"*Preventive Necessity for Pakistan: Fire and Smoke Evacuation Modelling Integrated with BIM for Smart Building Planning*"

Sir Syed University
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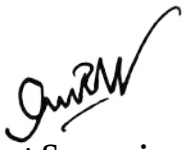
Certification

This is to certify that **SYED SHEES HAMID][2020S-CV-050]**, **[FARZAM ZAFAR][2020S-CV-056], [BASHAAR KHALID][2020S-CV-048], [USMAN ASIF][2020S-CV-046], [M.MUTASIM][2020S-CV-083]** have successfully completed the final year project **[FIRE AND SMOKE EVACUATION MODELLING INTEGRATED WITH BIM],** at the **[SIR SYED UNIVERSITY OF ENGINEERING AND TECHNOLOGY]**, to fulfill the partial requirement of the degree **CIVIL ENGINEERING.**



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Preventive Necessity for Pakistan: Fire and Smoke Evacuation Modelling Integrated with BIM for Smart Building Planning

Sustainable Development Goals

(Please tick the relevant SDG(s) linked with FYDP)

SDG No	Description of SDG	SDG No	Description of SDG
SDG 1	No Poverty	SDG 9	✓ Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3	✓ Good Health and Well Being	SDG 11	✓ Sustainable Cities and Communities
SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	✓ Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	✓ Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

Range of Complex Problem Solving			
	Attribute	**Complex Problem**	
1	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.	
2	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	
3	Depth of knowledge required	Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.	
4	Familiarity of issues	Involve infrequently encountered issues	
5	Extent of applicable codes	Are outside problems encompassed by standards and codes of practice for professional engineering.	
6	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.	
7	Consequences	Have significant consequences in a range of contexts.	
8	Interdependence	Are high level problems including many component parts or sub-problems	
Range of Complex Problem Activities			
	Attribute	**Complex Activities**	
1	Range of resources	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).	
2	Level of interaction	Require resolution of significant problems arising from interactions between wide ranging and conflicting technical, engineering or other issues.	
3	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.	
4	Consequences to society and the environment	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.	
5	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.	

Abstract

In response to recent tragic fires in Karachi, this research proposes a compassionate integration of Fire and Smoke Evacuation Modeling with Building Information Modeling (BIM). Inspired by incidents at Chase grocery store, RJ mall, Aisha Manzil (Arshi center), and the most recent mall blaze that claimed 10 lives and injured over 20, urgent measures are needed to prioritize lives and fortify communities.

Reports estimate 12,000 to 15,000 lives lost annually due to a lack of building codes, fire safety equipment, and public education. Shockingly, over 70-75% of buildings in Karachi lack fire safety arrangements.

Fueled by empathy, this research aims to create a safer environment by developing a detailed BIM model enriched with building information. Using advanced fire and smoke simulation software, it provides real-time visualizations to save lives and protect communities.

Beyond immediate concerns, the project aspires to reshape design and construction in Pakistan, blending precision with compassion. It stands as a promise to build a future where the impact of emergencies is minimized, prioritizing safety, well-being, and dignity.

Undertaking

I certify that the project **Preventive Necessity for Pakistan: Fire and Smoke Evacuation Modelling Integrated With BIM for Smart Building Planning** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

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We are also thankful to our friends and families whose silent support led us to complete our project.

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1.2 Statement of the problem

1.1 Introduction:

Background:

Fire hazards are a big threat to human life and property safety. According to the latest WHO data published in 2020 Fires Deaths in Pakistan reached 4,305 or 0.29% of total deaths. The age adjusted Death Rate is 1.95 per 100,000 of population ranks Pakistan #76 in the world. Effective evacuation planning in densely occupied buildings should be primarily put in place if both the number of injuries/fatalities and the level of property loss are to be minimized. However, it is not realistic, and is unethical to study human evacuation performance under a burning building. For this reason, computational tools tend to be the best approach for simulating fire growth as well as human response to fire hazards.

