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Effect of Classroom Arrangement on Fire Evacuation Scenarios in Educational Buildings

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Abstract

Fires in educational buildings cause great loss of life and property, but also negatively affect the spiritual and psychological development of students. It is necessary to minimize fire risks and create safe learning environments. For this purpose, national and international fire safety regulations and guidelines play a crucial role. Moreover, with the advance of technological capabilities, buildings should be analyzed using performance-based fire safety precautions and safe evacuation conditions must be thoroughly assessed. This study aims to provide recommendations for a fire-safe educational environment by determining the effectiveness of the relevant classroom arrangements and other precautions in educational buildings. The effects of classroom arrangements on students' evacuation conditions were investigated using a simulation program (Pathfinder) and the results were evaluated through comparative analyses. Classroom arrangements were investigated using four different formats: Traditional rows and columns arrangement, Cluster arrangement, U-shaped arrangement, and Stadium arrangement. The effects of classroom layout on fire evacuation time are discussed by considering a secondary school building located in Türkiye. In the assessment, the total evacuation time of the class(es), the escape door flow rate (pers/s), and the number of occupants staying in the room depending on the time were evaluated. As a result of the study, it was determined that the fastest evacuation time was the Traditional rows and columns arrangement. In addition, suggestions are presented for the removal of congestion during fire evacuation in different classroom arrangements. Fire safety should be transferred to architectural design and spatial organization as an important component in creating a safe learning environment in educational buildings.

Keywords

Classroom arrangement; Educational buildings; Evacuation; Evacuation simulation; Evacuation time; Fire safety

1. Introduction

Fires that occur in buildings for various reasons pose important risks in terms of life and property safety. Reducing these risks and providing for the safety of the occupants is possible with appropriate design considerations. Taking active and passive fire safety precautions in the design phases for buildings ensures that people stay safe in the event of a possible fire (Mróz et al., 2016).). In addition, fire spread between buildings should be limited and thus urban fires should be prevented by designing fire risk analyses with various scenarios (Srivanit, 2011). In the planning of fire safety precautions, it is important to undertake fire safety analyses in the context of the building and space and to analyze the growth, development, and extinction processes of the fire. The analysis of fire stages has a significant impact on the management of the evacuation time during the growth and progression of the fire (Della-Giustina, 2014). In this context, the rate of combustible materials (fire load), the placement of the day-to-day furniture, the occupant profile, and the evacuation possibilities are important components that should be considered for planning and design purposes. In the analysis of all these components, risk assessments are given priority according to the building usage class.

In educational buildings, which frequently are the most important and intensive places of use in the daily life of an individual, the fire factor should be considered in detail. The fact that the fire load is high in educational buildings and the age distribution of the occupant profile is small greatly increases the fire risk factor resulting from panic (Nadzim & Taib, 2014). Due to the low ability of students to analyze, detect, and respond to fire risks, serious injuries and problems can occur during a fire evacuation. As such, it is important to transfer fire awareness to students and create fire safety awareness among students. According to the National Fire Protection Association (NFPA 101), 'educational occupancies shall include all buildings used for educational purpose through the twelfth grade by six or more persons for 4 or more hours per day or more than 12 hours per week' (National Fire Protection Association [NFPA], 2024). By definition, the building occupant profile consists of students, teachers, and service staff. In educational buildings, occupants are located in classrooms, laboratories, conference rooms, offices, administrative, and other entertainment spaces. Fires in educational buildings have caused great loss of life and property and also caused injuries to many students, including due to smoke inhalation. In the United Kingdom, fires occurred in 7281 education buildings between 2009 and 2019 (BusinessWatch, 2020). In the recent period, it has been determined that there were fires in 449 educational buildings in the 2021-2022 financial year period (Clark, 2022). In the United States, the NFPA report stated that fire departments responded to an estimated average of 4760 building fires per year in education buildings in 2014-2018. It has been determined that 43% of these fires occured intentionally; 31% were caused by cooking equipment; and 19% were caused by playing with a source of the fire (Campbell, 2020). Encouragingly, it has been reported that the number of fires in educational buildings in the United States has decreased by 67% since 1980 (Campbell, 2017; Campbell, 2020). Critical factors such as arson, lack of safety awareness attitudes, electrical system faults, unsuitable cooking equipment, cigarettes, and flammable and combustible materials elevate risk of fire in educational buildings (Hassanain, 2006). Statistical results on fire safety for developed countries show that there are problems in the implementation and control mechanisms for the creation of fire safety precautions in educational buildings. Analyzes for educational buildings should be based on building materials, building elements, and buildings. In this context, it is considered a priority to analyze the fire safety precautions in the classrooms where students and teachers are most frequently and investigate the evacuation conditions of the occupants.

