Fire Safety Evacuation Plan for the Canteen at Aalborg University Esbjerg Campus

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Abstract

Emergency fire safety 'preparedness' plays an enormous role especially in high-occupancy areas like university campuses. The principal topic of our study is to create a fire safety evacuation plan particularly for the canteen in building A's basement at Aalborg University's Esbjerg campus. This report delves into a systematic approach which incorporates risk analysis, simulation, and stakeholder engagement where occupant safety, reduce fire evacuation time, and minimize fire-related hazards are our primary concern. A thorough risk assessment was conducted utilizing both qualitative and semi-quantitative tools, the Bow-tie Analysis and Risk Matrix respectively to find out the possible fire hazards and prioritize the risks. The identified main hazards through our brainstorming during the campus inspection, basically the canteen kitchen area are flammable products, electrical problems, human mistakes and malfunctioning cooking equipment. Recommendations were given after the hazards analysis for instance, routine maintenance, appropriate storage, and fire safety training. Automated fire-rated doors with magnetic holders and hanging fire safety evacuation layouts near all exits with whole campus were also emphasized to minimize life and property damage. The Pathfinder simulation software was used in the study to model five fire incident scenarios namely All Exits Operational, Canteen Main Exit Block, Library Main and Secondary Exit Block, Canteen Main Exit and Linking Library Door Block, Canteen Main Exit and Linking Lounge Door Block whose would help to optimize evacuation procedures, guaranteeing a swift and efficient egress. To ensure robust workplace safety, interaction among different stakeholders, particularly University administration closely relation to Cafeteria Management can play a crucial role. Our results highlight the combination of technological advancements and human behavior to ameliorate the emergency preparedness cycle. This report dives into the depths to create a safe environment for all campus residents by addressing vulnerabilities and promoting culture safety. Our suggested plan sets a standard for fire safety in campus by improving quick response capabilities and aligning with long-term operational risk management goals.

Acronyms

AAU - Aalborg University

DEMA - Danish Emergency Management Agency

NFPA - National Fire Protection Association

AMIU - Aalborg University Esbjerg Campus Work Environment Committee

G4S - G4S Security Services

RSET - Required Safe Egress Time

DWEA - Danish Working Environment Authority

SOPs - Standard Operating Procedures

DCP - Dry Chemical Powder

PA - Public Address

BR18 - Building Regulations 2018

OSHA - Occupational Safety and Health Administration

CFD - Computational Fluid Dynamics

AMS-AAU - Aalborg University's Administrative and Maintenance Services

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1. Introduction

People's safety in public areas and buildings during emergencies has received a lot of attention lately. Recent cases and institutional responses demonstrate this heightened awareness. For instance, At the University of Berkeley, disabled students filed a class action lawsuit challenging inadequate evacuation protocols, leading to mandatory building evacuation measures for persons with disabilities.[1]

Fire incidents have been considered one of the most common but dangerous as well because it led to a lot of loss of human lives and properties. Fire incidents occur with alarming frequency in the United States, with fire departments responding to a fire every 21 seconds, and one home structure fire reported every 88 seconds.[2]

The World Health Organization reports that more than 300,000 deaths are caused annually by fire-induced burns, with 95% of these deaths occurring in low- and middle-income countries. Studies indicate that at least 75% of fires are preventable, highlighting the importance of proper safety measures and awareness.[3]

There is a growing need for effective evacuation strategies in response to the increasing frequency of man-made disasters like fires, and toxic gas leaks. The Occupational Safety and Health Administration (OSHA) has established specific regulations requiring businesses to develop comprehensive emergency evacuation and fire prevention plans under 29 CFR 1910.38. [4] Due to this reason, the area of fire safety emergency or evacuation planning has been a good area of research recently.

Universities must account for individuals with different mobility needs and disabilities. Past legal cases have shown that institutions can face lawsuits if they fail to provide adequate rescue protocols for disabled or immobile individuals. [1] That is why, universities are legally required to ensure the safe evacuation of all persons on their premises, including staff, students, contractors, disabled persons, and members of the public. This obligation stems from various safety regulations and laws that mandate proper emergency preparedness.[5] Therefore, on university campuses with huge populations of students and staff, the importance of having a clear and effective evacuation strategy is unavoidable. [6]

The evacuation signal is indicated by the continuous sound of a fire alarm in the building owned, leased, or maintained by Aalborg University (Esbjerg). Everyone who is notified by the alarm must leave the premises as soon as possible and without incident. Constructing evacuation plans is considered one of the ways that are tested during drills twice in a year. However, in practical life, performing a drill is comparatively expensive and not everyone in the building actively participates in it. Moreover, some of them don’t take it seriously. In this context, computer-based modeling (Simulation) of evacuation processes in the actual activity became more widespread. These tools enable the analysis of human behavior in high-stress emergencies, allowing evacuation strategies to be adjusted to align with expected or planned parameters.[7]

Aalborg University Esbjerg is a public institution that has more than one building which has been designated A, C1, C2, D, F building. The campus has developed over the years to include new structures, the latest being building C2 which was established in 2015, the first structure having been built in 19654. Just like any big institution, Aalborg University Esbjerg must ensure that adequate safety measures are adhered to. Around 700 students and about 110 employees are housed on campus which includes potential non-residential facilities such as classrooms, laboratories, engineering workshops, a 'students' cafeteria', Smuthullet and other study areas. The need for such a fire emergency action plan, policies and procedures, fire systems maintenance, and staff and student emergency action training are self-evident in the case of the protection of the University.[8]

Within the canteen facilities that attract large populations daily, unique fire hazards exist. The nature of fire breakouts and how people in an environment they may not be familiar with might react and behave often determine how well or how fast evacuations are performed. Hence, there is a need for an effective evacuation plan that is specifically designed to take care of these aspects. One such plan should consider the location and size of the canteen, its likely occupancy patterns, and the location of the available evacuation shelter. [8]

This paper focuses on creating a fire risk assessment and evacuation plan that considers people using the canteen located in the basement of Building A at Esbjerg Campus. The goal is to improve emergency preparedness, reduce the risk of injuries, and make the campus safer for everyone. By using tools like risk analysis and simulating different scenarios, we aim to find the best ways to handle fire risks and suggest improvements to make the area safer.

1.1 **Motivation**

While considering studying Safety and Risk management, an assessment of the emergency is essential as it helps in saving lives and maintaining safety. Pursuing our master's course in Risk and Safety Management has entitled us to acquire both theoretical and practical knowledge in addressing safety issues in the relevant field.

Operational risk management is a discipline that focuses on identifying, assessing, and mitigating risks associated with routine events. As part of our master's course in Risk and Safety Management, we have come a long way in learning and practicing risk assessments, and management. Simultaneously, we are studying emergency management throughout the semester which involves preparedness, response, recovery, and mitigation strategies. Our report "Fire Emergency Evacuation Planning for Canteen Occupants on the Esbjerg Campus," is motivated by the need to develop a structural approach towards simulation by managing the risks constituted by potential fire emergencies in high-densely areas.

The canteen on the Esbjerg Campus serves as an active gathering point for students and staff, making it particularly vulnerable to fire hazards and emergencies. Given the complexity of the environment, it is significant to simulate operational risks like fire in the canteen's existing layout, occupancy patterns, and safety measures. By thoroughly analyzing these factors, our report focuses on proposing a targeted fire emergency evacuation plan that amplifies the safety and efficiency of evacuation procedures.

Additionally, effective operational risk management in our case involves not only technical aspects but also occupant behavior of the canteen that can significantly influence the success of evacuation strategies.

The pursuit of our report is to establish a systematic approach to prioritizes the safety evacuation of the occupants on the Campus. By developing a simulation for a fire emergency evacuation plan, we are determined to contribute to a safety culture that empowers individuals to recognize and respond to risks effectively.

1.2 Problem Formulation

Fire emergency planning for the canteen at Aalborg University Esbjerg Campus demands an innovative and systematic approach to ensure the safety and efficiency of evacuations during fire emergencies. Whether the existing evacuation plan needs improvement, especially in addressing scenarios involving unforeseen barriers such as blocked escape routes, door malfunctions, or overcrowded exits, We create a primary hypothesis question and a supporting question for our project which is

- *How can fire emergency planning for the canteen at Aalborg University Esbjerg Campus be improved using simulation tools like Pathfinder to optimize evacuation efficiency and safety?*
- *In case any unplanned barriers come up, like blocked escape paths, failure of doors, or crowded exits, what will be the alternative scenario during a fire?? How can simulations like Pathfinder be used to analyze these scenarios and optimize evacuation strategies to address such challenges?*

Given the complexity of human behavior in emergencies and the spatial constraints of the canteen, simulation tools like Pathfinder offer a powerful solution. By simulating various fire scenarios, these tools can analyze the movement of occupants, identify bottlenecks, and assess alternative evacuation strategies. This study focuses on optimizing evacuation efficiency by integrating simulation insights into the planning process. The findings aim to provide actionable recommendations for strengthening emergency preparedness and fostering a safety-oriented culture on campus.

To fulfill the problem formulation, conduct a detailed risk assessment of the canteen using tools like Bow-Tie Analysis and Risk Matrix to identify potential hazards, such as flammable materials, equipment failures, and human error. Use Pathfinder to simulate evacuation scenarios under varying conditions, including peak occupancy, blocked exits, or equipment malfunctions, and model different fire sizes and locations to encompass a range of situations. Gather data on the canteen layout, occupancy patterns, and existing fire safety measures, employing time-based analysis to calculate evacuation timelines like Required Safe Egress Time (RSET). Analyze simulation outputs to identify bottlenecks and optimize evacuation routes by proposing adjustments to infrastructure, signage, and safety equipment. Collaborate with stakeholders, including canteen management and emergency services, to ensure strategies are practical, and conduct training sessions for staff and occupants to implement updated evacuation procedures effectively.

1.3 Delimitation:

1.This report focuses mainly on the fire evacuation plan in the canteen of basement A at AAU campus with including stakeholders like students, faculty members, administrative staff, maintenance personnel, kitchen staff, and occasional visitors gather ignoring other buildings of the campus namely C1,C2,F,D,E where large occupants are also generally seen.

2.In case of risk assessment methodologies Bow-tie method and Risk matrix had been used on fire hazards within the canteen neglecting other complicated methods like Fault tree analysis and Failure mode and effects analysis.

3.Our report evaluates risks from flammable materials, electrical faults, kitchen equipment hazards, while structural failure like building collapse due to overloading was not considered.

