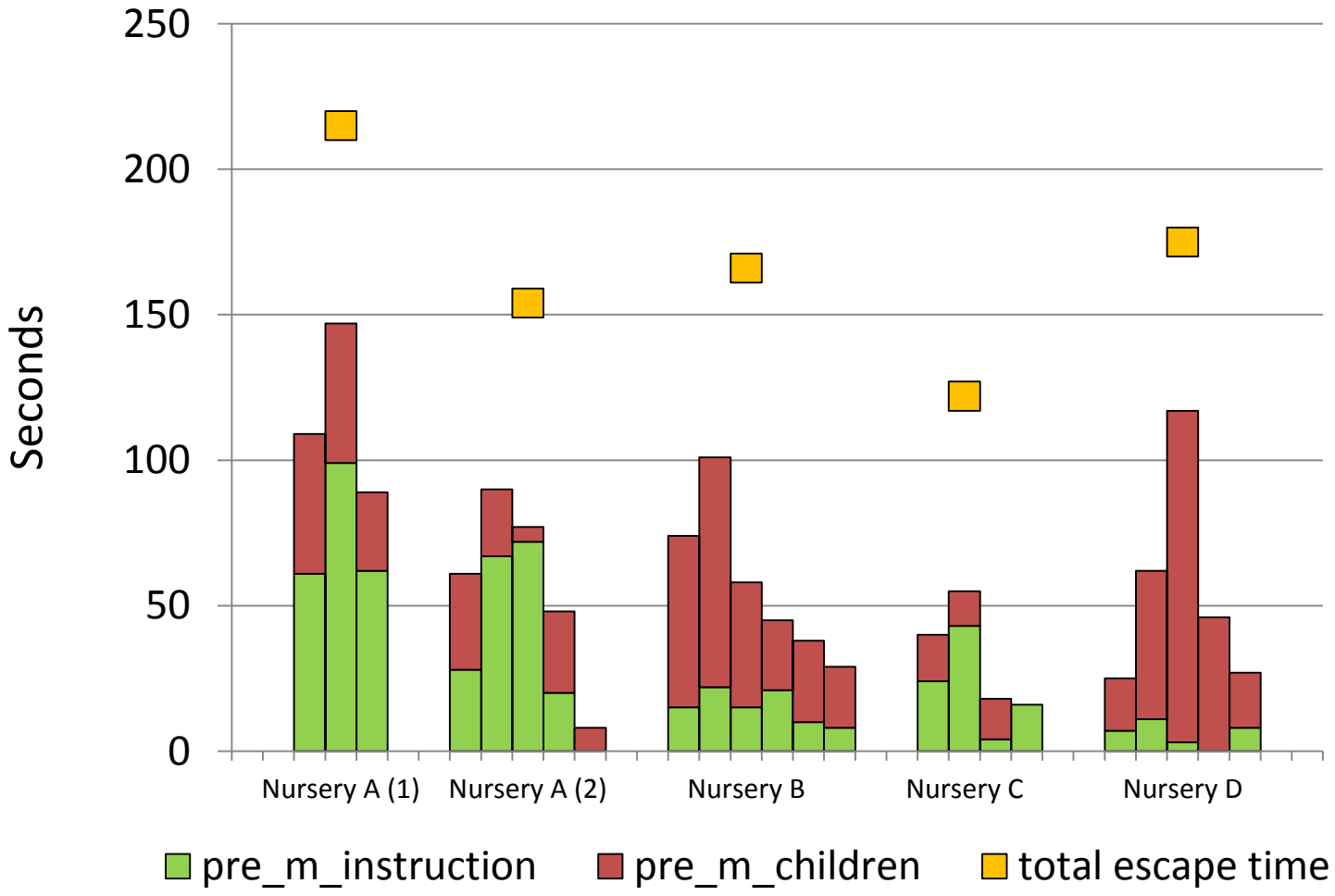
- A short moment after educators themselves have interpreted the alarm, they assemble the children in order to initiate an in a body evacuation
- The children reacted differently to this call - also depending on their distance to the educators
- Influence on the group-related pre-movement time:
  - individual pre-movement times of the children
  - individual mobility until reaching their group

- The collective escape movement did not begin until all children have assembled

Exercise Results – Walking speed

- During the escape movement, the walking speed of the pedestrian flow was determined by the slowest child (or educator), with an educator at the head of the group guiding the children and a second educator driving the children at the end of the group