For fire safety precautions, it is important to construct performance-based regulation instead of prescriptive-based regulation. It is necessary to provide building-specific fire safety precautions and investigate occupant-based evacuation possibilities. In this study, the effect of classroom arrangement on the total evacuation time of the class was analyzed over the classes in a typical education building. This paper aims to provide recommendations for a fire-safe educational environment to create a safe educational environment by determining the effectiveness of the relevant layout parameters in the creation of fire safety precautions for classrooms in educational buildings.

2. Literature Review

Educational buildings constitute building designs that carry great risks in terms of fire safety. The high occupant load, high fire load, and low fire awareness according to the education level increase the risk factor. My literature review includes studies that have used different analytical approaches in addressing fire risk, such as questionnaire studies, regulatory compliance assessments, on-site observation, and evacuation systems research (Table 1). Klüpfel et al. (2003) investigated evacuation simulations in an educational building. Fire drills were carried out in the existing building and fire evacuation scenarios were analyzed using empirical methods. It was found that evacuation times during the drills were significantly shorter (about 1.5 times shorter) compared to those from the empirical simulations. This was attributed to teachers effectively managing students during real-life situations. Additionally, a key finding was that repeated fire drills led to a reduction in evacuation time. Chunmiao et al. (2012) analyzed crowd movement and evacuation procedures during a fire. The study modeled the building in 3D and utilized the BuildingExodus software for simulating fire evacuations. The findings revealed a linear relationship between the occupant load and the time required for deceleration. Additionally, efficiency assessments were performed on the building's maximum occupant capacity and evacuation times of the exits. Ono et al. (2015) conducted a fire drill in a secondary education building to measure the walking speeds of students aged 6-14. The analysis revealed that age did not significantly affect their speeds. The students' walking speeds in corridors ranged from 0.4 to 1.8 m/s, while on stairs, speeds varied between 0.8 and 1 m/s. The study highlighted the importance of teachers assisting younger students during evacuations. Additionally, it was found that older students achieved walking speeds comparable to those of adults. Hu and Chen (2014) conducted a fire evacuation analysis of a university library using the Pathfinder simulation program. The study identified issues such as uneven distribution of the occupant load, lack of coordination between the northern and southern building spaces, and disparities in deceleration capacity between these areas. To reduce evacuation time, several optimizations were suggested, including enhancing the fire resistance of the stairs, training the staff, and reorganizing the reading areas. Yang et al. (2016) show in their experimental study that herding behavior is conducive to effective evacuation when the initial density of pedestrians in a room with only one exit is moderate. For guided crowds, group dynamics characterized by gathering, conflict, and balance emerge, suggesting that a large number of guides does not provide a positive effect on evacuation. It highlights the need to study guided crowd dynamics under complex configurations, such as more complex groups and obstacles. Demirel et al. (2017) evaluated a faculty building's compliance with national fire regulations during the architectural design phase. In the assessment, recommendations were made for areas of the building that did not meet the regulations and these were incorporated into the architectural project. The findings of the case study contribute to improving the inspection process and enhancing the clarity of national fire regulations, while also reducing subjectivity in evaluations. Vanumu et al. (2020) conducted emergency evacuation analyses for educational buildings, considering various factors such as occupant load, door width, average occupant age, body mass index, gender ratio, number of students, and classroom capacity. The analysis revealed that door width and the number of students significantly impact total evacuation time. It was found that evacuation time decreased exponentially with increasing door width up to a certain point, after which further increases in width beyond the standard did not affect the evacuation time. Novanandini et al. (2019) evaluated a laboratory building used for educational purposes based on active and passive fire safety precautions, as well as fire safety management principles. The assessment referenced both national and international fire regulations. The study provided recommendations to enhance fire safety precautions in the building examined as a case study. Ilori and Sawa (2020) examined the effectiveness of fire emergency management and emergency preparedness plans in public and private secondary schools at the national level to mitigate risk. The study found that none of the secondary schools had an emergency preparedness plan in place. Additionally, it revealed that schools lacked safety committees to manage fire and disaster safety efforts. The study recommended the development of a standardized emergency preparedness manual for secondary school buildings in collaboration with relevant stakeholders. Rostami and Alaghmandan (2021) focused on controlling student behavior and maneuvering principles through fire drills in an elementary school building. Fire evacuation maneuvers were simulated using the Pathfinder program, which was based on probability distribution functions of operations. The study examined how factors like staircase width, landing depth, and staircase shape affected evacuation time. In addition to the elementary school, the study provided recommendations for buildings with high-occupancy areas. Salaheldin et al. (2021) developed a regulatory compliance assessment tool for educational facilities based on internationally adopted fire safety codes. The tool included 34 fire safety prevention items, covering aspects such as emergency exits, fire prevention and control systems, electrical installations, emergency exit doors, hygiene precautions, and various fire prevention scenarios. The tool was tested using a case study to validate its methodology and detailed recommendations for enhancing fire safety precautions were provided. Hassanain et al. (2022) developed a fire safety management framework for educational buildings consisting of 8 steps, based on regulations from the National Fire Protection Association (NFPA 101), the International Fire Code (IFC), and the Saudi Building Code. A checklist was created as part of this framework. The methodology was demonstrated through analyses of an educational building case study, which revealed significant issues related to fire safety precautions, including compartment construction, fire drills, and hydrant requirements. Lorusso et al. (2022) explored the integration of a virtual reality platform with numerical simulation tools to recreate dynamic fire emergency scenarios. The structure was modeled in real time using Building Information Modeling (BIM) and fluid dynamics software. The study tested the model's applicability using an elementary school building as a case study. The virtual reality platform enabled users to experience first-person, evolving fire emergency scenarios within the selected school building. Sinpan et al. (2022) used the social force model to simulate the evacuation of a general building population and a crowd leader evacuation with the leader in an experimental area. In the experimental study, a comparative analysis was conducted to show the effect of an agent that attempts to tell all evacuees in the area to exit. The experimental results show that the agent can effectively evacuate all evacuees in the experimental area. However, it is emphasized that the agent must be trained in fire evacuation procedures in a new or more complex environment for effective time and crowd management. Templeton et al. (2024) conducted a systematic review of agent-based evacuation models to determine how social interactions and communication approaches between agents are simulated and which key variables related to evacuation are addressed in these models. They argued that the most promising models are those that model information communication between agents, between authorities and agents, and that model the influence between agents according to the strength of their social connections. The review suggests that future agent-based evacuation models should discuss how group processes affect emergent outcomes such as evacuation time, number of agents exiting, route and path selection, flow, and congestion.