Creating a 3D model in Revit is an essential step for comprehensive fire safety assessments, capturing architectural, structural, HVAC, and electrical details. This allows for realistic fire simulations and occupant flow modeling. Importing the Revit model into PyroSim, specialized fire simulation software, excels in modeling fire and smoke behavior, considering geometry, materials, and thermal properties. Simulating occupant behavior, including evacuations, is critical for evaluating plans and enhancing safety.

The Revit-PyroSim combination empowers professionals to identify hazards, optimize safety measures, and ensure compliance with codes. PyroSim and Pathfinder integration improves fire safety analysis. PyroSim's detailed fire simulations take smoke behavior and fire location into account. The generated geometry is then exported for Pathfinder, which offers insights into tactics and advancements when simulating evacuations.

Safety simulations have more immersion thanks to virtual reality (VR). To incorporate 3D models, behavior, and fire situations, compatible hardware and software are needed. As inhabitants, users are able to engage, navigate, and go through evacuations. Monitoring in real time and Feedback makes scenario exploration possible, improving emergency response and safety professional training.

Introduction to Project:

It is crucial that Pakistani grocery stores integrate building information modeling (BIM) with a fire and smoke evacuation system. The infrastructure and layout of the store are precisely represented in 3D via BIM, allowing for efficient preparing and modeling various evacuation situations. Through integration, evacuation routes are guaranteed to be as efficient as possible, bottlenecks are detected, and fire safety equipment is placed in critical locations. During fire crises, BIM also makes it easier to monitor and coordinate in real-time with emergency services, which leads to a quicker and more coordinated response. All things considered, the incorporation of BIM into fire and smoke evacuation systems improves security, reduces damage to property, and guarantees adherence to local laws—all of which are essential for protecting people and property in grocery stores.

All things considered, this integrated method utilizing Revit, PyroSim, Pathfinder, and VR strengthens safety measures in building design and construction, lowers risks, and improves fire safety assessments, eventually resulting in safer buildings and prepared inhabitants in the event of a fire.

1.1 Statement of the problem

FIRE ERUPTS IN MULTI-STOREY VICTORIA SHOPPING CENTRE NEAR KARACHI'S ZAINAB MARKET

A huge fire erupted in a multi storey building of mega shopping centre Victoria located near Abdullah Haroon Road in Karachi which has reportedly claimed heavy financial loss. Fire erupted early in the morning when the departmental store was closed. The fire engulfed fourth-storey of the building, destroying the valuables including groceries, clothings and other items. Rescue sources told that four fire fighting vehicles were busy dousing the inferno. The fire completely turned the goods of 4 to 5 shops into ashes. Moreover, the fire fighters were facing difficulties in extinguishing the blaze as they could not enter inside the building owing to thick smoke.

LAHORE'S PACE SHOPPING MALL GUTTED BY INFERNO

A massive fire in a multi-storey Pace Mall at Gulberg early on Monday gutted hundreds of shops, leaving emotional scenes when the traders were helplessly seeing their merchandize reducing to ashes. The disturbing part of the tragic incident was that dozens of fire-extinguishing units and trained crew of Rescue 1122 and the Civil-Defence were unable to secure any portion of the plaza.

A Rescue 1122 spokesman told that approximately 20 vehicles and 60 personnel took part in the operation. Almost all 404 Shops, several counters and offices were reduced to ashes in the blaze that started late on Sunday and continued till 11:45 am on Monday. The district government declared it a Grade "A" fire.

CENTAURUS MALL FIRE: LARGE BLAZE AT ISLAMABAD MALL PUT OUT

Emergency services put out a large fire that broke out at the Centaurus Mall in the centre of the Pakistani capital, Islamabad. Police told that everyone in the shopping centre was evacuated safely and no casualties were reported.

The preliminary investigation has found that there was no proper lighting at the place of the emergency exit of the shopping mall. A Bronto fire truck was initially used to extinguish the fire from a height of 200 feet.