4.The report delves into Danish buildings regulation and the Fire Services Act for the evacuation plan; where other standards like Eurocode, NFPA were not deployed.

5.Our writing does not recommend significant fire escape routes with proper dimension for instance aisles width, stair width, door width, window width etc.

6.Limited access to certain historical fire incidence data (e.g., casualties, insurance premium) as there was no accident in this campus; the depth of the risk assessment was constrained.

This delimitation ensures the report remains focused, pragmatic, and matched with its main goal of enhancing fire emergency preparedness plan and evacuation efficiency with the specified area.

2. Methodology

The study utilizes a mixed-method approach, that is- conducting quantitative simulations as well as performing qualitative risk assessments, in devising a reasonable and effective fire evacuation plan for the canteen at Aalborg University's Esbjerg Campus.

2.1 Data Collection method

The relevant data was then acquired by conducting physical infrastructure observations such as mapping out the layout of the canteen, documenting the existing fire safety equipment, locating emergency exits, and evacuation routes. Simultaneously, occupancy studies were performed as well to collect data on the maximum number of people using the facility during peak hours, the usage patterns, and the movement of people around the facility during different times of the day. In view of such aspects, these methods thoroughly outline the migration processes of the people in the canteen which is very useful in designing an evacuation plan that is sensible and practical.

2.2 Risk Assessment

During the risk assessment process, a Bow-Tie Analysis and a Risk Matrix are employed for fire hazard identification and risk evaluation which are both systematic. They allow for the systematic identification of the factors leading to and the impacts of a fire occurrence which aids in risk management.

2.3 Evacuation Planning

In this phase, the locking of routes is undertaken to determine the most appropriate evacuation routes and the location of appropriate assembly points outside the canteen region. These features are important in improving evacuation procedures and assuring the safety of the occupants in the event of an emergency.

Time based analysis also aids in planning by determining the Required Safe Egress Time (RSET) which helps in assessing the time taken by the occupants to vacate the area fully. This analysis also integrates the measurement of detection and alarm intervals to assess the degree of adequacy of the existing fire protection measures in terms of response time and evacuation time.

2.4 Stakeholder Analysis

A detailed stakeholder engagement was performed to confirm that the fire evacuation plan for the Esbjerg Campus canteen is practicable as well as all inclusive. The consultations involved visiting the canteen management in order to appreciate the operational constraints, working with the emergency services in order to integrate the plan with safety principles, as well as inviting building maintenance staff to consider the design aspects.

2.5 Simulation

Simulations on the computer regarding evacuation mechanisms to analyze the region under which evacuees would settle other than the primary modeling parameters. Scenario based predictions were also done to assess in real time the management of these emergencies, these measures in general increased the dependability as well as the effectiveness of the evacuation plan.

3. Results

3.1 Risk Assessment

Risk assessment is essential for identifying and prioritizing potential hazards that may impact health and safety in any environment such as universities, industries and hospitals etc.

3.1.1 Bowtie

Materials like paper products, several cleaning solvents, food wrap materials, cooking oil, and grease can all ignite a fire by accident. Plumbing and gas system errors, surfaces becoming too hot, grease build-up, or oil being refused when already hot, are all difficulties when using cooking devices. Electrical equipment dangers are caused by circuit overloads, bad wiring, loose or broken cords and plugs, and bad use of extension cords. Furthermore, dust and the existence of rodents and bugs add more danger. Dust which builds on wire, lights, or appliances may promote overheating and start a fire. Rodents of all kinds gnawing on wires create sparks or short-circuits. People's negligence such as leaving things unattended or lack of knowledge of fire safety further escalates the risks.

For preventing the occurrence of accidents, it is important to store the combustible materials in fireproof containers, to make sure their permanent disposal at intervals, and burning the food in a safe manner. The main aspects of the instruction are supervision of the materials such as wires, gas and any items that could cause a negative impact to the food cooked, checking that there is enough ventilation and a safe location where oil is disposed. Restriction of electrical safety appliances operation within safe limits, up keeping the cords, using certified tools and minimizing the number of extension cables used will limit the use of circuits, thus improving the safety. To address issues relating to dust and vermin, cleaning on a regular basis, the use of dust-filtering systems, measures that will integrate prevention, and materials that are resistant to rodents will be required. The risk of human error can be reduced by providing fire training to employees, creating a positive safety culture, effective SOPs, and conducting drills periodically to affirm the organization efficient in case of a fire.

It is important to always have an easy access to fire extinguishers, fire rated walls, automatic fire doors and smoke ventilation systems in the event of a fire. Adding properly marked aisles, unblocked exit pathways, proper emergency lighting and places of congregation are also important. Always providing a means to contain the fire like separating the involved parts, putting class k fire extinguishers in kitchen, and cleaning the grease from the kitchen ventilation system will help to contain the fire. If structural elements such as wires have got damaged, they should be first recognized and removed and respective parts substituted. Also, installation of cut-off switches is a wise step. A combination of pest deterrence processes and rodent-proof materials should offer adequate protection for electrical equipment. Attention must be paid to negligence through incident reviews, policy revision, and support of fire safety personnel.

Neglecting the fire hazards has the risk of damaging property, having a negative impact on people's lives.

Threats	Preventive Barriers	Hazard	Recovery Barriers	Consequences
1. Flammable Materials: Source of ignition from paper materials, food packaging products, cooking oil, kitchen cleaner and grease formation during cooking. **2. Cooking Equipment:** Gas leakage from gas cylinders and faulty wiring for the induction oven. Cooking surfaces become overheated. Large scale grease formation that leads to fire. Hot cooking oil that has been disposed of improperly.	1. (a)Storage of flammable materials should be ensured properly. (b)Materials should be fire-resistant (e.g., as per NFPA). (c)Garbage and packaging materials must be dumped duly. 2. (a)Regular maintenance of wiring and gas cylinders. (b)Inspection and calibration of cooking equipment on a regular basis. (c)Ensure proper ventilation throughout the system.	**Fire Explosion**	1. (a) Supply adequate fire extinguishers and fire blankets so that trained personnel can extinguish small fires quickly. (b)Use fire-rated walls, doors, windows and ceilings in areas where flammable materials like paper products, cooking oils, and kitchen cleaners are stored. Fire doors should be automatically closed during a fire to prevent spreading. (c)Install smoke, heat and flame detectors as per fire detection drawing where fire hazards exist, especially kitchens and storage areas. These systems can detect smoke, heat and flame and send signals to the control panel as well as fire bell rings. (d) Maintain clear aisles marking (at least 1m width as per NFPA) and regularly follow egress routes, emergency lighting, and assembly points.	1. Property loss 2 Injury or Life loss 3. Financial loss 4. Vermin Infestation to other areas 5. Impose legal or financial penalties

3. Electrical Equipment: Short circuits. Messy wiring. Overlapping cables. Rusty copper lugs. No earthing connection. **4. Accumulation of dust - soot and vermin presence (Rodents, Insects, etc.):** Overheating of electrical cables due to the accumulation of dust-soot. Sparks from electrical wiring due to chewing of rodents.	(d)Disposing of hot oil safely (use of containers, waiting for cooling). 3.(a) Shun overloading in the circuits. (b)Conduct electrical safety inspections by following the manual. (c)Use certified and rated electrical equipment. (d)Provide at least two earthing connections for each piece of equipment.		2. (a) Affected areas should be isolated to prevent fire from spreading and reducing damage. (b)Swiftly and safely evacuate personnel to minimize harm. (C)Make sure that kitchens are equipped with both foam type and DCP fire extinguishers, specifically designed to extinguish fire arising from cooking oils and fats. (d)Shut down the equipment immediately that overheats to prevent ignition again. (e)Remove accumulated grease as soon as possible and prevent fire from spreading through ventilation ducts. 3. (a)Ensure that damaged cables and plugs are quickly identified and isolated from the main power source. Install rated circuit-breakers that can immediately disconnect power to the affected area. (b)Rapidly replace rusty lugs to restore safe operation.	

5. Human Error: Sloppy cooking from the chef. Lack of knowledge regarding fire safety (personnel incorporated with the kitchen).	4. (a) Cleaning and maintenance of false ceilings. (b)Provide dust filters or proper ventilation systems to reduce dust accumulation. (c) Conduct pest control such as regular inspection, trapping, and removal of vermin. (d) The ceiling should be properly sealed (for instance, any gaps/holes). (e)Vermin-resistance wiring during the installation. 5. (a)Fire safety training by the fire department. (b)Deployment of safety culture and standard operating procedures (SOPs).		(c) Protect personnel from electrocution or fire hazards caused by damaged equipment. (c) Distinguish unsafe extension cables from use until they are replaced. (d)Replace extension cables with permanent wiring to reduce the risk of overloading. 4. (a) Isolate power immediately and inspect the wiring to prevent further fire incident. (b)To avoid damaging electrical systems, employ rodent-resistant materials and follow strict pest control procedures. 5.(a) Address safety committee meetings to reduce sloppy and accelerate awareness by reviewing incidents and updating safety record books. (b) Fire safety officers should visit every day to monitor fire safety procedures and hazards as well provide guidance in emergencies.	

3.1.2 Risk Matrix

Risk Matrix of Fire Explosion		Severity				
		Insignificant (1)	Minor (2)	Significant (3)	Major (4)	Severe (5)
Probability	Almost Certain (5)	Medium (5)	High(10)	Very High (15)	Extreme(20)	Extreme(25)
	Likely (4)	Medium (4)	Medium(8)	High(12)	Very High (16)	Extreme(20)
	Moderate (3)	Low (3)	Medium(6)	Medium(9)	High (12)	Very High(15)
	Unlikely (2)	Very Low (2)	Medium (4)	Medium(6)	Medium (8)	High(10)
	Rare (1)	Very Low(1)	Very Low(2)	Low(3)	Medium(4)	Medium(5)

Table 2: Risk Matrix

Source: [23]

The 5*5 semi-quantitative matrix illustrates the probability of hazards in the Y-axis and the severity of those hazards in the X-axis. The risk matrix is divided into six colors (i.e., blue, light blue, green, yellow, red, dark red) with four regions where (very low, low) indicates acceptable risk, medium region shows manageable risk, high area describes significant risk necessitating instant action and (very high, extreme) narrates unacceptable risk with quick action.

First, the probability and the severity of flammable materials like paper products, food packaging, cooking oils, kitchen cleaners, and grease formation are extreme with higher value (25) due to daily cooking in the kitchen except weekends.