Table 1. Summary of literature review

Authors	Source	Materials and Methods
Klüpfel et al. (2003)	Traffic and Granular Flow'01, Springer	Empirical Data - Fire Drills and Simulation
Chunmiao et al. (2012)	Systems Engineering Procedia	Simulation (BuildingExodus)
Ono et al. (2015)	5th International Symposium Human Behaviour in Fire	Fire Drills - Analysis of Walking Speeds
Hu and Chen (2014)	Procedia Engineering	Simulation (Pathfinder)
Yang et al. (2016)	Physica A: Statistical Mechanics and Its Applications	Experimental Study - Guide Crowd Analysis
Demirel et al. (2017)	TUYAK 2017 - International Exhibition and Symposium on Fire and Safety	Regulatory Compliance Assessments
Vanumu et al. (2020)	9th International Conference on Pedestrian and Evacuation Dynamics	Fire Drills - Analysis of Door Width and Age Profile
Novanandini et al. (2019)	IOP Conference Series: Earth and Environmental Science	Regulatory Compliance Assessments
Ilori and Sawa (2020)	Asian Journal of Advanced Research and Reports	Interviews and Questionnaires Emergency Preparedness Plan
Rostami and Alaghmandan (2021)	Journal of Building Engineering	Fire Drills, Simulation (Pathfinder)
Salaheldin et al. (2021)	International Journal of Emergency Services	Regulatory Compliance Assessments
Hassanain et al. (2022)	International Journal of Built Environment and Sustainability	Regulatory Compliance Assessments Checklist Analysis
Lorusso et al. (2022)	Buildings	Simulation (MassMotion) Fluid Dynamics Software, Virtual Reality
Sinpan et al. (2022)	6th International Conference on Algorithms, Computing and Systems	Experimental Study Unity ML-Agents Toolkit
Templeton et al. (2024)	Safety Science	Literature Review (Web of Science - ScienceDirect)

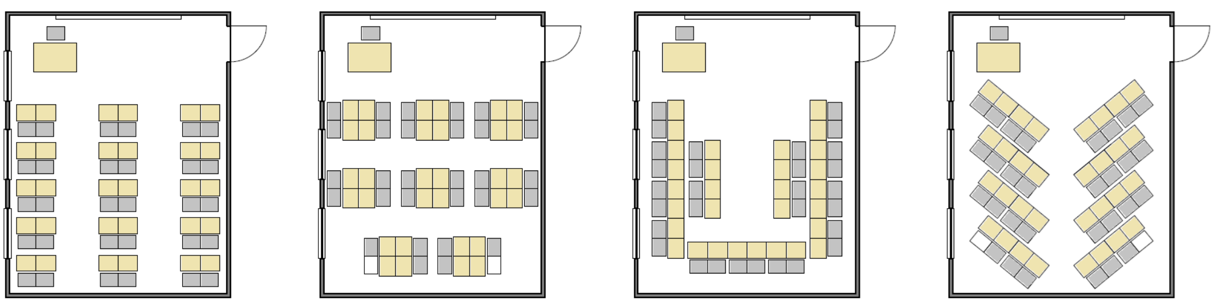
My literature review focuses on fire safety precautions in educational buildings. Separately, a review is being conducted on the analysis of fire risks and occupant profiles in educational buildings. First of all, it is noteworthy that prescriptive-based regulation controls generally are carried out in research. However, with the advance of technology, the development of performance-based solution suggestions also has taken its place in the literature. During the evacuation simulation, investigations are carried out in the educational buildings to evacuate students in a short time. Based on my literature review, educational buildings often are taken as a whole, within the scope of fire safety, but very little has been done specific to classrooms, which is a gap in the literature. As the most frequent and most intensive areas of use in the school, the effect of the classroom layouts on the total evacuation time of the school is of great importance.