Exercise Results - Measured pre-movement times and escape times



Summery of the exercises results

- 426 people were involved in the exercises
- Escape movement was always structured and the groups stayed together the entire time
- The alarm system was criticized by the heads of each nursery school
- Educators had difficulties in interpreting the alarm signal
- In principle, after an alarm - whether it was an alarm tone or verbal communication - a similar behavior could always be observed:
  - The children waited for instructions
  - Thus, the children have behaved dependently, but not irrationally
- Some younger children (< 3 years) were not able to respond promptly or adequately to instructions, and may need to be collected by an adult and then carried or held by the hand
- In "untrained" nursery schools there is a clear potential for optimization regarding the pre-movement time

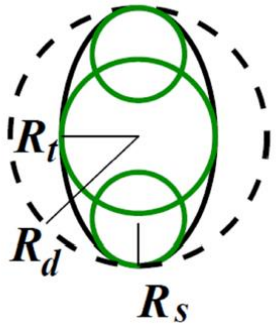
Simulation of the evacuation exercises with FDS+Evac

- Characteristics of Herding Agents in FDS+Evac:
  - Look around to see what other agents are doing
  - When these move to an exit, the herding agents try to follow them
  - If there is no known exit or agent in the vicinity of the herding agent, it will stay in its initial location until the end of its pre-movement time
  - If the nearest neighbor of a herding agent starts the escape movement, then the herding agent will follow the neighbor regardless of its own pre-movement time
- Herding Agents can only partially represent the reality in nursery schools
  - An independent escape of the children or selfish behavior of the educators can generally be excluded
- An approach to a group model is implemented in the current version of FDS+Evac
  - function is not documented in the FDS+Evac manual
  - functionality of this group model is questionable
- The special evacuation situation in nursery schools is simulated using this function: GROUP_EFF, GN_MIN and GN_MAX

Unimpeded walking speed and body dimensions in FDS+Evac

Body type	R_d [m]	R_t / R_d [-]	R_s / R_d [-]	d_s / R_d [-]	Speed [m]
Adult	0.255 ± 0.035	0.5882	0.3725	0.6275	1.25 ± 0.30
Male	0.270 ± 0.020	0.5926	0.3704	0.6296	1.35 ± 0.20
Female	0.240 ± 0.020	0.5833	0.3750	0.6250	1.15 ± 0.20
Child	0.210 ± 0.015	0.5714	0.3333	0.6667	0.90 ± 0.30
Elderly	0.250 ± 0.020	0.6000	0.3600	0.6400	0.80 ± 0.30

Korhonen & Hostikka, 2017



Adaptation of model parameters in nursery schools- Horizontal walking speed of children

Horizontal walking speed of children according to Larusdottir & Dederichs (2012)

Age group	Horizontal walking speed [m/s]	
	Minimum	Maximum
Children aged 0 - 2	0.21	1.00
Children aged 3 - 6	0.41	1.40

- measurements were obtained at a low density (< 0.5 persons/m²)
- represent the free movement

Modified walking speed in FDS+Evac

Age group	Horizontal walking speed [m/s]	
	Minimum	Maximum
Children aged 1 - 2	0.61	0.73
Children aged 3 - 6	0.72	1.07

Adaptation of model parameters in nursery schools- Modified body dimensions in FDS+Evac

- Unimpeded walking speed and body dimensions in FDS+Evac

Body type	R_d [m]	R_t / R_d (-)	R_s / R_d (-)	d_s / R_d (-)	Speed [m]
Adult	0.255±0.035	0.5882	0.3752	0.6275	1.25±0.30
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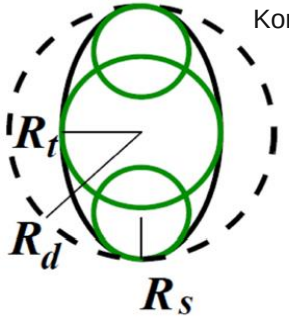


- Modified body dimensions in FDS+Evac

Age group		Children aged 1 - 2	Children aged 3 - 6
Body diameter (2*R_d); Uniform distribution	Minimum	0.175 m	0.201 m
	Maximum	0.232 m	0.297 m
Torso diameter (2*R_t)		0.156 m	0.176 m
Shoulder diameter (2*R_s)		0.050 m	0.054 m