Secondly, the probability and the severity of hazards from gas cylinders leakage, overheated surfaces, and improper disposal of hot cooking oil are very high because cooking equipment like an oven must be used for constant cooking with potential for explosion.

Thirdly, the likelihood and the severity from short circuits, messy wiring, and lack of earthing may be high due to lack of proper maintenance. Fourthly, the probability and the severity by the cook's carelessness and the lack of fire precautionary knowledge during the cooking are medium because man is inherent to error by birth and the chef/cook may be the newcomer or freshly joined. Finally, the likelihood and the severity from the accumulation of dust on electrical components and rodents chewing on wires are low to very low value (1) due to strong pest control and proper maintenance.

3.2 Stakeholder Analysis

High	**Keep Satisfied** • Esbjerg Kommune • Danish Insurance Company • Ministry of Defence	**Manage Closely** • University Administration • Canteen Management (Jespers Torvekøkken) • Fire Safety Equipment Provider (G4S) • Fire Department (FALCK) a. Police b. Hospital c. DWEA
Power Low	**Monitor with Minimum Effort** • DEMA (Danish Emergency Management Agency) • Maintenance Contractors • Catering Suppliers	**Keep Informed** • Students • Faculty • Visitors • kitchen Staff • Cleaning Staff • Local Community • AMS-AAU • Occupational Health and Safety officer
	Low	Interest High

Table 3: Stakeholder Analysis

3.2.1 Manage closely

When there's a fire incident in a university canteen, various stakeholders combine their resources to produce a joint and effective response action system. The responsibility for everyone maintaining safety on university premises equally lies with the University Administration, who oversee taking control of structural tasks as well. This entails defining and flanking sound emergency plans, putting in place adequate prevention measures, and managing other interested parties to limit and eliminate risk and loss potential.

Jespers Torvekøkken, the canteen managers have indicated a major part in operations in the daily basis compliance with the fire provision instructions. It includes educating personnel, performing control exercises on daily basis, and coordination with ambulance, police and the fire department in case of the fire. Furthermore, they give crucial elements that will simplify the activity that will be conducted after the fire.

As a provider, G4S has provided for each room in the premises of the correct equipment, so fire extinguishers, MCPs and sprinklers are correctly maintained and services effectively done. They are also effective in education of the canteen employees on the proper equipment handling. [13] [14]

FALCK has the position of the first order of business for firing incident control. They control all works having begun with evaluation of the problem and ending with extinguishing and rescuing people. If it comes to a situation that requires involving of the police or treatment in hospital, the canteen staff including students are taken care of by the police in the first place, who determine whether public order is reasonably safe, maintaining possible disruptions through crowd control. [13] [14]

The Danish Working Environment Authority (DWEA) takes care in making sure that there is workplace safety compliance in all workplaces by carrying out investigations into incidents and thereafter, recommending what improvements would be instituted to avoid similar occurrences in the future. [14]

To ensure an appropriate response, there is a necessity of meeting at regular intervals to enhance communication in regard to fire safety procedures as well as the response to emergencies. This would enhance the relationship among the stakeholders and enable them to work together in the event of an emergency. [13] [14]

3.2.2 Keep Satisfied

Within the fire safety administration system at the university canteen, Esbjerg Kommune has a great deal of authority but a comparative lack of interest. It is primarily tasked with the enforcement of fire regulations, maintenance of safety standards and assistance in reply to organization. A municipal authority has oversight of public security and construction codes thus making it a central asset in a fire safety setting. Danish Insurance Company on the other hand has a lot of influence especially since it is the one paying the sums insured and has interest at managing risks. [19] It is also important in assessing fire damage control measures taken by the university and ensuring the company's indemnity requirements are met. Lastly, this group also includes The Ministry of Defence but this last-mentioned organization has more moderate power in this group in regard to international security and natural emergency management. Even though it is expected that a fire problem originates in a university, its efforts are directed at policies and resources on national level which aid in civil emergencies. [12]

3.2.3 Monitor with minimum effort

Different stakeholders, like Dema and Maintenance Contractors and Catering Suppliers, have low power and low interest about fire protection measures at the university canteen. DEMA or Danish Emergency Management Agency which is subordinated to the Ministry of Defence is in this case also on a low power and low interest. For Example, while DEMA is responsible for most aspects of national emergency preparedness, it is difficult to envision their direct involvement in a localized fire issue in the canteen unless there is a larger emergency event that needs attention. Maintenance Contractors do the regular maintenance and repairs and have little relevance in emergency situations. They are also critical in the preparation of food and catering services and have little to do with the fire safety management. Such stakeholders are not suggested to be actively involved but should be kept abreast of the most pertinent safety issues. [14]

3.2.4 Keep informed

The third group, which may be referred to as Keep Also Informed group, comprises people who possess high concern towards the civil defence against fires that may occur within the premises of the university canteen but have little ability to effect policies. This group includes Students, Faculty and Visitors with the last category as the most prone to risks during crises. Staff of the Kitchen and cleaning Staff also fall in this category since they operate directly within the canteen set up and should be informed about the likelihood of fire incidents and what to do in case of a fire breakout. The Local Community wants to know safety measures so that its region is not vulnerable to any threat. AMS-AAU is operating in assisting the achievement of fulfilling the standards set across the institution on safety principles. Further, the Occupational Health and Safety Officers who are embedded in three services, that is, Services, Biochemistry and Energy have each a designated safety officer whose task is to ensure that there is a heightened sense of fire awareness, and the required measures are observed within the areas. Fire safety is a very sensitive issue and through this channel Regular communications, training and other updates on fire safety measures are to be spread among the members. [15]

4. Building

The AAU Basement acts as an energetic center that assumes various functions depending on the user group in question. Consultations with administrative, kitchen, maintenance staff, and study secretaries reveal a rich tapestry of functions in the Inventory of Activities for Autumn 2024.

Within the basement, notable educational activities are conducted in meeting rooms that are allocated for ease, as is the case with student group work on projects and assignments. Cleaning activities are also maintained. The basement is also a social space as the dining area and the study environment room are used frequently for social activities and events in honor of certain occasions. Breakfast, lunch and informal talks are even more socialized with the help of a canteen.

In addition to this, the basement also performs its social function but supporting academic ones as well, through the library which is suitable for individual, group, and project work owing to the quiet environment that it offers.

4.1 Basement Infrastructure

The AAU Campus Esbjerg basement houses a critical infrastructure of essential systems that ensure the building's smooth operation. To develop a robust fire evacuation plan, a thorough understanding of the basement's layout and the specific functions of these installations is paramount. This knowledge enables the identification of potential hazards, the location of critical control points, and the determination of optimal evacuation routes. Information was gathered through direct observation.

Key installations within the basement include:

- **Smoke Detection System:** Monitors air quality for early detection of smoke and fire.
- **Heating and Ventilation System:** Regulates temperature and air circulation.
- **Alarm System:** Triggers alerts in case of emergencies.
- **Elevator:** Provides vertical transportation for occupants.
- **Energy Supply:** Powers the building's electrical systems.
- **Water, Drainage, and Plumbing:** Manages water supply and waste disposal.

4.2 Basement Layout

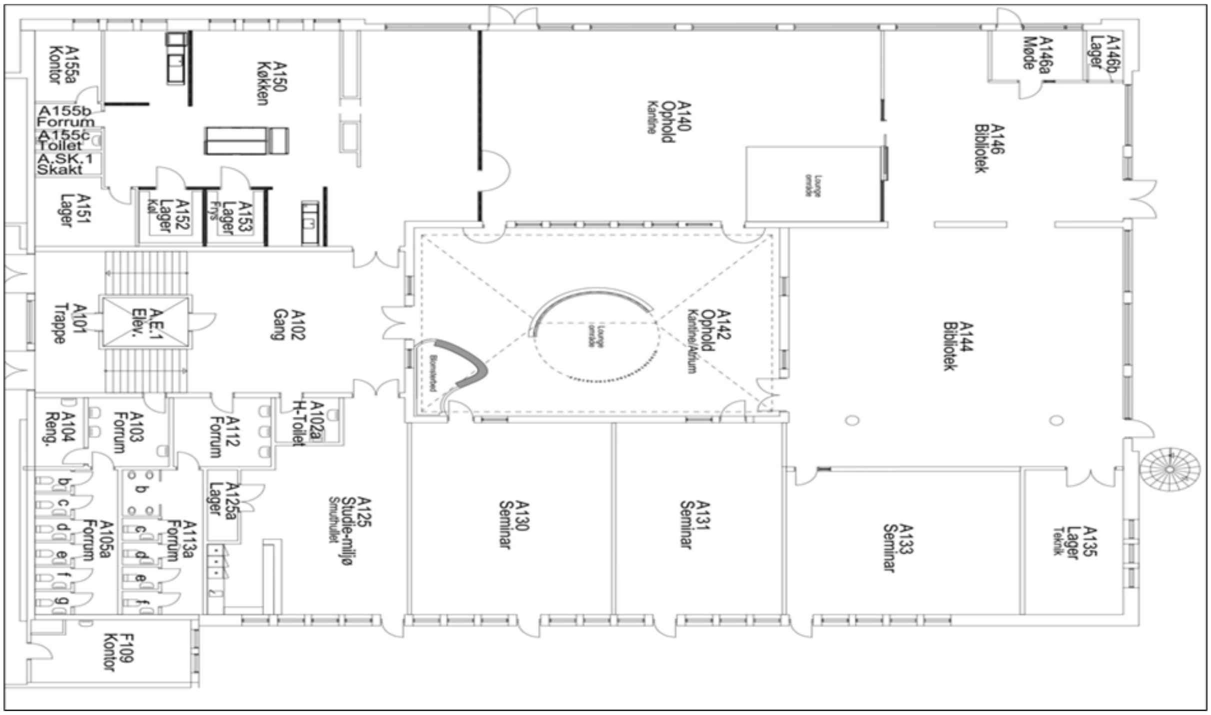

Figure 1: Basement Layout

The AAU Campus Esbjerg basement, spanning 915.66 square meters, is divided into 18 distinct rooms, each serving specific purposes. A detailed breakdown of the rooms is provided on the accompanying table.