3. Materials and Methods

The evacuation possibilities of the classrooms were investigated to improve the safety conditions during a fire in the education buildings. Within the scope of the research, a typical secondary school building located in Eryaman, Etimesgut district of Ankara, the capital of Türkiye, was examined in detail as a case study. The school building was constructed in 1987 as a 4-storey building. The building was formed with a rigid framed reinforced concrete structure system. There are 26 classrooms in the school. In all classes for the case study, the classroom arrangement is Traditional rows and columns. The clear width of the classroom exit doors was measured as 85 cm. Each classroom desk is 110 x 40 cm. The height of the desk is 66 cm. Each classroom chair is 110 x 35 cm. The height of the chair is 41 cm (Figure 1).

Figure 1. Case study: Classroom arrangement in secondary school, Türkiye.

In this paper, the effect of standard classroom arrangements on fire evacuation times was examined. The research focused on the analysis of classrooms and classroom evacuation times as areas of intensive use. The Traditional rows and columns arrangements, which currently are the standard, were first discussed in the layout plans. Traditional rows and columns arrangements are a layout where physical environment solutions and student-teacher communication are successful in creating a suitable learning environment (Tanahashi, 2007). Cluster arrangement is considered a layout scheme that encourages group work (Lotfy, 2012). It is a preferred arrangement, especially in younger age groups. The U-shaped arrangement is mostly preferred as a seminar training arrangement, but it facilitates joint classroom studies. However, it does not provide a suitable learning environment for individual studies due to potential distractions (Ramli et al., 2013). The Stadium arrangement creates a suitable learning environment thanks to the central position of the teacher and direct interaction with the students. However, a large space is needed for Stadium arrangements (Norazman et al., 2019) (Figure 2). Thus, Traditional rows and columns arrangements are the widely preferred approach for schools in Türkiye.



(a) (b) (c) (d)

Figure 2. Plan types on classroom arrangemnets; (a) Traditional rows and columns arrangement, (b) Cluster arrangement, (c) U-shaped arrangement, and (d) Stadium arrangement.

A standard classroom plan was created based on the case study. The classroom plan has a rectangular geometry of 6.3 m x 8 m. Occupant profiles were arranged to include 30 students (11-14 age range) and 1 teacher in each class (Millî Egitim Bakanlıgı Okul Oncesi Egitim ve Ilköğretim Kurumları Yönetmeligi, 2014). Although the Cluster arrangement and Stadium arrangement include 32 seats, 30 students are planned in the classroom. In the arrangements, students primarily prefer locations close to the teacher for an efficient learning environment. (Figure 2). Teachers were included in the evacuation simulation. However, in the investigations, the teacher does not have a leader or agent role. During the simulation, teachers and students are directed to escape through the most familiar fire evacuation route. The effect of the four alternative layouts on the class evacuation times, assuming the same door width, was analyzed within the scenarios. The four different classroom layouts (Traditional rows and columns arrangement - L1, Cluster arrangement - L2, U-shaped arrangement - L3, and Stadium arrangement - L4) and the door width and clear opening of 85 cm (D1) were investigated as the scenario parameters. The scenarios were analyzed with comparative assessment of the four different scenarios (LXD1). The Pathfinder 2024 software, developed by Thunderhead Engineering and created with an occupant-based motion/partial behaviour model (Thunderhead Engineering, 2012, 2017), was used for calculating evacuation times. Since the case study was located in Türkiye, the anthropometric characteristics of the students were obtained from studies throughout the country and transferred to the simulation program (Hastürk & Usta, 2014; Kaya & Erkarslan, 2019). Additionally, row measurements were created within the framework of standard data and used to populate the model (Chung & Wong, 2007). The walking speed of the students during the evacuation was considered to be 0.6-0.8 m/s (Ono et al., 2012; Wang et al., 2020). In the simulation, it was assumed that all students start evacuation simultaneously. This assumption was accepted as the students being warned and taking action simultaneously in case of an emergency. Students were positioned so that they were at their desks before the evacuation starts. Considering that people may turn sideways when passing through congested areas, a reduction coefficient was applied in the program to be used only when passing through congested passages. This value was set to 0.7 so that the calculations were made to be 0.7 times the shoulder width only when passing through congested crossings (Thunderhead Engineering, 2021).