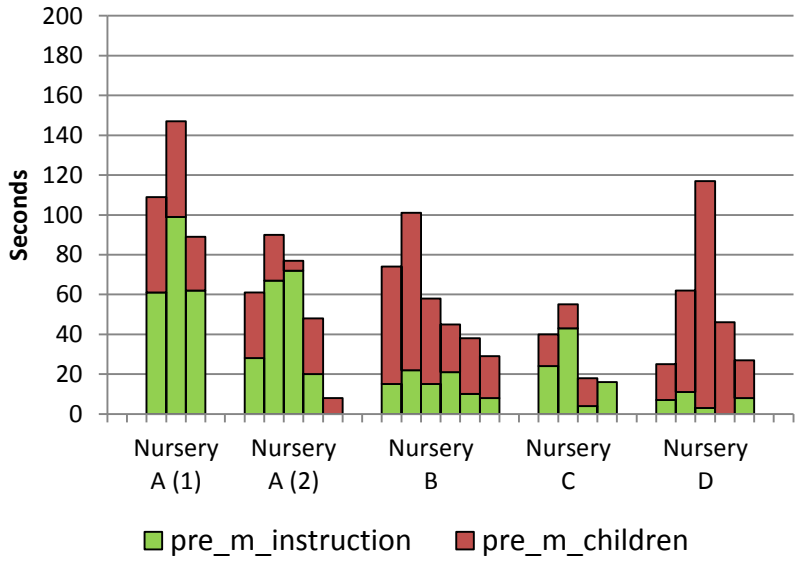
Adaptation of model parameters in nursery schools – Pre-movement time

- Children's pre-movement times in pre-school education institutions determined by Kholshchevnikov (2012)

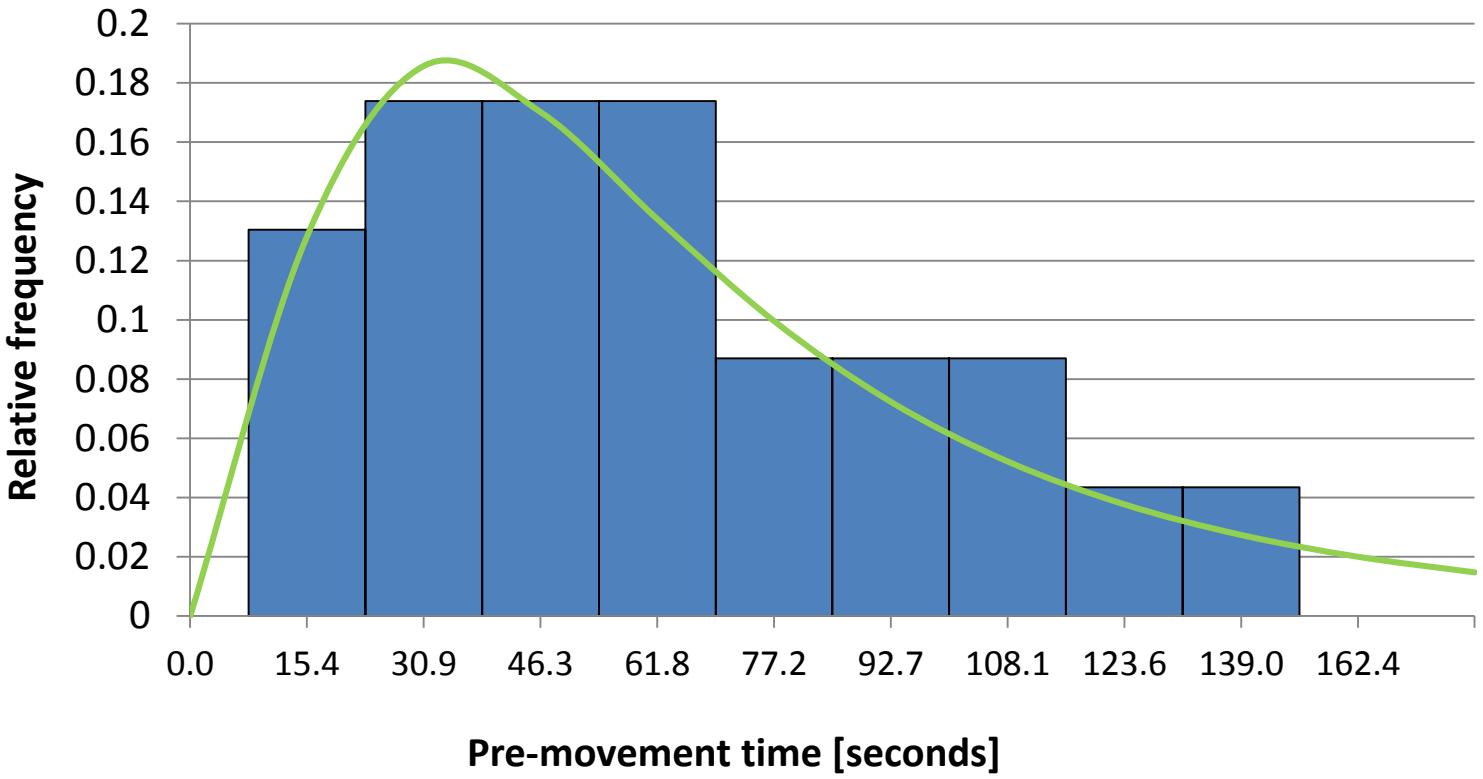
Season / Provision	Time requirement [min]
summer/ no additional clothing	0.6
spring and autumn / additional clothing	5
winter / intensive additional clothing	7.5
wrapping the children in blankets	1.1