Room	Area (m²)	Seat	Room	Area (m²)	Seat
A 135 Warehouse	11.52		A 131 Seminar	25.37	30
A 133 Seminar	26.81	24	Kitchen Serving Area	22.03	—
A 146 Library	96.34	55	A 150 Kitchen	32.48	—
A146a Library meeting	3.49	5	A 153 Storage (Freeze)	2.5	—
A146a Warehouse	1.6		A 152 Warehouse	2.6	—
A140 Canteen	61.34	78	A 102 Walkway	24.10	—
A 142 Canteen / Lounge Area	56.13	45	A 125 Study Environment	24.01	31
A 130 Seminar	31.07	30	A 125a Warehouse		—

Table 4: Basement Room Specifications

4.3 Legislation

Danish legislation regarding fire emergency plans is primarily governed by the Building Regulations (BR18) and the Fire Services Act. These regulations outline detailed requirements for fire safety, including emergency planning. One of the main drivers for fire risk assessment is legislation specifically relating to fire safety. this typically includes:

1. Building Regulations
2. Fire Emergency Plans [9]

4.3.1 Building Regulations

Sections 453 to 458 detail regulations for calculating built-up percentage, plot area, floor area, building height, distances, and the number of floors. Section 453 defines the built-up percentage as the ratio of floor area to plot area. Section 454 explains that the plot area includes cadastral land, shared free spaces, and specific road areas but excludes zones where construction is not allowed and non-adjacent land registry numbers. Section 455 defines floor area as the sum of gross areas of all floors, including basements, attics, and staircases, but excludes low-ceiling basements, open balconies, fire escapes, and small lofts. Section 456 outlines height measurement from natural terrain or level plans, with allowances for sloping grounds and exemptions for items like antennas and solar panels. Section 457 specifies horizontal measurement of building distances, disregarding basements and small projections, with certain allowances for features like bay windows above public spaces. Section 458 establishes that each floor, including basements and usable attics, counts as one, with municipal discretion for staggered floors and living areas in attics. [10]

4.3.2 Fire Emergency Plans from the Emergency Act

Section 1 explains the activities that are done by state and municipal rescue services to prevent and mitigate damage during the course of an emergency. There is a mandate that Section 9 of the Act imposes on municipal councils to establish and coordinate the management of rescue service, which is under an emergency commission. Section 10 permits municipalities to devise ways of integrating services with those of adjoining areas and create joint committees. National preparedness requirements should be adhered to in the case of large-scale emergencies plans which were detailed in Section 5. These plans must be cooperative in nature and updated regularly. [11]

Fire and rescue services focus on preventing, reducing, and managing injuries and damage caused by accidents, disasters, and acts of war, with the responsibility split between national and municipal services. The National Fire and Rescue Service Structure is managed by the Minister of Defence, the national fire service is overseen by the Danish Emergency Management Agency (DEMA), which coordinates emergency responses and provides assistance to municipalities, particularly during large-scale incidents. [12]

4.3.2.1 Municipal Fire and Rescue Service

The municipal council has control over the municipal fire and rescue services and appoints an emergency management commission to supervise them. Such services can liaise with other municipalities, but such liaison must be approved by the competent authority. Their primary roles encompass handling emergencies and catastrophes, overseeing evacuations and making provision for firefighting facilities in terms of water supply. In addition, municipalities can enter contracts with various organizations or the national service so that such backup may be obtained if necessary. [12]

4.3.2.2 Legal Provisions

While performing firefighting and rescue tasks, agencies must ensure that any suspicious or relevant evidence is reported to the police. Also, they can use open water resources to carry out their business activities in a timely manner so that the consequences of the emergency can be managed satisfactorily, and further losses are minimized. [12]

5. Existing Fire Safety System

Fire Safety Equipment is necessary when a fire breaks out to save lives and resources. Such equipment is available to minimize damage by providing sufficient protection from outbreaks by detecting, fighting and containing flames until warnings can be raised. Below is a table listing the equipment available in the study area.

Equipment Name	Total Number
Fire Extinguishers	2
Emergency Exits Signs	12
Smoke Detectors	34
Manual Fire Alarm	8
Fire Hose	3
Fire Blanket	1
Control Panel	3
Fire Doors	DB 30 and DB 60

Table 5: Fire Safety Equipment Inventory

5.1 Focus Area Fire Safety System

However, even in the absence of such facilities, the occupants of the study area are well protected, as there is no single area in the study area that is devoid of fire safety equipment, fire Fighting equipment, red fire extinguishers every one of them. For directing the occupants to the exit doors, green colored emergency exit signs are provided so that occupants of the room can easily read the notice. To be notified as quickly as possible in case of smoke, which might happen even if there is no fire, time is of the essence; therefore, smoke detectors have been installed so that they may be used in the event of a fire. There are also manual call points for users for operation of the alarm system within the relevant area that are clearly visible. Users can use fire hoses or fire blankets in case of small flames. All the above including the control panel that is used centrally in the room for effective management of the system. The green arrows offer easy navigation and explain the exit routes that the occupants must take which are already given in the floor plan with the arrows. There are two types of fire doors serving the study area called DB 30 and DB 60 which offer an enclosure of 30 and 60 minutes respectively. It will be shown that these elements constitute together with individual and asset fire safety systems all in one or just simply the best there is in fire insurance. [16]

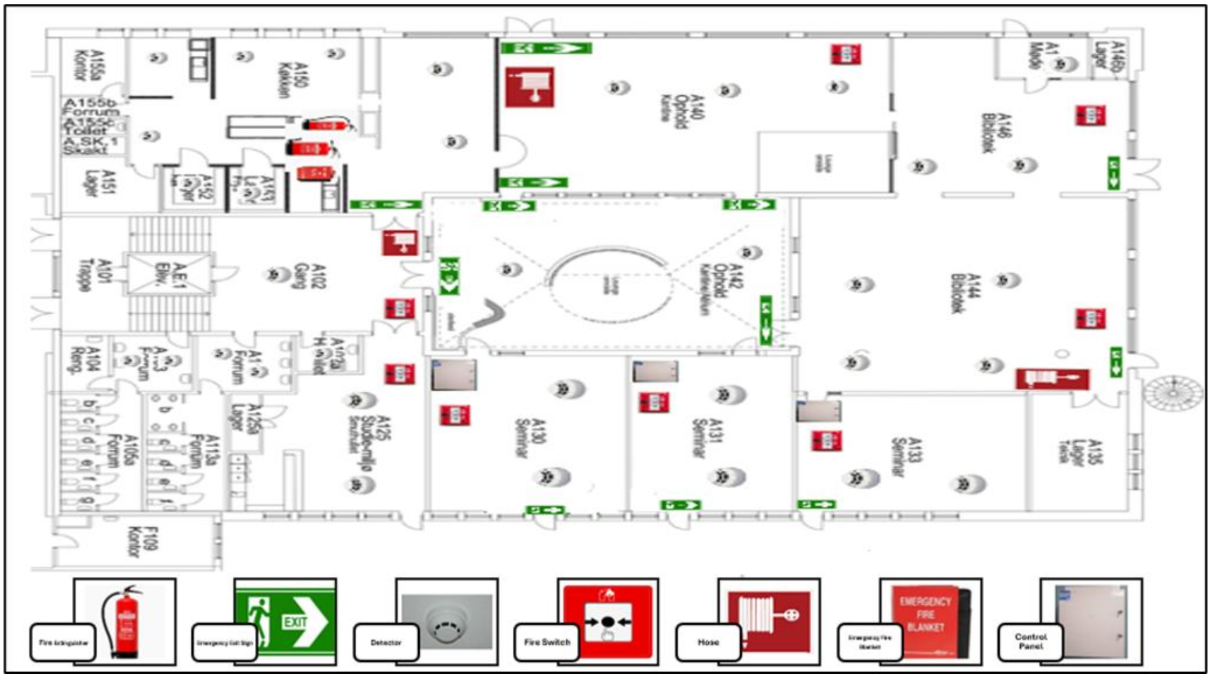

Figure 2: Existing Fire Safety System Map

5.2 Building fire equipment Standards

There should be emphasis on the right selection of fire safety equipment as per a detailed and a well-informed fire risk assessment. This goes a long way in ensuring that firefighters as well as other people are safe during fire incidents. Automatic Pressurization System (provisional: DS/EN 12101 6 standard) is one of the important pieces of equipment which assists in avoiding movement of fumes into protected escape routes in the event aids are installed in touch areas such as stairways and corridors. Another important piece of equipment, Fire Blankets (standards: DS/EN 1869), [17] are foreseen to be in place in kitchens for potentially fast smothering of small kitchen fires. Hand-held Fire Extinguishers (provisional: DS/EN 3-7, 3-8, 3-9 standards) should be user-friendly at all locations as their primary role is suppressing small fires. Smoke alarms: Fire detection systems Smoke Alarm Systems are very much helpful in a situation where Smoke along with its associated odour is present, which could alert many occupants potentially increasing the chances of reaching safe points. Complying with the guidelines set out in the Building Regulations about the installation of Alarm Systems for evacuation purposes is highly recommended.

Fire hose reels soaked in water (standards: DS/EN 671-1, 671-2, 671-3) allow carrying out firefighting activities on large areas as they are readily available. [17] Delivering effective operational performance of any equipment requires an oversight of its professional installation, periodic inspections, and regular maintenance. Services that involve these activities need trained professionals to ensure adherence to technical standards and improve the reliability of the system. Training on easy equipment operation as well as evacuation drill should be given to the occupants to improve their responsiveness where possible. Meeting the requirements of local buildings by laws as well as local fire codes and getting in touch with the insurance company for their needs is required to be on the safe side both safety wise and legally. Making critical choices on the equipment, getting it installed by a professional, always maintaining them, and following the regulations blindly brings about a complete fire prevention strategy. [16]

