

# THE IMPACT OF INWARD OPENING DOORS ON EVACUATION DYNAMICS IN HERITAGE BUILDINGS

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# ABSTRACT OVERVIEW

Evacuating through inward opening doors has always been associated with the presumed challenges in terms of door opening and safe egress during fires. This study investigates the dynamics and challenges associated with this, aiming to provide insights for safeguarding evacuation.

A literature review and evacuation experiments were conducted, comparing inward to outward opening doors through examining parameters such as occupant density, door opening force, presence of a corridor, and walking distance.

The findings highlight that evacuating through inward opening doors is slower during the initial stage of egress due to increased interactions required among evacuees and that high occupant densities near the door affect door opening in a negative way.

The presence of a corridor in front of the door slightly reduces people flow but promotes organized group formations, facilitating door opening. Increased walking distance before reaching the door reduces occupant density close to the door, hence simplifying the door opening process. The number of people using the door does not significantly impact door opening, indicating the importance of rather managing occupant density.

The study concludes that prerequisites for safe evacuation through inward opening doors requires appropriate door fittings, low occupant density near the door and fast door opening maneuvers.

#### INTRODUCTION AND BACKGROUND

Evacuation through inward opening doors has long been and is still as of today considered problematic. This due to the potential risk of situations where a queue and the resulting occupant density in the direct proximity of the door prevents or limits the possibilities of opening the door, and thus obstructs safe egress in case of fire.

Many countries' building codes allow the use of inward opening doors in escape routes. The reason is that in many cases it is practical to let the door swing inwards, but it may only be allowed to some types of premises or to limit the number of people who is expected to pass through such a door.

In recent years, many injunction orders have been issued for buildings of cultural and historical value where inward opening doors combined with premises exceeding the capacity of 30 people, have been highlighted as the problem. At the same time, complying with these requirements for existing buildings can often result in a large negative impact on built cultural heritage. Due to lack of knowledge and guidance in this area it is difficult to make an informed decision on how to assess these competing objectives.



#### SCOPE AND OBJECTIVE

At present, there is limited scientific research focusing specifically on this type of evacuation process and more specifically the initial stage of egress and the possibilities of opening the evacuation door. This study aims to contribute to fill this knowledge gap by investigating the factors that influence the effectiveness of evacuating through inward opening doors.

The project primarily focuses on buildings of cultural and historical significance and value, where the possibility of alterations of the building's design is limited. However, the findings may also have relevance in the design of new buildings.

The goal of the project is to identify key parameters influencing the risk of queuing and other factors affecting evacuation conditions when utilizing inward opening doors. To achieve this, a comprehensive literature review and a series of evacuation experiments has been conducted.

#### METHODOLOGY

#### **Part 1 – Literature review**

As part of increasing knowledge about the use of inward opening doors a literature review was carried out. The literature review has focused on the following topics:

- Regulations and other recommendations governing the use of inward opening doors for escape in new buildings.
- Research linked to people flows and people's actions when using inward opening doors for escape.
- Fires that have occurred where it can be suspected that inward opening doors may have had an impact on the evacuation process or on deaths that have occurred.

#### **Part 2 – Evacuation experiments**

A series of evacuation experiments were conducted, comparing the performance of inward opened doors to outward opened doors. Data were collected using eight video cameras. Various parameters were examined, including initial occupant density, door opening force and fittings, presence of a corridor (flow congestion), and walking distance, to gain a deeper understanding of their impact on door opening, people flow, and overall evacuation efficiency.

In summary, the analysis of collected data was conducted by studying the following aspects:

- Group formations when
  - 1. Approaching the door
  - 2. Passing through the door
- Opening of the door
  - 1. Interaction of people when opening the door
  - 2. Occupant density when opening the door
  - 3. Time needed to open the door
  - Occupant flow through the door
    - 1. Overall people flow
    - 2. People flow in the initial stage when passing through the door



# **RESULT OVERVIEW**

#### **Part 1 – Literature review**

Inward opening doors may be used for evacuation in many countries, but the requirements vary from one country to another. To some extent, this could be related to differences in terminology, but the variation is still between 10 and 150 people. Table 1 reports the summary conditions for the use of inward opening doors for some countries.