4. Results and Discussions

The effect of classroom arrangements on the evacuation of classes as part of fire safety precautions in educational buildings was analyzed. In the analysis, the results of the total evacuation time of the class(es), the escape door flow rate (pers/s), and the number of occupants staying in the room depending on the time were evaluated. Door flow rates are expressed as the number of people passing through the door per unit of time. The flow rate does not depend on a single variable (density, speed, and distance). As density increases, the flow rate increases. However, high density reduces occupant speed. Especially in evacuation simulations, individuals coming from different parts of the building affect the flow rate differently depending on time. It was determined that the fastest evacuation time in classroom arrangements was in Traditional rows and columns arrangements (41 s), and the slowest evacuation time was in Stadium arrangements (53 s) (Table 2).

Table 2. Evacuation time according to simulation results

Scenarios (LXD1)	Total Evacuation Time, s	Door Flow Rate Max. Level, pers/s
L1D1	41 s	0.98
L2D1	44.8 s	0.82
L3D1	43.3 s	0.78
L4D1	53 s	0.79

4.1. Traditional rows and columns arrangements

Total evacuation time was determined as 41 seconds in Traditional rows and columns arrangements (L1D1) in classroom layouts. It was observed that most of the congestion occurred between the two rows closest to the exit. It was determined that there was a controlled exit system in the classroom evacuation and accordingly, the number of students in the classroom decreased properly. Furthermore, the flow rate at the classroom exit door constantly increased and the highest flow velocity at the exit door reached 0.98 m/s at 37 seconds within the scope of the evacuation time. Congestion arising from row arrangements in the classroom caused a decrease in flow rate (Figure 3). In such evacuation conditions, increasing the door width does not provide effective results in reducing the total evacuation time. However, the classroom arrangements need to be reviewed and it is appropriate to plan the rows and columns arrangements to reduce the evacuation time.

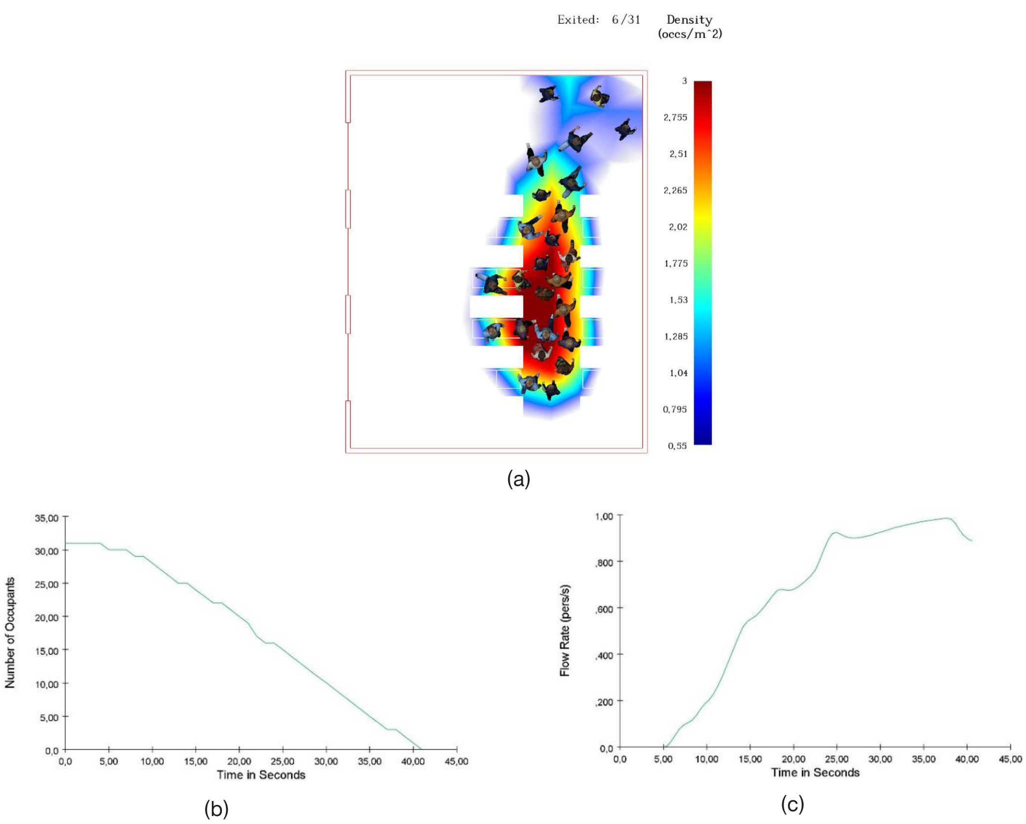


Figure 3. Analysis of evacuation in Traditional rows and columns arrangements; (a) The appearance of congestion at 13 s 6/31 person, (b) Number of occupants staying in the classroom, (c) Flow rate at the exit door.