5.3 Fire Event Response Plan

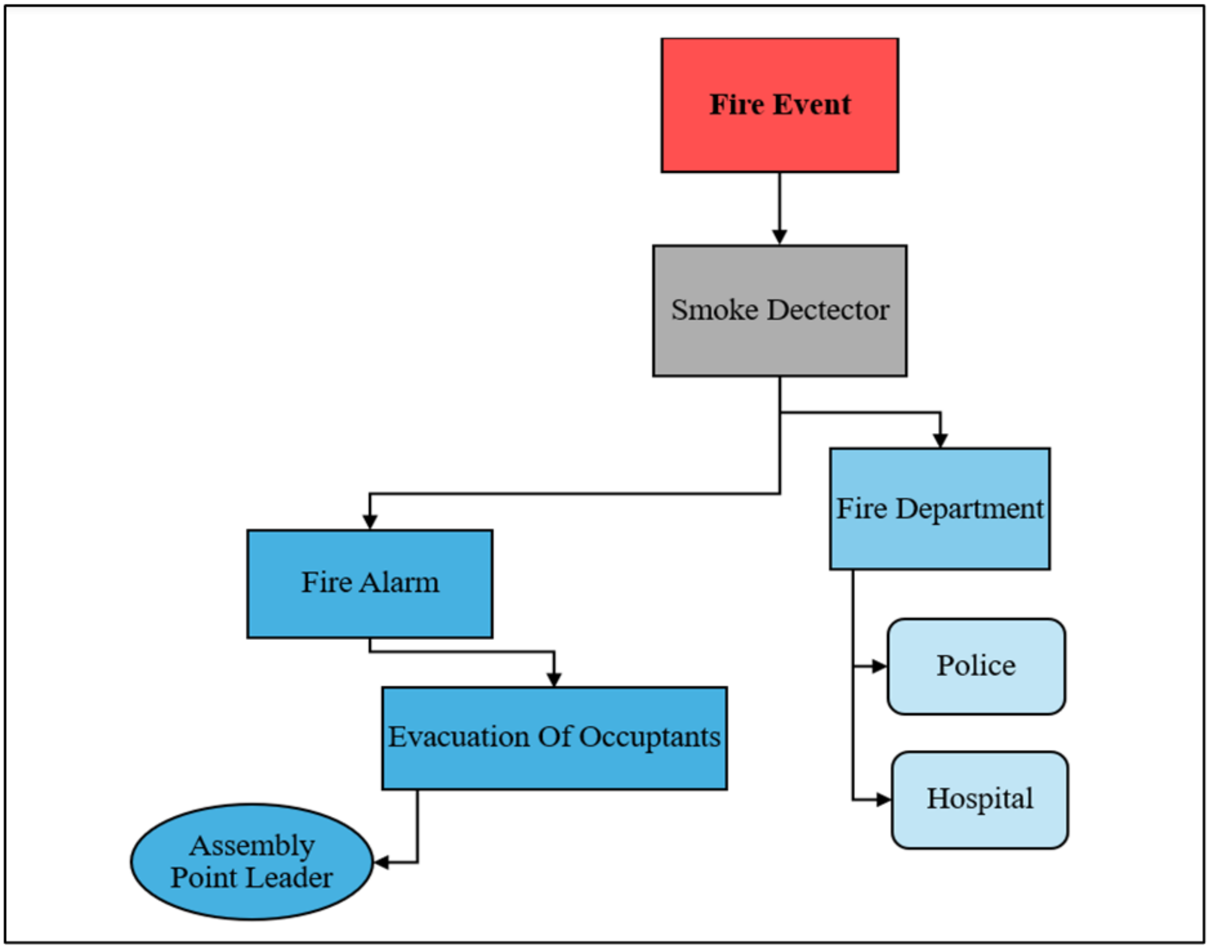

Figure 3: Emergency Response

The process starts when the fire alarm goes off and communicates to the occupants of the premises. This communication is automatically transmitted to the fire brigade. The process starts with the fire range team who are highly skilled personnel in charge of the fire situation. They join forces with Jesper and Peter, the building service technicians, to scour the premises.

As soon as that happens, the police are immediately notified in the event any of the members in the inspection gets injured. Serious injuries or deaths will necessitate the reporting of them.

The first officers to arrive at the scene will evaluate the surrounding area. If it is suspected that the contributing factor resides within the workplace environment, the DWEA will be invited to give further insight.

However, in most scenarios (around 90%), the source is likely to be electrical in nature. Under such conditions the police contact G4S who provides physical security and additional risk management services and emergency response. With G4S's experience in the five core areas of Electrical systems, it's only prudent that they can manage the situation quite well.

If it is determined that an external factor like smoking was the cause of the event the AMS of the university takes jurisdiction in accordance with the procedures outlined in the manual. The fire bridge team and the AMS section then cooperate to decide on the Line of Action that is appropriate to the situation.

The fire safety investigation is carried out in this manner which enables the investigation of fire risk factors to be quick and comprehensive to avoid greater risks and the safety of the entire campus is put in focus.

5.4 Existing Emergency Response Plan

The fire alarm gets activated by the smoke detector which in turn, informs all the people in the building to leave. In this case, all the people present in the building are required to make a quick departure using the maps that are provided to them beforehand, so that the evacuation is organized smoothly.

Figure 4: Safety Point Source: Aalborg University

Light blue shirts can also be found at the entrance in the fire cupboard during a fire safety drill. Members of the AMIU Committee who are trained in fire drills should put on a blue shirt immediately. A person who puts on a blue shirt first, becomes the Assembly Point Leader whose duty is to bring together colleagues at the assembly point while keeping everyone calm.

Members of staff are required to help the occupants reach the assembly point which is all about the safety of all. [18]

5.4.1 AMIU Committee

5.4.1.1 Purpose

The AMiU at Aalborg University Esbjerg (AAU Esbjerg) is dedicated to fostering collaboration and dialogue on safety, work environment, study environment, preparedness, and related initiatives. Its primary mission is to create synergy between these areas, enhancing and maintaining them to make AAU Esbjerg an attractive place to study and work. AMiU seeks to ensure a well-coordinated approach to health, safety, and overall well-being for both students and staff. [18]

5.4.1.2 Organization

AMiU is composed of representatives from various institutes, departments, and units at AAU Esbjerg, with each unit retaining its autonomy. The committee plays a key advisory role in workplace matters, including:

- Conducting annual discussions on the working environment.
- Monitoring and guiding working environment groups.
- Preparing workplace assessments.
- Investigating accidents and health-related incidents.
- Managing reports of threats and violence.
- Defining the structure of the working environment organization. [18]

AMiU holds bi-monthly meetings to address safety and security concerns, promoting open communication and collaboration across all departments. This proactive approach helps maintain a safe, healthy, and supportive environment for everyone at AAU Esbjerg.

AMiU organizes a fun summer event where participants can engage in emergency preparedness activities, including siren response drills and safety plan reviews. Informational safety posters are also prominently displayed across the campus to raise awareness.

Figure 5: Emergency Safety Poster Source: Aalborg University

Currently, 80% of staff are trained in fire equipment usage; however, staff turnover, especially among PhD and postdoctoral researchers, has temporarily lowered the overall training completion rate to 40%. [18]

5.4.1.3 AMiU Membership

AMiU and its members encompass essential personnel from different units at Aalborg University Esbjerg guaranteeing representation and even distribution in matters concerning security and welfare. The membership includes:

- Campus Manager (Chairperson of AMiU).
- Work Environment Representative from each research section at AAU Esbjerg (either a manager or employee).
- Representative from FS AAU Esbjerg, covering areas such as Administration, Student Office, IK/Housing, and Student Guidance.
- Representative from CAS Esbjerg.
- Representative from ITS.
- Representative from Admission Course (AK), appointed by AK.

Members serve a two-year term. If a member leaves during their term, the represented group or the member themselves appoints a replacement. Additionally, one AMiU member is designated to participate in AMIU, ensuring alignment and coordination across broader organizational levels. [18]

6. Occupants

For an effective emergency response plan to work the building occupants' needs and vulnerabilities must be well understood. This will help in formulating parameters on age, mobility, and mobility among the population and hence evacuation strategies are developed on the evacuation of all people.

6.1 Occupant Profile and Considerations for Building Evacuation

6.1.1 Primary Occupants: Students

Most of the students occupying the facility are young adults. Most students know where the various rooms in the buildings are located to some extent. Because of their age and experience, they are often accustomed to operating in a team, which may facilitate an orderly evacuation. On the other hand, Jespers Torvekøkken is in charge of the kitchen chores. This group consists of competent workers who can self-rescue in the event of a fire.

6.1.2 Secondary Occupants: Lecturers and Staff

Because of the safety precautions taken, other individuals, such teachers and staff, might be familiar on egress routes. Since most of them remain in offices or lecture halls, their occupancy patterns are stable.

Furthermore, A four-person team from external organization also serve the institution by maintaining the facility's cleanliness. They are also familiar with the evacuation protocols for fire emergencies.

6.1.3 Tertiary Occupants: Special Event Attendees

The particular building might also accommodate guests and short-term tenants who are not well acquainted with the internal arrangement of the particular building as well as the hazardous circumstances of the building. Because some people may not be able to locate the exits for evacuation routes, this ignorant condition might cause disruptions and cause delays in the case of an evacuation.

Furthermore, a certain segment of the population may have physical, sensory, or cognitive limitations, which necessitate the addition of additional facilities.

On our observation, students, in relatively most cases, spend what is called free time in the library, canteen and study centers. Majority of the administrative personnel do use the canteen to eat and go back to the offices afterwards, some others prefer to eat lunch in the canteen.

6.2 Occupancy Patterns and Variability

6.2.1 Early Arrivals (10:00)

The Canteen opens with a small group of approximately 10 people, as estimated by observation.

6.2.2 Midday Rush (12:00)

A significant increase in occupancy occurs as students finish the lecture period that begins at 8:15. This is lunch time which is the busiest hour of the day.

6.2.3 Evening (16:00)

Occupancy gradually declines after 14:00, indicating the end of the primary activity period.

The chart summarizes data in our sight regarding daily average presence in the building differentiating between the students and the members of the administrative staff. It provides the total number of occupants in each of these categories and further gives their concentration in specific zones such as the canteen, seminar room, library, and study environment.

Occupants	Total	Canteen	Seminar room	Library	Study environment
Students	**400**	**30**	**20**	**30**	**10**
Administration	**90**	**20**	**-**	**-**	**-**

Table 6: Allocation of Occupant in different Facilities

The basement has the capacity to hold roughly 300-400 people such as students, teachers as well as visitors in the course of special activities such as parties, seminars, and external lectures. It's further important to develop adequate procedures for crowd movement to guarantee the safety of all tenants relevant during the evacuation.

Interpreting the class timetable around the week can help explain certain cycles in the use of facilities. Such information is very important in designing a rational evacuation system for offices about maximum rush levels of their use.

It is the normal situation that attendance of Fridays occupancy of the building is lesser than the attendance of peak days. As well as possible decreases in guest and staff numbers should be considered when reliable evacuation plans are developed.

6.3 Evaluation of the Questionnaire

The questionnaire targets gathering information comprising your knowledge and even experiences regarding fire disasters. Following these guidelines, we seek to understand the safety practices of people and establish the strengths and weaknesses in safety practices and enhance the safety for every person in the environment.