Firefighters faced extreme difficulties in extinguishing the fire beyond the 17th floor. The top floor of the mall had glass windows but no proper ventilation. As a result, the building's temperature rose and smoke began to accumulate within.

It was suggested that the mall adopt contemporary equipment like smoke alarms and fire detectors and setting up the upper floor's ventilation.

GAPS IDENTIFICATION

The "Fire and Smoke Evacuation using Building Information Modeling (BIM)" project has the potential to overcome a number of significant global gaps in fire safety and evacuation protocols. The main areas where this project can assist in bridging these gaps are as follows:

Data-Driven Fire Safety Planning

- Gap: The absence of comprehensive and current data on building systems, occupant information, and structures occurs in many nations, which creates a gap in the ability to adequately plan for smoke and fire evacuations.

- Filling the Gap: This project can provide a consistent and extensive building data repository through the use of BIM, enabling data-driven fire safety planning and improving readiness globally.

Efficient Evacuation Strategies

- Gap: During emergencies, ineffective evacuation plans frequently cause confusion, delays, and increased risk.

- Filling the Gap: The efficiency of evacuations can be increased internationally by using BIM-based simulations to assist develop and enhance evacuation methods that are relevant to building designs, occupancy, and fire scenarios.

Real-time Fire and Smoke Simulation

- Gap: In many areas, real-time simulation of smoke and fire spread is not extensively used, which makes it more difficult to react swiftly and efficiently to fire occurrences.

- Filling the Gap: Through this research, emergency response and evacuation plans can be improved by introducing real-time fire and smoke simulation capabilities that can be modified and applied internationally.

Interagency Coordination

- Gap: During emergencies, there is frequently insufficient coordination between emergency services, building management, and first responders, which results in less than ideal responses.

- Filling the Gap: By giving real-time data on building conditions, fire locations, and occupant information, BIM-based solutions can enhance interagency cooperation and facilitate more efficient emergency responses globally**.**

Compliance with Fire Safety Codes

- Gap: Unsafe building conditions result from the difficulties many nations face in implementing and adhering to fire safety laws**.**

- Filling the Gap: Through the creation of compliance reports and guaranteeing that BIM-based fire safety systems comply with legislation, this initiative can assist nations in raising their levels of safety and compliance.

Retrofitting Existing Buildings

- Gap: Due to budgetary restrictions and technological difficulties, retrofitting existing buildings with contemporary fire protection equipment is an international challenge.

- Filling the Gap: The project can offer a foundation for increasing fire safety precautions in older buildings across the globe, integrating BIM data, and renovating existing buildings.

Standardization and International Collaboration

- Gap: The lack of standardized approaches and international collaboration in fire safety hinders the development of best practices.

- Filling the Gap: Adopting BIM for fire safety can result in worldwide cooperation and standardization initiatives to provide consistent practices and standards for evacuation and fire safety protocols.

Public Awareness and Education

- Gap: Confusion and panic during evacuations can be caused by inadequate public education and awareness of fire safety precautions.

- Filling the Gap: The public can be educated about fire safety and given clear directions in an emergency by using BIM technology to produce educational materials and applications.

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Urban Planning and Building Design

- Gap: In many places, fire safety precautions are not always given priority in urban planning and building design.

- Filling the Gap: By placing a strong emphasis on fire safety, BIM can have an impact on urban planning and building design techniques, which could result in safer building layout and construction across the globe.

By filling in these gaps and putting the initiative into action across multiple nations and areas, we can drastically improve the world's capacity for fire safety and evacuation, which will eventually save lives and reduce the amount of property damage caused by fires. To establish a safer and more consistent strategy to fire and smoke evacuation, international collaboration and the sharing of best practices will be necessary.

Chapter 2

2.1.1 Goals/Aims and Objectives

2.1.2 Motivation

2.1.3 Assumption and Dependencies

2.1.4 Methods

2.1.5 Report Overview

2.1.1 Goals/Aims/Objectives

- To develop an advanced evacuation model incorporating building layout, fire dynamics, smoke spread, and occupant behavior for realistic simulations.