4.2. Cluster arrangements

The total evacuation time was determined as 44.8 seconds in the Cluster arrangements (L2D1) in classroom layouts. During the evacuation, it was observed that most of the congestion was at the exit door and then between the two rows near the exit. It was determined that the congestion at the exit door was in the first 15 seconds of the total evacuation time. The classroom layout was effective in reducing the evacuation time, but the door width increased the total evacuation time. It was observed that there was a controlled exit system in the classroom evacuation and accordingly, the number of students in the classroom decreased smoothly and gradually. The highest flow velocity at the exit door reached 0.82 m/s at 23 seconds within the scope of the evacuation time. Congestion in the exit door caused a decrease in flow rate (Figure 4). In such evacuation conditions, increasing the width of the exit door gives effective results in reducing the total evacuation time.

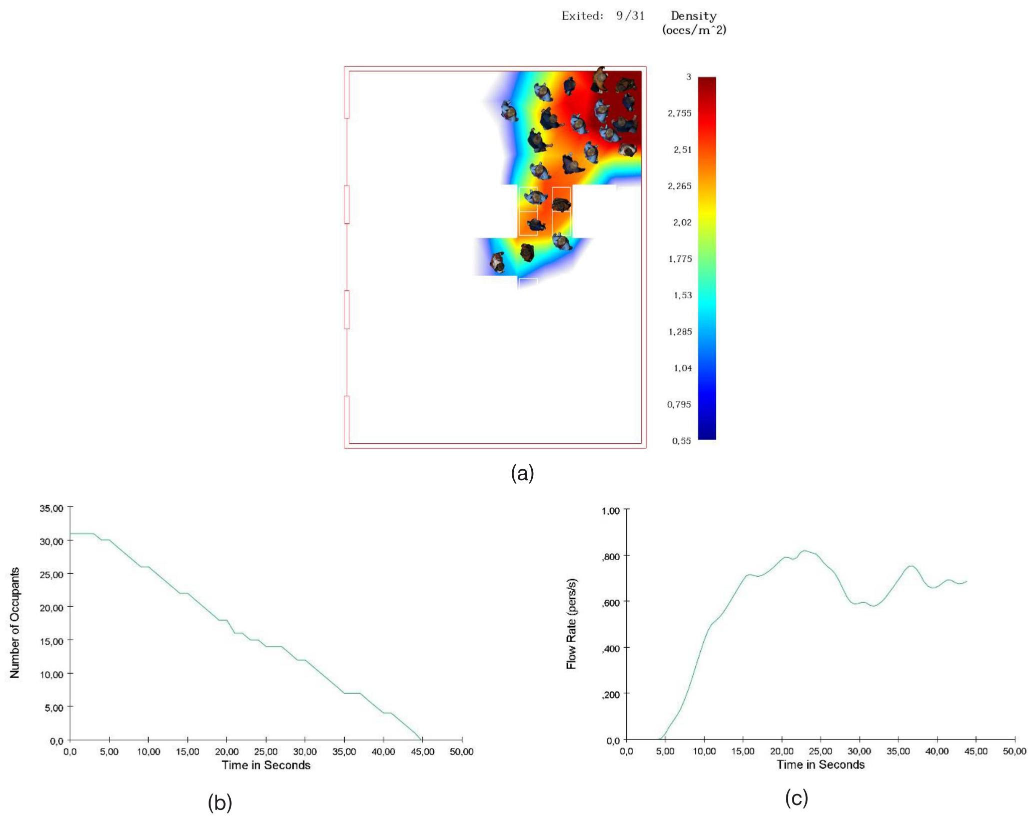
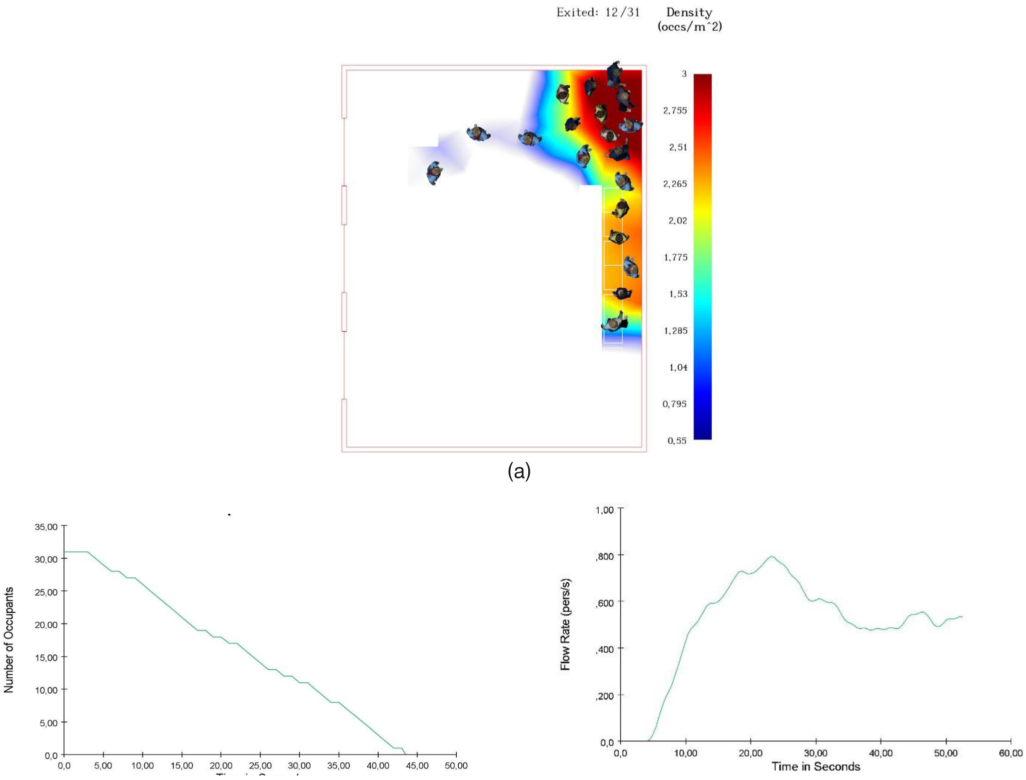