6.3.1 Gender-Based Differences in Fire Emergency Preparedness and Awareness

During fire emergencies, males have illustrated a remarkable level of preparedness and awareness. They are more familiar with the application of fire equipment, such as extinguishers, and actively participate in drills, highlighting their understanding of safety measures and assembly points. This trend is very useful in our focus area, the canteen, which is mostly occupied by males.

In contrast, females demonstrate the opposite pattern. During fire emergencies, females tend to show lower levels of preparedness and awareness comparatively. They are generally less familiar with the application of fire extinguishers and are rarely expected to participate in drills, indicating a limited familiarity with fire safety measures and assembly points. This trend is also particularly noticeable in our focus area, the canteen, which has fewer female occupants compared to males.

6.3.2 Professional Influence on Evacuation During Fire Emergencies:

During the fire emergency, administration members seem to be far more aware and trained regarding evacuation processes. The same can be said about students as well, especially freshmen, as they are not very aware of the collection points, seldom take part in the fire drills, and are not knowledgeable about the proper use of fire safety equipment. They have not only been properly trained but are also able to help other people in distress during an emergency

6.3.3 Demographic Insights

As our survey indicates, the students come from vastly different regions including Denmark, other parts of Europe, and even some Asian countries. At AAU, it is mandatory to conduct fire emergency drills on an annual basis. However, a recent finding by observation has shown that the largest percentage,57% of the students took part in these drills while only 43% of them did not participate mainly because they were fresh grain with no knowledge on the drills taking place or were new to the institution.

As regards knowledge and utilization of assembly points, 65% claimed to have knowledge of and/or used these points while the 35% were not informed or had not used these points. Impressively, adoption of equipment by all respondents across the board was 100 percent, showing full compliance in that area. However, 70 percent of men only have canteen visits, the rest 30 percent do not have such visits, but this male percentage is still considered rather high.

Equally, of these female students participated in these drills only 48 percent. Newer students or those who did not have knowledge of the drills being conducted were some of the reasons why the other 52% were unable to participate. This level of knowledge and practice of assembly points as well as how to operate fire materials such as fire extinguishers, was equally balanced in this case since 52 % of the females were reported to have this information while 48 % did not. For the females, like the males, the canteen visit was not common practice for 30 % of them while 70 % of them visited the canteen.

Therefore, our results point to a need for improved communication and outreach concerning emergency drills especially regarding new students. Proper dissemination of information regarding fire drill assembly points and participation in various drills can go a long way in improving preparedness level. Filling these shortcomings, AAU will be able to inculcate the safety culture and prepare every student how to act in case of emergency situations.

7. Discussion

7.1 Evacuation Timeline

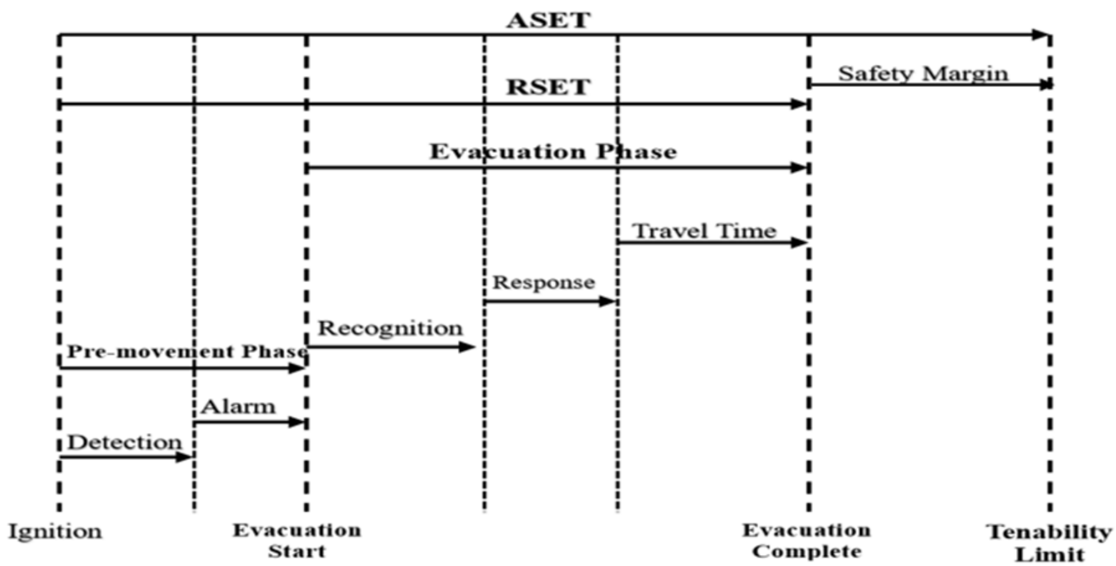

Figure 6: Evacuation Timeline

7.1.1 Available Safe Egress Time (ASET)

The time available for occupants to evacuate a space before conditions become untenable due to fire, smoke, or heat. ASET is calculated using fire dynamic models based on scenarios such as detection time and fire growth.

7.1.2 Required Safe Egress Time (RSET)

It denotes the duration needed for all the occupants of the building to safely exit the structure. It comprises the time for detection, alarm, reaction, moving out and moving time. ASET should always be greater than RSET for the protection of life.

7.1.3 Safety Margin

The difference between RSET and ASET. A positive safety margin means that there is enough time for any person to evacuate in a safe manner.

7.2 Phases of Evacuation

The time required for all occupants to evacuate the building safely, from the initiation of alarm to the last occupant reaching safety. It includes

1.Pre-movement Phase

2.Evacuation Phase

7.2.1 Pre-movement Phase

- **Ignition:** The start of the event (e.g., fire).
- **Detection:** The point at which the event is noticed or detected.
- **Alarm:** When the fire alarm is triggered, occupants are alerted. This can be through auditory, visual, or tactile systems.

7.2.2 Evacuation phase

Occupants begin traveling towards exits using available paths. For assisted evacuees, this may include lifts or mobility devices as per building-specific emergency protocols. The time from when an alarm is raised to when occupants begin moving toward exits. it includes recognition time, response time, and travel time,

- **Evacuation Start:** The moment people begin to evacuate.
- **Recognition Time:** Time taken to recognize the emergency.
- **Response:** The time it takes for people to react to the alarm and start moving.
- **Travel Time:** The time it takes occupants to move from their starting location to a place of safety. Components include:
  - **Walking Time:** Time to traverse the distance to an exit or safe area.
  - **Queuing Time:** Time spent waiting due to congestion.
  - **Flow Time:** Time for people to pass through exits.
- **Evacuation Complete:** The final point when all people have safely exited the building.

7.2.3 Tenability Limit: This represents the point beyond which conditions become unsafe for human life. It's crucial to complete the evacuation before reaching this limit. [20]

7.3 Simulation Scenarios

7.3.1 Simulation Setup

The simulation set up includes an extensive documentation process that seeks to enhance the accuracy and the level of realism. It consists of planning the canteen space by including all the necessary components of the structure such as rooms, corridors, doors, windows , and exits. There are also adjusted individual profiles assigned which bear different representations such as students, employees, and visitors with respect to their rate of mobility and average walking speed. The behavioral aspects of the occupants in the course of evacuation are also taken in to account including delay time, concentration near the exits and the selection biases associated with using an exit that is much closer to them. In addition, the simulation also considers the cause of fire with regard to the fact that there may be several points where the fire could start.

This combined approach maintains an effective context for the design of realistic scenario based analysis.

7.3.2 Base Scenario Assumptions

The total occupancy is 303, the majority are in the chair seating and in a comfortable position. It is expected that every person will try to move out right after the alarm, though the timing may vary owing to the knowledge of the location and their ability to move. While the test or simulation is conducted it is assumed that the canteen will be open and that the number of people visiting will be normal.

In the pre-movement background scenario: adults who are visitors would experience a delay of 20-40 seconds because of their average level of mobility and their lack of knowledge of the area. University students fall into two categories: students from Europe (student 1) tend to spend moderate to delay of 30 to 60 seconds when moving around as they need to gather their belongings, while students from outside Europe (student 2) spend 20 to 40 seconds which is a reasonable time relative to cultural differences. NULL Disabled teenagers require the help of an adult and hence the delay of 20 to 40 seconds is understandable relative the decreased speed to move, moved. Disabled persons also experienced a delay of 30 to 60 seconds as they are unable to initiate motion rapidly; and this is likely to reduce their speed. Persons with restricted mobility such has those who use wheelchairs are estimated to take an additional 30-60 seconds as they are dependent on a helper. [8]

In the base case scenario mobility parameters have been allocated to each of the predefined groups who were able to supplement the tests and pertinent literature with mobility information from practice drills that each of the occupants had encountered.

Making the assumption that adults have a minimal delay and a normal walking pace, students walk at the speed of 1.2 m/s. At 1.0 m/s, teenagers being integrated into the paired simulations require assistance to walk. Reduced mobility is reflected in that functional needs people walk at the speed of 0.8 m/s. Paired with four occupants in wheelchairs, they also move at the speed of 0.8 m/s but have the assistance of helpers for movement. [21]

Building code determines that all exits and the rest of the circulation spaces are in the general scope of the plan where automatic openings prevent exits from being opened unless they are locked, thus globally allowing three seminar room doors to remain locked while lectures go on. All of the tools and devices used for emergency lighting and signage are also working. Also, through risk analysis, the likelihood of blocking and door failure has been included in the consideration for analysis.

7.3.3 Scenario 1: Baseline (All Exits Operational)

- **Goal**: Evaluate evacuation efficiency under normal conditions and establish the baseline RSET.
- **Assumptions**:
  - ➢ Fire in the kitchen but does not obstruct any exits.
  - ➢ Occupants evacuate using their nearest or familiar exits.

Figure 7: Baseline

7.3.3.1 Scenario Analysis

When assessing egress safety the objectives included checking on evacuation times and most importantly target time critical 'bottleneck' areas likely to threaten safety. The constraint was the door blockage and door failure and sections of the building were simulated and isolated so as to understand the impact that it has on evacuation of the building. In addition, congested exits were also modelling to know their experiences of how design of the building would assist in congestion in that sector. This is useful as it enlightens the flow of people within the building hence areas that ought to be considered in future safety designs could be identified.

In baseline case was set to a level where all the occupants would be capable to evacuate safely within the total required safe egress time RSET that was regarded as 2.30 in this study. After analyzing the bottleneck we lack major bottlenecks of congestion and delay and hence means that the evacuation under normal condition when all the doors where functional was efficient. Referring to this scenario, the other features or their results in the future scenarios, which may be barriers or the change of evacuation behavior.