- To utilize Pyrosim's advanced features for precise and realistic fire and smoke simulations, enhancing the accuracy of fire safety analyses.

- To easily incorporate Pyrosim's fire simulation data into Building Information Models (BIMs) to offer a comprehensive perspective on fire safety issues, facilitating knowledgeable decision-making for safety, engineering, and architectural experts.

➢ Objectives:

- **To develop an advanced evacuation model**

In order to create realistic simulations, an enhanced evacuation model that takes into account building layout, fire dynamics, smoke dispersion, and human behavior is being developed.

- **To utilize Pyrosim**

To improve the quality of fire safety studies by making use of Pyrosim's sophisticated capabilities for accurate and lifelike fire and smoke simulations.

- **To integrate Pyrosim's fire simulation data**

To easily incorporate Pyrosim's fire simulation data into Building Information Models (BIMs) in order to offer a comprehensive perspective on fire safety issues and empower safety experts, engineers, and architects to make well-informed decisions.

Sustainable Development Goals (SDGS)

We are working to help the United Nations accomplish a number of Sustainable Development Goals (SDGs) by putting the "Fire and Smoke Evacuation using Building Information Modeling (BIM)" initiative into action.

Sustainable Cities and Communities (SDG 11)

By enhancing fire and smoke evacuation protocols, this initiative closely correlates with SDG 11: "Sustainable Cities and Communities," which aims to improve urban safety and resilience. Furthermore, through encouraging the use of standardized BIM technologies and improving fire safety.

Industry, Innovation, and Infrastructure (SDG 9)

Through encouraging innovation in building management and safety procedures, the project subtly advances SDG 9: "Industry, Innovation, and Infrastructure."

Quality Education (SDG 04)

Additionally, the project's focus on public awareness and education advances community understanding and readiness for fire safety, which supports SDG 4: "Quality Education." In conclusion, by promoting safer, more resilient urban settings, the project significantly contributes to the advancement of these global sustainability goals.

Life on Land (SDG 15)

The preservation, rehabilitation, and sustainable management of terrestrial ecosystems are the main topics covered by "Life on Land". The "Fire and Smoke Evacuation using Building Information Modeling (BIM)" initiative focuses more on emergency response, urban safety, and building management than it does on this particular SDG. On the other hand, the project's indirect objective of enhancing fire safety can aid in lowering the possibility of environmental damage brought on by uncontrolled fires, which is consistent with the larger idea of sustainability and safety for both urban and natural settings. Although it isn't a direct goal, the effort can help lessen the harm that urban fires do to the environment.

- **Scope:**

Data Collection and Integration

obtaining and incorporating mechanical, electrical, structural, and architectural data to create an all-inclusive BIM model.

Creating protocols and data standards for BIM integration

Real-time Simulation

Developing a smoke and fire simulation system that uses BIM model data to include building-specific information.

ensuring the simulation's accuracy and dependability.

Evacuation Strategy Development

Developing evacuation plans with simulation data. Taking into account different fire scenarios, such as their length, intensity, and location.creating evacuation route optimization techniques.

Communication Systems

Putting in place an intuitive interface that directs residents during evacuations. Delivering instructions via smartphone apps, augmented reality, or other technologies

Emergency Response Coordination

Granting first responders access to real-time data to improve their situational awareness. Assisting in the communication of first responders, building management, and residents.

Compliance and Reporting:

Creating instruments to produce reports on compliance. Making certain that the project complies with safety guidelines.

- ## Expected Outcomes:

The project's successful completion will lead to better fire and smoke evacuation protocols, increased building occupant safety, and improved emergency responder communication. Additionally, it will make observing safety rules easier and offer insightful information for continuous enhancements to evacuation plans and building safety.