Figure 4. Analysis of evacuation in Cluster arrangements; (a) The appearance of congestion at 15 s 9/31 person, (b) Number of occupants staying in the classroom, (c) Flow rate at the exit door.

4.3 U-shaped arrangements

The total evacuation time was determined as 43.3 seconds in U-shaped arrangements (L3D1) in classroom layouts. During the evacuation, the most congestion was observed at the exit door. It was determined that the congestion at the exit door was in the first 18 seconds of the total evacuation time. During the evacuation, it is noteworthy that the students moved close to the wall due to the arrangement of rows. It was observed that there was a controlled exit system in the classroom evacuation; accordingly, the number of students in the classroom decreased smoothly and gradually. This shows that U-shaped and Cluster arrangements in classroom layouts have similarities within the scope of evacuation processes. It was determined that the highest flow velocity at the exit door reached 0.78 m/s at 18 seconds within the scope of the evacuation time. Congestions at the exit door caused the flow rate to decrease (Figure 5). In such evacuation conditions, increasing the door width gives effective results in reducing the total evacuation time.



(b) (c)

Figure 5. Analysis of evacuation in U-shaped arrangements; (a) The appearance of congestion at 18 s 12/31 person, (b) Number of occupants staying in the classroom, (c) Flow rate at the exit door.

4.4 Stadium arrangements

The total evacuation time was determined as 53 seconds in the Stadium arrangements (L4D1) in classroom layouts. During the evacuation, it was observed that there was congestion between the row and the wall closest to the exterior wall. It was determined that the congestion at the exit door was in the first 10 seconds of the total evacuation time. Furthermore, there was no controlled exit system in the classroom evacuation; as a result of this situation, the number of students in the classroom decreased unevenly. The flow rate at the classroom exit door increased until the first 23 seconds and then decreased continuously. It was observed that the highest flow velocity at the exit door reached 0.79 m/s at 23 seconds within the scope of the evacuation time. Congestion arising from row arrangements in the classroom caused the flow rate to decrease (Figure 6). In such evacuation conditions, increasing the door width does not provide effective results in reducing the total evacuation time. However, the classroom arrangements need to be reviewed and it is appropriate to plan the rows and columns arrangements to reduce the evacuation time.