7.3.4 Scenario 2: Canteen Main Exit Block

- **Goal**: Test RSET when one primary exit (Canteen Main Exit) is unavailable due to a fire near that location.
- **Fire Scene**: Fire at Canteen Main Exit.
- **Assumptions**:
    - ➢ Evacuees nearest to Canteen Main Exit must reroute to the next closest exit.
    - ➢ Potential congestion at the remaining exits as a result of repositioning.

Figure 8: Canteen Main Exit Block

7.3.4.1 Scenario Analysis

In the second scenario of a blocked egress, the total required safe egress time (RSET) increased to 50 seconds as compared to the base case scenario. In RSET, the identification of the bottleneck analysis at the exits numbered 130 and 131, during which they were congested from the 17th second after evacuation commenced to its end. The effectiveness of alternative paths was also considered and it was found out that the staircase and library exit doors were good starting points for the occupants to change their routes without significant delay at the blocked exit which increased the rate of the evacuation process.

7.3.5 Scenario 3: Library Main and Secondary Exit Block

- **Goal**: Analyze the impact of losing the library main Exit and a secondary exit, on evacuation efficiency and RSET.
- **Fire Scene**: Fire at Library Main Exit and Small Exit lock due to technical reasons.
- **Assumptions**:
    - ➢ Students and teenagers who sit close to the Library's Main Exit and Small Exit may encounter delays as they identify alternative paths.
    - ➢ The other 6 Exits must handle the additional increased load.

Figure 9: Library Main and Secondary Exit Block

7.3.5.1 Scenario Analysis

The total RSET increased to 60 seconds as compared to the baseline scenario in the third case as the main library exit and the smaller library exit were blocked. In a bottleneck analysis exits 130 and 131 were the other places where the congestion was visible and they were in line with the congestion pattern in scenario 2. These locations were repeatedly crowded from 20 seconds into the evacuation process until the entire evacuation was complete. Assessing the displaced routes placed the staircase as a useful means of redirection that enabled the occupants to escape the obstructed exits and made the evacuation less complicated and more efficient.

7.3.6 Scenario 4: Canteen Main Exit and Linking Library Door Block

- **Goal**: Evaluate evacuation dynamics with one primary exit (Canteen Main Exit). The linking library door is blocked, creating a higher strain on other exits.
- **Fire Scene**: Fire at the Canteen Main Exit and Linking Library Door Blocked due to some technical issue.
- **Assumptions**:
  - ➢ Significant congestion at other Exits.
  - ➢ Increased delays because of reformation and potential panic and distress among occupants.

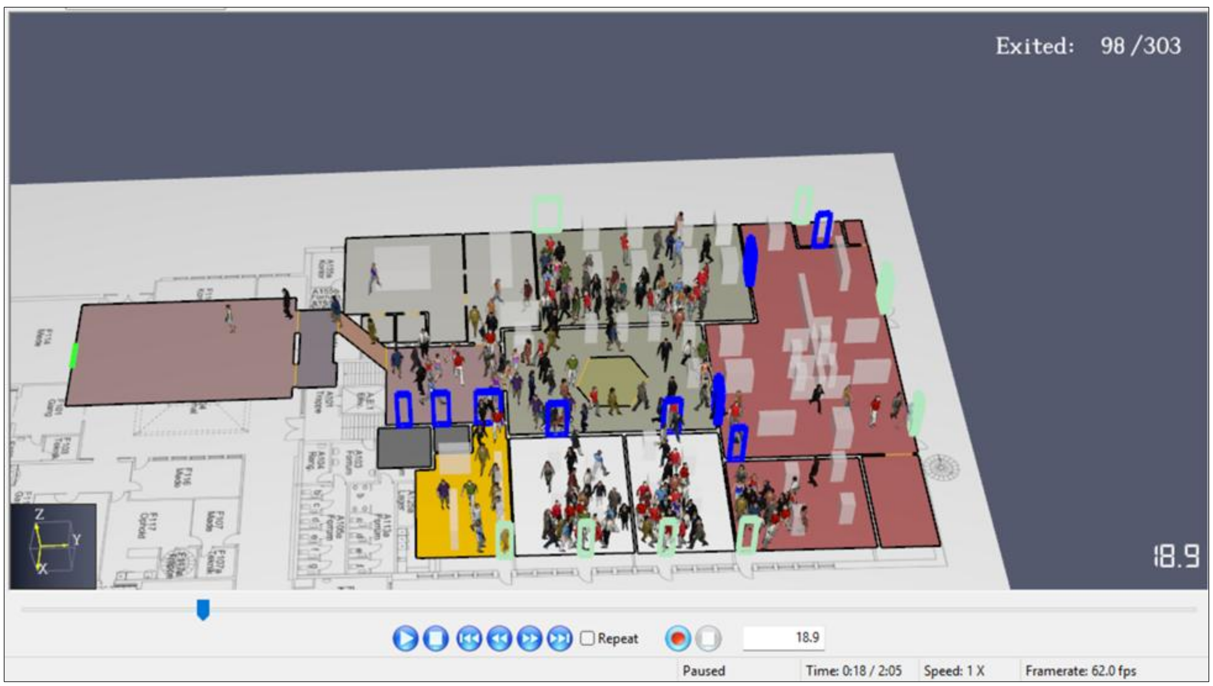

Figure 10: Canteen Main Exit and Linking Library Door Block

7.3.6.1 Scenario Analysis

When only one main exit and exit door connecting to the library were blocked, the SAFE ESCAPE TIME (RSET) increased to 50 seconds over the baseline scenario. Based on the bottleneck analysis, exit 130 and exit 131 were always congested as in Scenario 2, and these areas were congested from 17 seconds after the start of evacuation to the end of evacuation The analysis of other available routes also revealed that the stairs could be used for relaying occupants thereby reducing the time lost due to the blocking of exits and improving the evacuation flow.

7.3.7 Scenario 5: Canteen Main Exit and Linking Lounge Door Block

- **Goal**: Test RSET when one primary exits (Canteen Main Exit) and Linking Lounge Door are blocked, creating reliance on other Exits.
- **Fire Scene**: Fire at Exit Canteen Main Exit blocked and Linking Lounge Door stuck due to unknown reason.
- **Assumptions**:
    - ➢ Occupants near blocked exits (Canteen Main Exit and Linking Lounge Door) face longer rerouting distances.
    - ➢ Bottlenecks are expected at other Exits due to increased traffic.

Figure 11: Canteen Main Exit and Linking Lounge Door Block

7.3.7.1 Scenario Analysis

Compared to the reference run, in scenario five with only a central exit open and one link door open from the canteen, the overall RSET gained a substantial increase to 1 minute and 10 seconds. The bottleneck analysis conducted revealed continuous congestion at exit 130, exit 131, and the meeting room, showing significant congestion commencing after 20 seconds until the completion of evacuation. Further investigation into the alternatives showed that the staircase provided an effective rerouting solution, allowing occupants to bypass the blocked exits and making the evacuation process easier and faster.

The analysis provides an indication that the design of the structural building supports effectively efficient evacuation processes, hence estimating a total evacuation time of about 2.10 seconds, even upon fire incidents in various locations.[22]

Simulation Scenario	Description	Total Exits	Evacuation Time (te)	RSET (min) = * (td+ ta)+ te	ASET (min)	Safety Margin (min)
Scenario 1	No Block Exit	8	1:15	2:30	3	+00:30
Scenario 2	Canteen Main Exit Block	7	1:35	2:50	3	+00:10
Scenario 3	Library Main Exit and Small Exit Block	6	2:15	3:30	3	-00:30
Scenario 4	Canteen Main Exit and Linking Library Door Block	6	2:05	3:20	3	-00:20
Scenario 5	Canteen Main Exit and Linking Lounge Door Block	6	2:25	3:40	3	-00:40

*We assume that detection time (td) of the incident is 45 seconds, and Time for alarm (ta) to be raised is 30 seconds.

Table 7: Analysis of Evacuation Scenarios

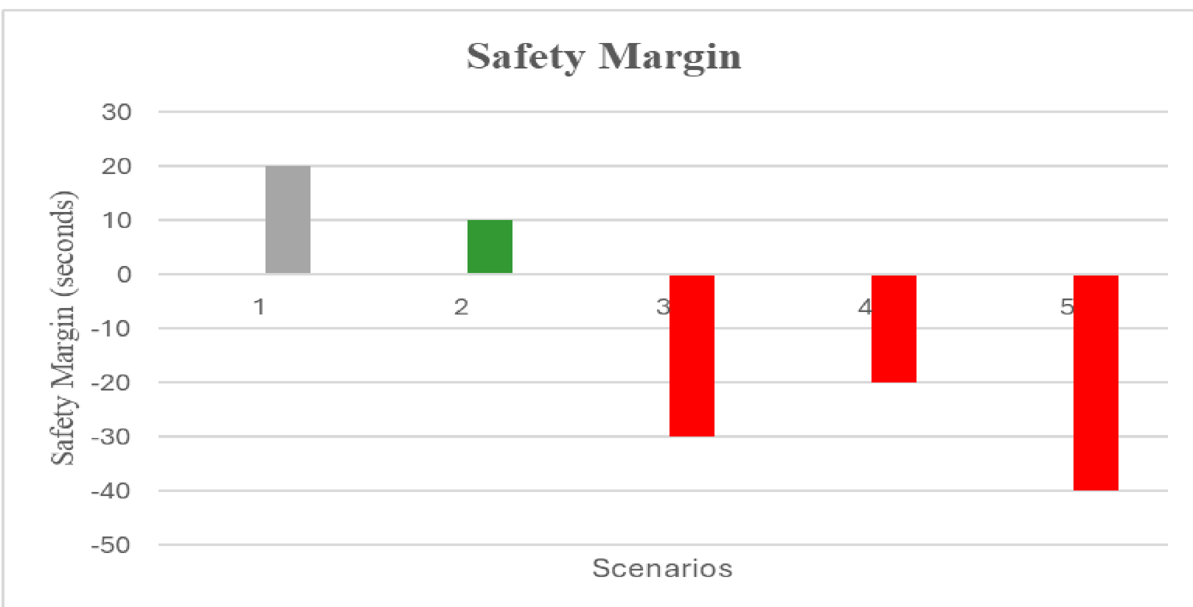

Figure 12: Safety Margin

The safety margin graph uses green bars to indicate safe scenarios with positive margins and red bars to highlight unsafe scenarios with negative margins, providing a clear visual distinction between evacuation success and risk.