Chapter 3

2.1.1 Methodology

2.1.1 Methodology

MODELLING ON REVIT

The following methods can be used to create a 3D fire evacuation system model in Revit for a two-story grocery shop that is 60 feet by 60 feet. First, create two floors in Revit to represent each level and set up the project with the appropriate units and scale. Bring in the two stories' architectural floor plans, making sure they are accurate and in line. Next, outline the walls, cut door and window openings, and label the wall surfaces with materials that faithfully represent the wall's composition. Use materials you'd find in a regular grocery store to model the ceilings and flooring, making sure they have the right finishes and textures.

GENERATING VIRTUAL REALITY (VR) RESULTS

To collect data on fire dynamics, smoke distribution, occupant mobility, and evacuation methods at a grocery store, the methodology entails running fire and evacuation simulations in PyroSim and Pathfinder. To include the simulation data into a virtual reality environment that mimics the retail layout, export the data. Create a dynamic virtual reality interface that allows for real-time navigation and fire visualization.

Verify the correctness of the VR simulation by comparing its results with PyroSim and Pathfinder. Gather user input for improvements, record the procedure, and utilize it as a teaching aid. Maintain it frequently to keep it current with shop modifications. An immersive tool for training, research, and raising awareness of fire safety is produced by this methodology.

FIRE SIMULATION ON PYROSIM:

A methodical approach is necessary in order to use PyroSim to simulate a fire on the imported Revit 3D model while modifying the simulation parameters and material properties for improved realism. First, make sure that the 3D model is properly scaled and aligned when you import it from Revit into PyroSim. Next, adjust material parameters for materials like HDPE, ethanol liquid, and wood to match real-world values. These properties include density, specific heat, and thermal conductivity. Establish the parameters of the simulation simultaneously. For example, set a fire spreading speed of 6.34 m/s, configure sources of ignition, select time steps and durations, and integrate smoke and heat detectors if necessary. Next, build a computational mesh with an emphasis on important areas such as possible fire paths and escape routes in order to enable precise computations. Run the simulation and keep an eye on its.

EVACUATION STRATEGY ON PATHFINDER:

• Use a clear technique to incorporate PyroSim simulation findings into Pathfinder for the purpose of developing a grocery store evacuation plan that works. First, export important information such as temperature, smoke, and fire propagation from the PyroSim fire simulation. Import the store's 3D geometry into Pathfinder, identify barriers, and create occupant profiles using the PyroSim output. Ascertain that the evacuation objectives are in line with PyroSim's findings by clearly defining the evacuation routes, assembly locations, and exits.

• Then, use the PyroSim-modified layout to create Pathfinder simulations where customers can explore the store. Examine the simulation's output to determine how effective the evacuation was, spot any possible bottlenecks, and adjust the evacuation plans and routes as necessary. To guarantee adaptation to different occupancy situations or fire scenarios, do scenario testing. Keep a record of the entire procedure,

Chapter 4

1. 6.1 Summary and Future work

This research uses a rigorous technique to develop a building's resilient fire evacuation model. After accurate Revit modeling and lifelike PyroSim fire simulations, the emphasis switches to Pathfinder in order to devise an effective escape plan. Every procedure is thoroughly documented, from the export of data to the creation of strategies. Converting simulation data into an immersive Virtual Reality (VR) tool for fire visualization and real-time navigation is the last finishing touch. This succinct method enhances safety in any architectural setting by seamlessly combining accurate modeling, realistic fire simulation, efficient evacuation planning, and immersive VR technology.

Chapter 5

7.1 Conclusion & Recommendation

To sum up, our idea is a revolutionary step forward in the field of evacuation and fire safety planning. We are able to surpass current industry standards by combining accurate modeling, complex simulations, and immersive virtual reality technologies in a seamless manner. This creative method creates a dynamic tool for training and increased awareness in addition to supporting safety procedures. Future-focused, the effective application of these developments promises to reshape standards and guarantee the development of more robust, adaptable, and safe built environments.