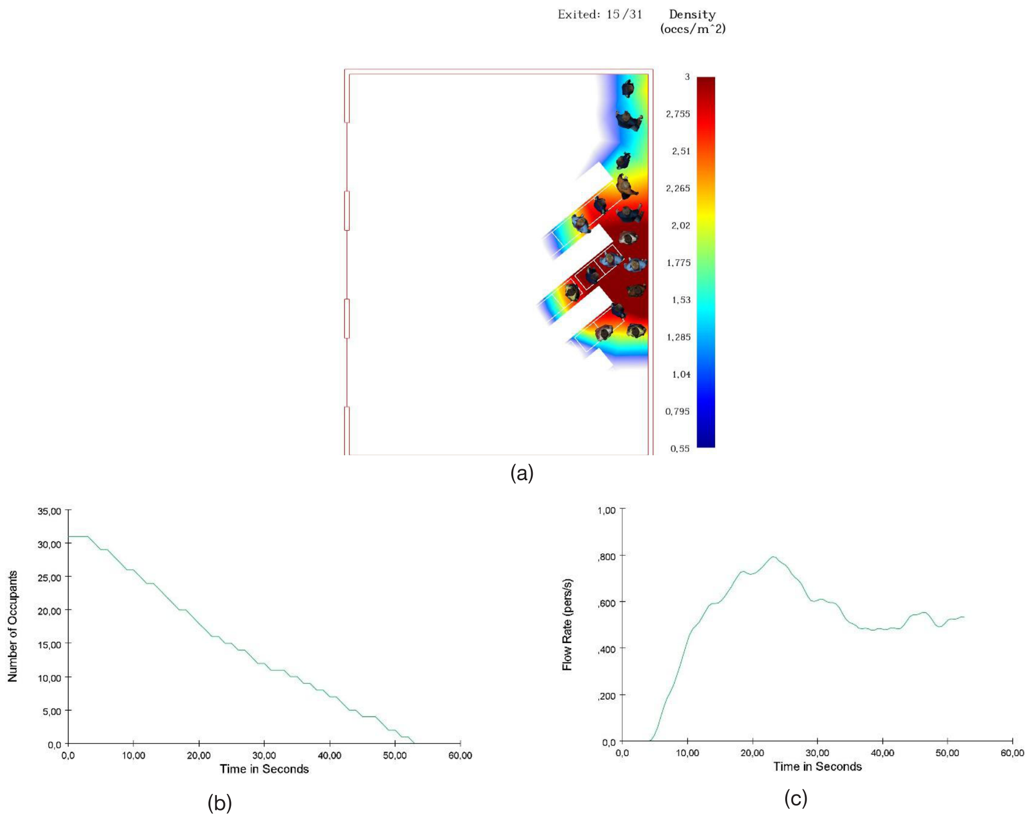


Figure 6. Analysis of evacuation in Stadium arrangements; (a) The appearance of congestion at 23 s 15/31 person, (b) Number of occupants staying in the classroom, (c) Flow rate at the exit door.

It is known that educational buildings have an important role in the development of students. Modern and functional educational buildings equipped with today's technologies should be designed primarily according to students' need for a safe environment (Lambie et al., 2018; Li et al., 2023). Fire safety and evacuation possibilities in educational buildings should be evaluated in this context and classroom arrangements should be planned according to appropriate strategies (Celik et al., 2024). In this study, classrooms are considered the most basic spatial unit in educational buildings, and the effects of classroom arrangements on fire evacuation time are investigated. In the evacuation planning, while congestion between desks was observed intensely in Traditional rows and columns and Stadium arrangements, congestion at the exit door was observed in U-shaped and Cluster arrangements. The fastest evacuation time occurred in the classroom of Traditional row and column arrangements. Then, evacuation times were determined in the classrooms belonging to U-shaped, Cluster, and Stadium arrangements, respectively. In classroom arrangements, students' evacuation conditions and the creation of effective learning environments/practices should be considered and evaluated with a holistic approach (Kaewlai & Janjamlah 2018; Savolainen, 2023)..

5. Conclusion

In fire safety precautions, educational buildings are included in the risky building usage class group when considering the occupant profile and fire load. The fact that the students are in a state of panic during the fire and the presence of flammable materials in the environment explains this situation. The prescriptive-based regulations and checklists used today are not sufficient to establish fire safety precautions in educational buildings and their sustainability. For this purpose, it is necessary to develop performance-based fire safety precautions in educational buildings and investigate the evacuation conditions of students.

Since classrooms are the most basic spatial unit in educational buildings, the effects of classroom layout on fire evacuation time have been investigated. Constant student numbers and the change of classroom layouts over the same spatial characteristics affect the in-class evacuation times in different ways. The fastest evacuation time was formed in the class belonging to the Traditional rows and columns arrangements (41 s). Subsequently, the evacuation time was determined to be short in the classes belonging to the U-shaped (43.3 s), Cluster (44.8 s), and Stadium (53 s) arrangements, respectively. In-class congestions were observed extensively in the Traditional rows and columns and Stadium arrangements. In these types of classrooms, there is a need for wider distances between student rows and wider corridor distances between the rows. In the existing buildings, whose spaces/distances cannot be expanded, it is proposed to reduce the number of students in the classroom. Congestion at the exit door was observed extensively in the U-shaped and Cluster arrangements. The fact that the congestions were intense in these spaces showed that the students progressed rapidly between rows and there was an accumulation of students at the exit door. Increasing the door width in these types of classrooms can reduce the total evacuation time in these classroom arrangements. Besides, it is not possible to add a second door due to the classroom layouts. The rows and arrangements do not allow for a second door and doorway. Additionally, the fact that the door flow rate during evacuation in Traditional rows and columns arrangements is much higher than in other classroom layouts indicates the appropriate distribution of students in the classroom and the controlled escape process. It is concluded that Traditional rows and columns arrangements are suitable for fast evacuation conditions in classroom layouts while other row arrangements can be improved.

Classroom arrangements in educational buildings should not be created solely based on fire evacuation conditions. Other considerations must include that the learning environment is designed most appropriately; the teacher-student information transfer is designed correctly; and the classroom environment can respond to the needs of students in the optimal condition. Fire safety also should be evaluated as an important parameter within this framework and classroom layouts should be considered and designed in this context. For future research, fire evacuation simulation studies in complex classroom layouts and agent-based simulation studies with different simulation tools are recommended.

Declaration of Ethical Code

The author of this paper declares that the materials and methods used in this study do not require ethics committee approval and/or legal-special permission.

Author Contributions

This is a single-authored study, the author contributed 100% (Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization).

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