Country and building code or similar	Regulation in the building code
Sweden, BBR [1]	From a room holding maximum 30 persons.
Norway, Guidance to TEK17 [2]	From a fire compartment holding a maximum of 10
	persons.
Denmark, BR18 [3]	For doors serving up to 150 persons.
USA, NFPA 101 [4]	From a room holding a maximum of 50 persons.
UK (England) BS 9999:2017 [5]	For doors serving up to 60 persons.

Table 1. Inward opening doors in the building regulations.

There is also a lack of research that sheds light on the problems associated with inward opening doors for evacuation. Only two publications [6, 7] have been identified and these do not indicate any major differences between inward opening and outward opening doors.

A few more serious fires have also been investigated and in some of these there was information that some doors opened inwards. In one case, the investigation report states that people probably died because the door was opening inwards (Cocoanut Grove, 1942), but not that this was the only reason [8]. In the cases where there were inward opening doors, the fire spread was also often very rapid through the building, which means that the total time for evacuation was short. In other cases, it cannot be ruled out that doors in fact were locked. There is thus no clear evidence in the literature that it would be particularly problematic from a general perspective if doors for escape open inward or outward.

#### Part 2 – Evacuation experiments

The findings from this study reveal several important insights regarding evacuation through inward opening doors. One key observation is that evacuating through inward opening doors tends to be slower during the initial stage of egress compared to outward opening doors. This is primarily found to be due to the increased number of interactions required among evacues to open the door.

The impact of occupant density in the proximity of the door on door opening possibility was also examined. It was found that high occupant load densities (exceeding 3 persons/m<sup>2</sup>) pose challenges in opening the door, while lower densities do not exhibit significant impediments.

The presence of a corridor in front of inward opened doors modestly reduces the people flow through the door. However, it promotes a more organized group formation akin to a "zipper", potentially facilitating the door opening process during the initial stage of evacuation. Additionally, increased walking distance before reaching the door yields a lower occupant density in the immediate vicinity of the door, thereby facilitating easier door opening.

The number of people did not significantly affect the door opening process or the flow rate through the door.

The inclusion of a doorknob prolongs the door opening time, potentially impeding egress, particularly when combined with high occupant densities or large numbers of evacuees. In contrast, the door opening force, within the examined range (45-100 N), does not exert a significant influence on the evacuation process.



### CONCLUSION AND FURTHER RESEARCH

Based on the observations, it is concluded that safe evacuation through inward opening doors is possible, provided certain conditions are met. Fast and easy door opening maneuvers facilitated by appropriate door fittings are crucial. Furthermore, maintaining a low resulting occupant density of approximately 3 persons/m<sup>2</sup> or lower near the door seems to be essential. This could be achieved by increasing the walking distance to the door or introducing physical obstacles near the door to constrain or organize the flow of people.

This study identifies several areas that warrant further research to deepen our understanding of evacuation through inward opening doors. These areas encompass investigating the effects of door width, higher door opening forces, different door fittings, inclusion of individuals with movement impairment, variations in flow constraints, and validating the findings through additional evacuation experiments. Furthermore, an exploration of the effects of occupant density in immediate proximity to inward opening doors and the establishment of generic threshold values for dangerously high levels of crowding would significantly contribute to the enhancement of evacuation strategies and safety guidelines.

In conclusion, this study offers insights into the intricacies of evacuation through inward opening doors and highlights influential factors pertaining to door opening, people flow, and overall evacuation efficiency. The findings and recommendations presented in this study can aid in designing effective evacuation strategies and optimizing the performance of inward opening egress doors. By enhancing our understanding of the intricacies associated with evacuation through inward opening doors, we can advance building safety standards and contribute to the development of evidence-based guidelines and practices for emergency evacuations.

# REFERENCES

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