- Average pre-movement time including all measurements in our exercises is exactly

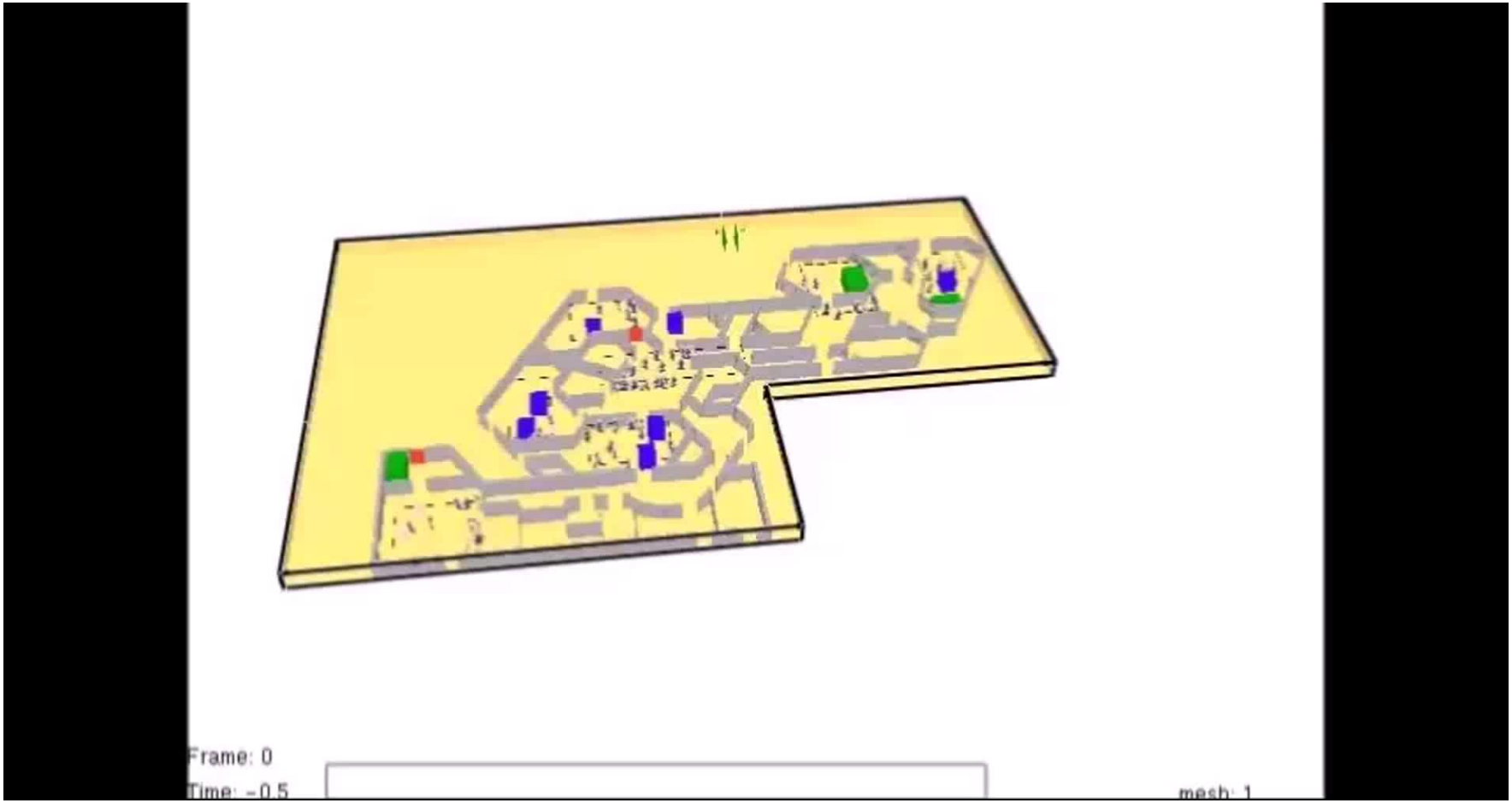
  1 minute



Adaptation of model parameters in nursery schools



Developed model in FDS+Evac



Simulation Results

Simulation	Evacuation time [s]				
	Nursery A(1)	Nursery A(2)	Nursery B	Nursery C	Nursery D
Mean Value (10 trials)	232	218	242	214	224
Min	214	200	230	203	209
Max	245	228	257	225	230
Exercise	215	154	166	122	175

- The defined pre-movement time in the simulation strongly determines the required evacuation time
- Data is applied for individual agents
- As the number of children (agents) within a created group in FDS+Evac increases, so does the likelihood that a child will be assigned a high pre-movement time or a low walking speed
- Worst-case input parameters are decisive in several groups

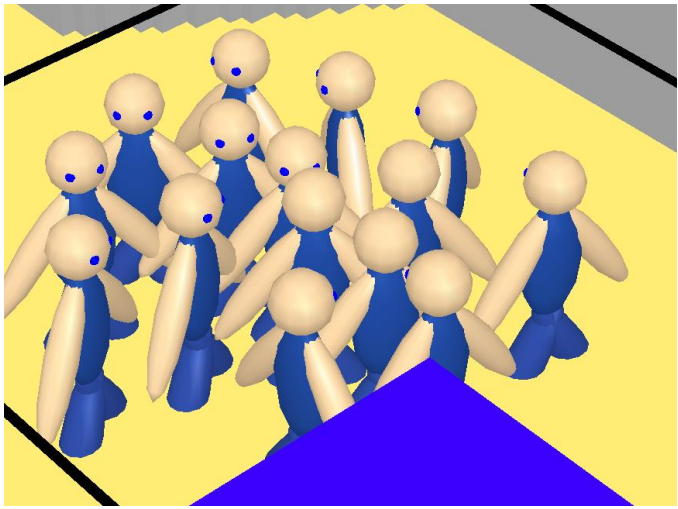
Parameter assignment in FDS+Evac

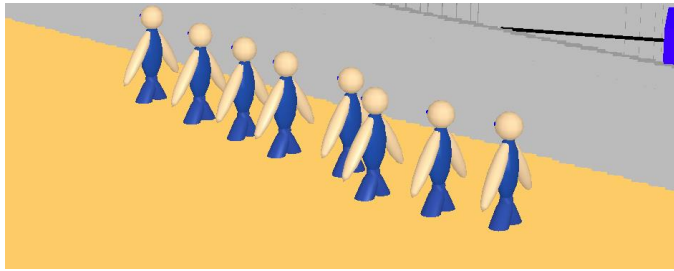
Conclusions

- Familiarity of educators with the alarm is of paramount importance and depends on the type of alarm system
- Pre-movement time, pre_m_instruction and pre_m_children can differ across nursery schools and also across groups
- **Key statements*:***
  - *Evacuation of the group is controlled by the educators*
  - *They have a decisive influence on the duration of the pre-movement time*
  - *Educators direct all actions to be performed during the pre-movement time*
  - *Educators must provide a variety of assistance, as holding hands or carrying children*
  - *Educators determine the walking speed of the pedestrian flow*

Conclusions

- With FDS+Evac the observed evacuation organization and behavioral patterns in nursery schools could only be implemented very simplified
  - Physical prerequisites of the children can be precisely implemented
  - Representation of the organizational process of an evacuation in nursery schools is not realistic
- It is difficult to countenance evacuation simulation models in order to compensate a missing structural or technical fire protection measures in nursery schools
  - There is a lack of knowledge about the escape behavior of children





group model

Conclusions - Potential for optimization regarding fire safety

Research has shown:

- More attention and investigation should be drawn to organizational fire protection measures and the alarm systems in nursery schools
- Statutory evacuation exercises and appropriate alarm systems can increase the level of safety in nursery schools where no voluntary evacuation exercises are performed
  - Successive optimization of the pre-movement times and the total evacuation time
- Evacuation simulations in nursery schools can be used for training purposes
  - An evacuation simulation in nursery schools can be compared with real exercises and the advantages of an (simulated) optimized evacuation can be demonstrated to the educators


Thank you for your attention!
Any questions?