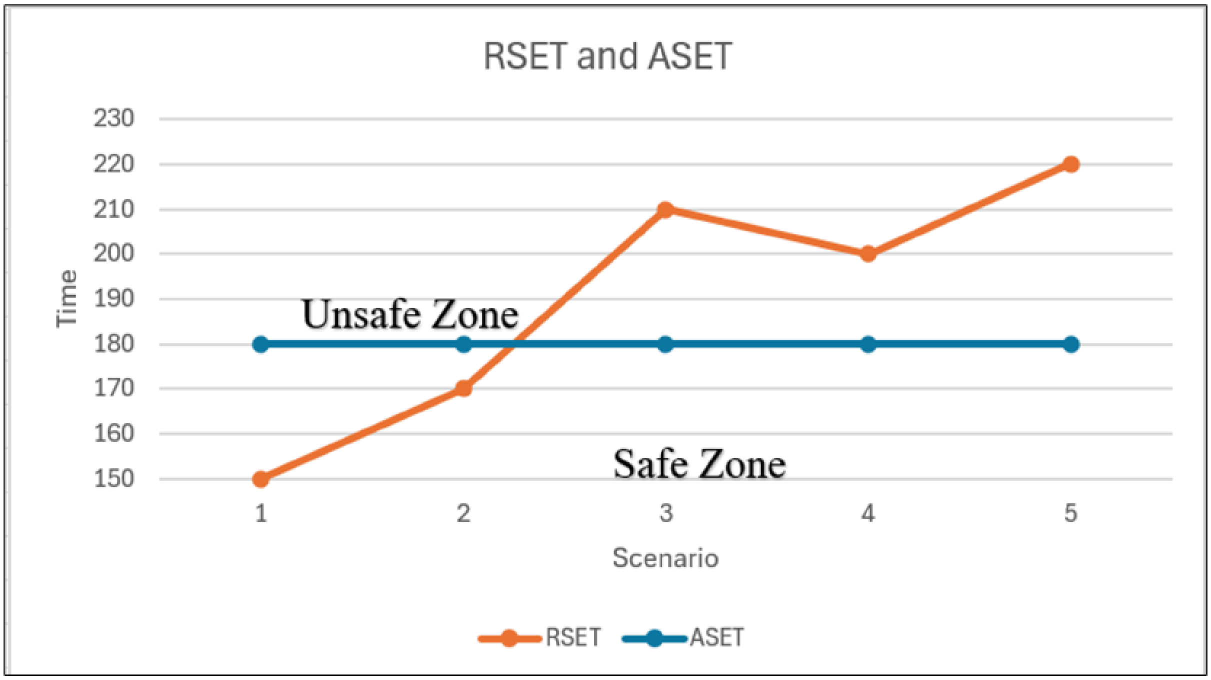

Figure 13: RSET and ASET

The graph clearly identifies the changes in Requirements for Safe Egress Tau((RSET), which stands for Real-time safety exit time, and ASET which stands for Available safety exit time, among the scenarios on the X axis and time count on the Y axis. Different lines show and plot the RSET and ASET values. There is a time when the ratio of the available safe egress time and the required safe evacuation time are unequal. Such is the situation when the RSET line moves higher than the ASET line of the graph The result as per the logic is that, it indicates high degree of risk when the evacuation time is longer than the period of ASET. On the other hand, the models when RSET line is upper than the ASET line is determination of low hazards physical conditions. In this graph we analyze dangerous models which for future conduction we might need to figure out a solution in order for people to exit the area more quickly.

7.4 Recommendations

As measures several things can be initiated to have a better results in the whole evacuation process. A proper level of protocol will be enhanced by installing proper directional signs in order for everyone to know what exits are open and the rest overcrowded. Additionally, we can train the staff to manage and direct the customers in times of emergency in order for the performance to integrate and enhance the emergency response simultaneously. Furthermore, automatic systems for unlocking doors can also be of great help as they ensure that people can move promptly to evacuate without wasting time and struggling by unlocking the doors manually.

8. Conclusion

There is a conclusion for the common risk factors that incluede the management and the Contingency Plan along with the Policies that beneficial and safe for the inusnuversty's Cafeteria. More importantly, there are potential factors including human behavior and structural as well as operational layering that need to be improved when it comes to risk for a fire insidient. Some of the Detected fire hazards still include dust accumulating on appliances like stoves and weak wires etc. And this can all be fixed with a better approach where strong policies and contingencies are made adjunctly.

Other than that, some of the easiest way to prevent and lower the odds of fire hazards are safe storage of wires and limits on their exposure , using very resistant materials to make walls, and having comprehensive strategies in times of attack and disasters to keep human life intact, and unnurtured walls. The smarter thing to do is to educate humans on how to handle situations which results in avoiding risk.

Considering their responsibilities the stakeholder analysis has established the following groups to be especially critical: university administration, canteen managers, emergency responders, and regulatory bodies. Their roles are interrelated which warrants joint actions to avert, mitigate and recover from fire events. There is a need to consider regular meetings, training and drills for improvement of collaboration and effective management of emergency responses. Others like insurers and municipal authorities are secondary stakeholders who assist with compliance and risk control.

A large number of students, teachers and visitors usually contribute a lot of complications and issues during evacuation impressing the need for evacuation tackling methods in plans. During high-density periods, careful planning is critical due to the variability in accompany level and local emergency level of different areas. It was noticed that in gender roles, professional factors and disbelief in successful performance, several common sheltered the observed performance differences.

It Is quite easy to see this study argues that being fire safety compliant in university canteen is not only about compliance but consistent and integrated effort. Reducing risks will be easier with a system that places emphasis on development through evaluation training programs and involvement of all interested parties. These issues need to be tackled or dire outcomes will arise such as destruction of property, people being injured and even the tarnishing of the schools name. The institution might be able to create a more hazard free zone for its occupants if all the suggestions provided are put in place.

Apart from adjusting the training programs strategies, future research might include advanced fire detection methods, evacuation simulations and other programs to guarantee the wellbeing of everyone involved. That will be including other comprehensive and progressive fire safety frameworks which will focus more on the stakeholders of the organization.

This study offers deep insight on the evacuation flow during different conditions at the campus, considering important factors that are related to how safely and efficiently conduits of egress are used. Based on some in-depth simulation modeling, we have flagged out some possible constraints and delays, as well as some ways that can be employed to up-grade the operational methodologies of evacuating the affected personnel and the looking at safety of the future.

The RSET achieved was two minutes thirty seconds in the worst case scenario where all exits were utilized at the same time and the evacuation turned out to be successful. However, it appears that if some reversing circumstances are applied, for instance, the closing of some exits, the time concerning the overall effectiveness, rose, and some exits had congestion issues. For example, in the scenarios of the Canteen Main Exit and the Linking Lounge Door being blocked, the overall evacuation time reached an astounding four minutes and ten seconds, further suggesting that the crowding and the lack of available exits was the primary cause of this significant delay.

The research emphasizes the importance of having backup ways of leaving a place so that losses are avoided. During emergency situations it was possible to divert occupants from the main flow of the building by using staircases and secondary exits and therefore relieving the congestion. Such findings confirms the general efficiency and effectiveness of the building structural elements and evacuation routes in ensuring safety of occupants during unfavorable conditions. However, the study also suggests the enhancement of training of the building occupants and their orientation regarding the emergency exits to decrease delays and make better use of alternative routes.

Our study, from a wide range perspective brings out the relationship that exists between the design, occupant and preparedness measures. It stresses the importance of collaboration, drills, communication on how to evacuate and even the integration of behavior dynamics into the means of evacuation process. Focusing on these factors will enable the institution to promote a culture whereby safety and resilience are part of the features, so that every occupant is able to respond to emergencies in the most effective manner.

Aalborg University in Denmark should be able to implement the recommendations that emanated from this study so as to set up a framework that will be able to deal with emergency measures such that minimal details from locked doors and windows are missed out so as to protect every person inside the building. This work is useful to safety planners and architects who want to improve evacuation plans in educational environments in different countries across the world.

9. Future Research

1. Future studies can be carried out with other simulation tools like SIMULEX, EXODUS for understanding fire emergency evacuation plan where PYROSIM can be used as a computational fluid dynamics (CFD) model for the smoke detection during fire incidents.
2. A robust analysis for disabled persons with the development of specialized evacuation tools (automatic PA system and AI guidance) in case of fire may be a great research scope.
3. Understanding human behavior (both psychological and sociological) in case of emergencies may be an enthusiastic topic of research. The AAU administrative section may take initiative during the cultural awareness program among the students from different countries.
4. Research could be done on how much fire suppression systems could be eco-friendly (for instance, instead of using CO2, DCP extinguishers;biodegradable fire agents with sustainable fire safety protocols).
5. Fire emergencies may be interrelated with other hazards, for example, earthquakes, floods etc. So, future research can delve into the depth of multi-hazard evacuation plans that will integrate fire safety with huge disaster management.
6. Research can be carried out on the application of heat detector, flame detector, automatic fire suppression system along with the feasibility of whole campus buildings being sprinklered with the cost-benefit analysis.
7. Further study may be operated for fire safety evacuation specifically for the large seminar room namely C1.117 and C1.119 at AAU Esbjerg Campus as the most seminars and programs with a huge audience takes place there.

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11. Appendix

Questionnaire: Fire Incident Evacuation Perception

Personal Information

Age:

Gender:

Position at AAU:

Nationality:

Fire Safety Perception

How often do you participate in fire drills at AAU?

- o Always
- o Often
- o Sometimes
- o Rarely
- o Never

How familiar are you with the evacuation routes in your building?

- o Highly familiar
- o Quite familiar
- o Somewhat familiar
- o Not familiar at all

How confident are you in evacuating safely when there's a fire?

- o Extremely confident
- o Quite confident
- o Slightly confident
- o Not confident at all

In a successful and safe evacuation, what do you think is the most important factor?

- o Clear signage
- o Regular fire drills
- o Calm and orderly behavior
- o Quick response from emergency services

- Other (please specify)

In case of a fire alarm, what could be your typical behavior?

- Immediately evacuate
- Wait for further instructions
- Observe others before deciding
- Assess and evacuate calmly.

Do you know where is our assembly point in case of fire evacuation?

- Yes
- No

How frequently do you go to the canteen?

- Once every two weeks
- Once a Week
- Several times a week
- Daily

Do you know how to use fire safety equipment such as extinguishers if needed?

- Yes
- No